Ministry of Higher Education & Scientific Research
Al-Rasheed University College
Computer Techniques Engineering department

وزارة التعليم العالي والبحث العلمي
كلية الرشيد الجامعة
قسم هندسة تقنيات الحاسوب

حقيبة تعليمية

بعنوان: Electrical Engineering Fundamentals

إعداد

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Introduction:

Electrical engineering is an engineering discipline concerned with the study, design, and application of equipment, devices, and systems which use electricity, electronics, and electromagnetism. It emerged as an identifiable occupation in the latter half of the 19th century after commercialization of the electric telegraph, the telephone, and electrical power generation.

وصف المقرر الدراسي

يوفر وصف المقرر هذا إيجازاً مقتضياً لأهم خصائص المقرر ومخرجات التعلم المتوقعة من الطالب تحقيقها مبرهناً عما إذا كان قد حقق الاستفادة القصوى من فرص التعلم المتاحة. ولابد من الربط بينها وبين وصف البرنامج.؛

1. المؤسسة التعليمية	كلية الرشيد الجامعة
2. القسم العلمي / المركز	هندسة تقنيات الحاسوب
3. اسم / رمز المقرر	أسس الهندسة الكهربائية
4. أشكال الحضور المتاحة	اسبوعي
5. الفصل / السنة	فصلين دراسيين / السنة الدراسية الاولى
6. عدد الساعات الدراسية (الكلي)	90 ساعة
7. تاريخ إعداد هذا الوصف	2022-8-14
8. أهداف المقرر	
الهدف من هذه المقرر إعطاء الطالب معلومات اساسية عن عناصر الدوائر الكهربائية و النظريات التى تستخدم فى تحليل الدوائر الكهربائية وتطبيقها عمليا.	

10. مخرجات المقرر وطرائق التعليم والتعلم والتقييم
أ- الأهداف المعرفية : اذا اتم الطالب هذا المقرر بنجاح فإنه يكون قادرا على ان: أ1- يتعرف على الرموز والمختصرات والوحدات والعناصر التي تستخدم في الدوائر الكهربائية. أ2- يميز بين دوائر التوالي والتوازي وطريقة نقل مصادر الطاقة بينهما. أ3- يحسب الجهد و التيار والطاقه في دوائر التيار المستمر التي تحتوي على مقاومات, مصادر تيار , مصادر جهد و مصادر جهد و تيار غير مستقلة ودوائر التيار المتناوب التي تحتوي على المحاثة والمتسعة . أ4- يستخدم الطرق والنظريات لتحليل الدوائر الكهربائية . أ5- يحسب القدرة المستهلكة بالدائرة و القدرة المستمدة من المصدر و اقصى قدرة منقولة الى الحمولة. أ6- يتعرف على انواع موجات دوائر التيار المتناوب وطريقة توليدها والعناصر التي تستخدم في هذه الدوائر. أ7- يطبق النظريات التي تستخدم في تحليل دوائر التيار المستمر على دوائرالتيار المتناوب. أ8- يتعرف على اجهزة القياس. أ9- يتدرب على استخدام الاجهزة الكهربائية المختبرية للقياسات المختلفة.

: اذا اتم الطالب هذا المقرر بنجاح فإنه يكون قادرا على ان:

ب1 – يصمم التجارب العملية وإجراءها وتحليل البيانات وتفسيرها التي تحقق الجانب النظري.
ب2 – يكتسب مهارة استخدام اجهزة القياس الكهربائي المختلفة.
ب3 – يحدد مشاكل الدوائر الكهربائية.
ب4- يتمكن من العلوم الرياضية والأساسية والهندسية الضرورية لإجراء تحليل وتصميم نظم الهندسة الكهربائية والالكترونية.

طرائق التعليم والتعلم
▪ المحاضرات النظرية (الحصول على أ 1- أ 9 من الفقرة 9) . ▪ التطبيق العملي في المختبر لمفردات المنهاج (الحصول على ب 1 - ب 4 من الفقرة 9) . ▪ أستخدام اجهزة القياس المختبرية. ▪ الحوارات والمناقشات خلال المحاضرات النظرية والعملية (الحصول على أ1- أ2 من الفقرة 9). ▪ الاستعانة ببعض المباديء الهندسية العامة والتي تصب بتحليل وتصميم المشكلة الهندسية بالاضافة الى الاستعانة بالقوانين والقواعد الخاصة بالهندسه الكهربائيه وذلك لتعيين مكمن المشكلة وحلها.
طرائق التقييم
▪ الامتحانات النظرية الدورية والفصلية للتحقق من أ 1 - أ 9 من الفقرة 9. ▪ الامتحانات العملية الدورية والفصلية للتحقق من ب 1 - ب 4 من الفقرة 9. ▪ الاختبارات القصيرة (Quizzes). ▪ الحوارات والنقاشات الصفية للتحقق من أ1- أ2 من الفقرة9 .
ج- الأهداف الوجدانية والقيمية : اذا اتم الطالب هذا المقرر بنجاح فإنه يكون قادرا على ان: ج1- يدرك مطلوبات مهنة الهندسة والمسؤولية الأخلاقية. ج2- يستوعب تأثير الحلول الهندسية على الأنشطة الاقتصادية والبيئية والسياق المجتمعي. ج3- يدرك االحاجة إلى التعلم مدى الحياة والقدرة على الانخراط فيه.
طرائق التعليم والتعلم

للوصول الى ج1-ج3 يتم عن طريق :

- المحاضرات النظرية.
- المحاضرات العملية والتطبيق العملي في المختبر.
- المناقشات الجماعية.

طرائق التقييم
للتحقق من ج 1 - ج3 من الفقرة 9 يتم عن طريق : ▪ الامتحانات النظرية الدورية والفصلية ▪ الامتحانات العملية الدورية والفصلية ▪ التقارير
د ـ المهارات العامة والتأهيلية المنقولة (المهارات الأخرى المتعلقة بقابلية التوظيف والتطور الشخصي). د1- تحديد وصياغة وحل المشاكل الهندسية. د2- تصميم التجارب واجراءها وتحليل البيانات وتفسيرها. د3- استخدام التقنيات والمهارات الهندسية الحديثة والأدوات اللازمة لممارسة مهنة الهندسة. **طرائق التعليم والتعلم** للوصول الى د 1 - د 3 يتم الاستفادة من تناول مشكلة هندسية عملية تخص هندسة الدوائر الكهربائية ويطالب بكتابتها على شكل تقرير وعرض نتائجه ضمن فترة زمنية محددة. **طرائق التقييم** الاستفادة من طريقة تقييم الفقرة ج من الفقرة9 .

10. بنية المقرر					
الأسبوع	الساعات	مخرجات التعلم المطلوبة	اسم الوحدة / أو الموضوع	طريقة التعليم	طريقة التقييم
1	T1+2	ان يكون الدارس قادرا على ان يفهم اساسيات الدوائر الكهرابائية	Symbols And Abbreviations, Units, Electric Circuit & It's Element.	عرض نظري بالاستعانة ببعض المبادىء الهندسية العامة	اختبار تحصيلي +واجب صفي
2	T1+2		The Direct Current Network. Kirchhoff's Laws & Their Use In Network Analysis.		
3	T1+2	ان يكون الدارس قادرا على ان يميز بين دوائر التوالي والتوازي	Series Circuits, Parallel Circuits, Series-Parallel Circuits , Open and Short Circuits, Source Transformation	عرض نظري بالاستعانة بالمخططات التوضيحية	اختبار تحصيلي +واجب صفي
4	T 1+2		Conversion Of Delta To Star Connection And Vice Versa.		اختبار تحصيلي +واجب صفي
5	T 1+2	ان يكون الدارس قادرا على ان يستخدم نظريات تحليل الدوائر الكهربائية	Nodal Voltage Method	عرض نظري بالاستعانة بالمعادلات والقواعد الخاصة بالدوائر الكهربائية	اختبار تحصيلي +واجب صفي
6	T1+2		Loop (mesh)Current Method.		
7	T1+2		Superposition Method.		اختبار تحصيلي +واجب صفي

اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمعادلات والقواعد الخاصة بالدوائر الكهربائية	Thevenin’s Theorem	ان يكون الدارس قادرا على ان يستخدم نظريات تحليل الدوائر الكهربائية للتيار المستمر	T1+2	8
		Norton’s Theorem		T1+2	9
اختبار تحصيلي +واجب صفي		Maximum Power Transfer Theorem		T1+2	10
اختبار تحصيلي +واجب صفي		Reciprocity Theorem		T1+2	11
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمخططات التوضيحية	The Alternating Current Network Types of Alternating Waveforms, Generation of Alternating Current, and Definitions related to Alternating Waveforms.	ان يكون الدارس قادرا على ان يفهم اساسيات دوائر التيار المتناوب	T1+2	12
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالقوانين والمخططات التوضيحية	The Mean Values of Current and Voltage		T1+2	13
		The Effective Vales of Current and Voltage		T1+2	14
اختبار تحصيلي +واجب صفي		Circuit Elements in the Phasor Domain		T1+2	15
		The Vector Diagram		T1+2	16
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالقوانين التوضيحية	Reviews for Complex Numbers and there mathematical operations th		T1+2	17
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمعادلات والقواعد الخاصة بالدوائر الكهربائية	Series and Parallel Ac Circuits	ان يكون الدارس قادرا على ان يتعرف على دوائر التوالي والتوازي للتيار المتناوب وتطبيق القوانين الحسابية	T1+2	18
اختبار تحصيلي +واجب صفي		The Instantaneous Power and Mean Power of AC, Reactive and Apparent Power		T1+2	19
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمعادلات والقواعد الخاصة بالدوائر الكهربائية	Using Kirchhoff's law's to solve AC circuits	ان يكون الدارس قادرا على ان يستخدم نظريات تحليل الدوائر الكهربائية للتيار المتناوب	T1+2	20
اختبار تحصيلي +واجب صفي		Using Loop's method to solve AC circuits		T1+2	21
اختبار تحصيلي +واجب صفي		Using Superposition's method to solve AC circuits		T1+2	22
		~~Using Thevenin’s theorem to solve~~ AC circuits		~~T1+2~~	23

اختبار تحصيلي +واجب صفي		Using Norton's theorem to solve AC circuits		T1+2	24
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمخططات التوضيحية	3- Phase Current, 3- Phase System, Y- Connection Delta Connection.	ان يكون الدارس قادرا على فهم اساسيات الدوائر ذات ثلاثية الطور	T1+2	25
اختبار تحصيلي +واجب صفي	عرض نظري بالاستعانة بالمعادلات والقواعد الخاصة بالدوائر الكهرومغناطيسية	Solving 3-phase networks with balanced loads, Solving 3-phase networks with unbalanced loads		T1+2	26
اختبار تحصيلي +واجب صفي		Electromagnetism, Permanent and artificial Magnets, The Magnetic Field, The flux density , The magnetic reluctance , The permeability , The mmf , The magnetic force , The electromagnetic circuits.	ان يكون الدارس قادرا على فهم اساسيات الدوائر الكهرومغنا طيسية	T1+2	27
اختبار تحصيلي +واجب صفي		The implementation of B-H curves for solving electromagnetic circuits		T1+2	28
		Transformers , The hysteresis losses , The eddy current losses		T1+2	29
اختبار تحصيلي +واجب صفي		Direct Current Machines, Direct Current Generators, Asynchronous And Synchronous Machines.		T1+2	30

10. البنية التحتية	
1- الكتب المقررة المطلوبة	*Boylestad, R. L. " Introductory Circuit Analysis", 4th Edition, Charles E. Merill Publishers.
2- المراجع الرئيسية (المصادر)	*Alexander C. K. and Sadiku M. N. "Fundamentals of Electric Circuits", McGraw- Hill Companies. *Alexander C. K. and Sadiku M. N. " Circuit Analysis, Theory and Practice", 2nd Edition, Robbins & Miller. *B.L Theraja, " A Text Book of Electrical Technology" ,4th Edition.
ا- الكتب والمراجع التي يوصى بها (المجلات العلمية , التقارير ,....)	
ب - المراجع الالكترونية, مواقع الانترنيت	***"Electrical Circuit Fundamental"***, http://www.electronics-tutorials.ws

HIGHER EDUCATION PERFORMANCE REVIEW: PROGRAMME REVIEW

COURSE SPECIFICATION

This Course Specification provides a concise summary of the main features of the course and the learning outcomes that a typical student might reasonably be expected to achieve and demonstrate if he/she takes full advantage of the learning opportunities that are provided. It should be cross-referenced with the programme specification.

1. Teaching Institution	Al-Rasheed University College
2. University Department/Centre	computer technology engineering
3. Course title/code	basics of electrical engineering
4. Programme(s) to which it contributes	Use of different electrical measuring devices
5. Modes of Attendance offered	weekly
6. Semester/Year	Two semesters / first academic year
7. Number of hours tuition (total)	hours 90
8. Date of production/revision of this specification	14/4/2022
9. Aims of the Course instructions is to give the student information about electrical .circuits, electrical circuits, and theories that are used in electrical circuits and	

10· Learning Outcomes, Teaching ,Learning and Assessment Methode
A- Knowledge and Understanding: If the student successfully completes this course, he will be able to: A1- Recognize the symbols, abbreviations, units and elements that are used in electrical circuits. A2- Distinguish between series and parallel circuits and the way energy sources are transferred between them. A3- Calculates voltage, current and power in DC circuits that contain resistors, current sources, voltage sources, non-independent voltage and current sources, and alternating current circuits containing inductance and capacitance A4- Uses methods and theories to analyze electrical circuits A5- Calculates the power consumed in the circuit, the power derived from the source, and the maximum power transferred to the load A6- Recognize the types of waves in alternating current circuits, the method of generating them, and the elements that are used in these circuits A7- Apply the theories that are used in the analysis of DC circuits to AC circuits A8- Familiarize yourself with measuring devices A 9- He is trained in the use of electrical laboratory equipment for different measurements.
B. Course specific objectives. If the student successfully completes this course, he will be able to: B1 - designs and conducts practical experiments, and analyzes and interprets data .that achieve the theoretical aspect .B2 - Acquire the skill of using different electrical measuring devices .B3 - Identifies electrical circuit problems .B4- Be able to master the mathematical, basic and engineering sciences necessary to analyze and design electrical and electronic engineering systems.

Teaching and Learning Methods
• Theoretical lectures (getting A-1 A9 from paragraph 9). • Practical application in the lab of the curriculum vocabulary (obtaining B1 - B4 from paragraph (9). • Use of laboratory equipment. • Dialogues and discussions during theoretical and practical lectures (get A-1a2 from paragraph 9). • Using some general engineering principles, which are intended to analyze and design the engineering problem, in addition to using the laws and rules of electrical engineering in order to identify the location of the problem and its solution .
Assessment methods
• Periodic and quarterly theoretical exams to verify A-1 A9 of Paragraph 9. • Periodic and quarterly practical exams to verify B1 - B4 of Paragraph 9. • Quizzes. • Classroom discussions and discussions to verify A-1a2 of Paragraph 9.

C. Thinking Skills : If the student successfully completes this course, he will be able to: C1- He understands the requirements of the engineering profession and ethical responsibility. C2- Understand the impact of engineering solutions on economic and environmental activities and the societal context. C3- Recognize the need for lifelong learning and the ability to engage in it.
Teaching and Learning Methods
To reach C1-C3 is through • Theoretical lectures. • Practical lectures and practical application in the laboratory. • Group discussions
Assessment methods
Verification of C 1 - C 3 of Paragraph 9 is done by: • Regular and quarterly theory exams • Regular and quarterly practical exams • Reports

D. General and Transferable Skills (other skills relevant to employability and personal development)
D1- Defining, formulating and solving engineering problems.
D2- Design and conduct experiments, and analyze and interpret data.
D3 - Using modern engineering techniques and skills and tools necessary to practice the engineering profession.
Teaching and learning methods
To get to D1 - D3, it is benefited from addressing a practical engineering problem related to electrical circuit engineering, and it is required to write it in the form of a report and present its results within a specified period of time.
Evaluation methods
Take advantage of the method of evaluation of paragraph C of paragraph 9.

11. Course Structure					
Week	Hours	ILOs	Unit/Module or Topic Title	Teaching Method	Assessment Method
1	T1+2	To be able to understand the basics of electrical circuits	Symbols And Abbreviations, Units, Electric Circuit & It's Element.	theoretical presentation Using some general engineering principles	Achievement test class homework +
2	T1+2		The Direct Current Network. Kirchhoff's Laws & Their Use In Network Analysis.		Achievement test class homework +
3	T1+2	The student should be able to distinguish between series and parallel circuits	Series Circuits, Parallel Circuits, Series-Parallel Circuits , Open and Short Circuits, Source Transformation	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
4	T1+2		Conversion Of Delta To Star Connection And Vice Versa.		Achievement test class homework +
5	T1+2	The student should be able to use the theories of electrical circuit analysis	Nodal Voltage Method	theoretical presentation with the help of With equations and rules for electrical circuits	Achievement test class homework +
6	T1+2		Loop (mesh)Current Method.		Achievement test class homework +
7	T1+2		Superposition Method.		Achievement test class homework +
8	T1+2	The student should be able to use the theories of DC circuit analysis	Thevenin's Theorem	theoretical presentation with the help of With equations and rules for electrical circuits	Achievement test class homework +
9	T1+2		Norton's Theorem		Achievement test class homework +
10	T1+2		Maximum Power Transfer Theorem		Achievement test class homework +
11	T1+2		Reciprocity Theorem		Achievement test class homework +

12	T1+2	To be able to understand the basics of alternating current circuits	The Alternating Current Network Types of Alternating Waveforms, Generation of Alternating Current, and Definitions related to Alternating Waveforms.	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
13	T1+2		The Mean Values of Current and Voltage	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
14	T1+2		The Effective Vales of Current and Voltage	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
15	T1+2		Circuit Elements in the Phasor Domain	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
16	T1+2		The Vector Diagram	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
17	T1+2		Reviews for Complex Numbers and there mathematical operations th	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
18	T1+2	The student should be able to identify the series and parallel circuits of alternating current and apply arithmetic laws	Series and Parallel Ac Circuits	theoretical presentation with the help of With equations and rules for electrical circuits	Achievement test class homework +
19	T1+2		The Instantaneous Power and Mean Power of AC, Reactive and Apparent Power		Achievement test class homework +

20	T1+2	The student should be able to use theories electrical circuit analysis	Using Kirchhoff's law's to solve AC circuits	theoretical presentation with the help of With equations and rules for electrical circuits	Achievement test class homework +
21	T1+2		Using Loop's method to solve AC circuits		Achievement test class homework +
22	T1+2		Using Superposition's method to solve AC circuits		Achievement test class homework +
23	T1+2		Using Thevenin's theorem to solve AC circuits		Achievement test class homework +
24	T1+2	The student should be able to use theories AC circuit analysis	Using Norton's theorem to solve AC circuits	theoretical presentation with the help of With equations and rules for electrical circuits	Achievement test class homework +
25	T1+2	The student should be able to understand the basics of three-phase circuits The student should be able to understand the basics of three-phase circuits	3- Phase Current, 3-Phase System, Y-Connection Delta Connection.	theoretical presentation with the help of by schematics illustration	Achievement test class homework +
26	T1+2		Solving 3-phase networks with balanced loads, Solving 3-phase networks with unbalanced loads	theoretical presentation with the help of With equations and rules for electromagnetic circuits	Achievement test class homework +
27	T1+2	To be able to understand the basics of electromagnetic circuits	Electromagnetism, Permanent and artificial Magnets, The Magnetic Field, The flux density , The magnetic reluctance , The permeability , The mmf , The magnetic force , The electromagnetic circuits.		Achievement test class homework +

28	T1+2	To be able to understand the basics of electromagnetic circuits	The implementation of B-H curves for solving electromagnetic circuits		Achievement test class homework +
29	T1+2		Transformers , The hysteresis losses , The eddy current losses		Achievement test class homework +
30	T1+2		Direct Current Machines, Direct Current Generators, Asynchronous And Synchronous Machines.	theoretical presentation with the help of With equations and rules for electromagnetic circuits	Achievement test class homework +

12. Infrastructure	
Required reading: · CORE TEXTS · COURSE MATERIALS · OTHER	*Boylestad, R. L. " Introductory Circuit Analysis", 4th Edition, Charles E. Merill Publishers.
Special requirements (include for example workshops, periodicals, IT software, websites)	Alexander C. K. and Sadiku M. N. "Fundamentals of Electric Circuits McGraw- Hill Companies. *Alexander C. K. and Sadiku M. N. " Circuit Analysis, Theory and Practice", 2nd Edition, Robbins & Miller. B.L Theraja, " A Text Book of Electrical Technology" th Edition.
Community-based facilities (include for example, guest Lectures , internship , field studies)	

13. Admissions	
Pre-requisites	
Minimum number of students	
Maximum number of students	

إرشادات للطلبة

- **الرغبة والحماس للتعليم**
- **كن مشاركاً في جميع الأنشطة**
- **احترم أفكار المدرس والزملاء**
- **أنقد أفكار المدرس والزملاء بأدب إن كانت هناك حاجة.**
- **احرص على استثمار الوقت**
- **تقبل الدور الذي يسند إليك في المجموعة**
- **حفز أفراد مجموعتك في المشاركة في النشاطات**
- **احرص على بناء علاقات طيبة مع المدرس والزملاء أثناء المحاضرة**
- **احرص على ما تعلمته في المحاضرة وطبقه في الميدان .**
- **ركز ذهنك بالتعليم واحرص على التطبيق المباشر**
- **تغلق الموبايل قبل الشروع بالمحاضرة**

الوحدة الأولى - الزمن: 90 دقيقة

أهداف المحاضرة الاولى:

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

التعرف على القوانين المهمة التي يستفاد منها الطالب

موضوعات

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التدريبية	الوسائل التدريبية
1	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

خطة إجراءات تنفيذ المحاضرة الاولى

الوحدة	المحاضرة	الإجراءات	الزمن بالدقيقة
الأولى	الأولى	الترحيب بالطلبة والتعارف معهم	90 دقيقة
		التعريف بالبرنامج وأهدافه وأهميته	

Electrical Circuits

POWERS OF TEN

$$1 = 10^0 \qquad 1/10 = 0.1 = 10^{-1}$$
$$10 = 10^1 \qquad 1/100 = 0.01 = 10^{-2}$$
$$100 = 10^2 \qquad 1/1000 = 0.001 = 10^{-3}$$
$$1000 = 10^3 \qquad 1/10{,}000 = 0.0001 = 10^{-4}$$

$$10{,}000.0 = 1\underbrace{0,000}_{1\ 2\ 3\ 4}. = 10^{+4}$$

$$0.00001 = 0.\underbrace{00001}_{5\ 4\ 3\ 2\ 1} = 10^{-5}$$

$$\frac{1}{10^n} = 10^{-n} \qquad \frac{1}{10^{-n}} = 10^n$$

EXAMPLE:

a. $\dfrac{1}{1000} = \dfrac{1}{10^{+3}} = 10^{-3}$

b. $\dfrac{1}{0.00001} = \dfrac{1}{10^{-5}} = 10^{+5}$

The product of powers of ten:

$$(10^n)(10^m) = 10^{(n+m)}$$

EXAMPLE

a. $(1000)(10{,}000) = (10^3)(10^4) = 10^{(3+4)} = 10^7$

b. $(0.00001)(100) = (10^{-5})(10^2) = 10^{(-5+2)} = 10^{-3}$

The division of powers of ten:

$$\frac{10^n}{10^m} = 10^{(n-m)}$$

EXAMPLE

a. $\frac{100,000}{100} = \frac{10^5}{10^2} = 10^{(5-2)} = 10^3$

b. $\frac{1000}{0.0001} = \frac{10^3}{10^{-4}} = 10^{(3-(-4))} = 10^{(3+4)} = 10^7$

The power of powers of ten:

$$(10^n)^m = 10^{(nm)}$$

EXAMPLE

a. $(100)^4 = (10^2)^4 = 10^{(2)(4)} = 10^8$

b. $(1000)^{-2} = (10^3)^{-2} = 10^{(3)(-2)} = 10^{-6}$

c. $(0.01)^{-3} = (10^{-2})^{-3} = 10^{(-2)(-3)} = 10^6$

Basic Arithmetic Operations

1- Addition and Subtraction

$$A \times 10^n \pm B \times 10^n = (A \pm B) \times 10^n$$

EXAMPLE

a. $6300 + 75,000 = (6.3)(1000) + (75)(1000)$
$= 6.3 \times 10^3 + 75 \times 10^3$
$= (6.3 + 75) \times 10^3$
$= \mathbf{81.3 \times 10^3}$

b. $0.00096 - 0.000086 = (96)(0.00001) - (8.6)(0.00001)$
$= 96 \times 10^{-5} - 8.6 \times 10^{-5}$
$= (96 - 8.6) \times 10^{-5}$
$= \mathbf{87.4 \times 10^{-5}}$

2- Multiplication

$$(A \times 10^n)(B \times 10^m) = (A)(B) \times 10^{n+m}$$

EXAMPLE

a. $(0.0002)(0.000007) = [(2)(0.0001)][(7)(0.000001)]$
$= (2 \times 10^{-4})(7 \times 10^{-6})$
$= (2)(7) \times (10^{-4})(10^{-6})$
$= \mathbf{14 \times 10^{-10}}$

b. $(340{,}000)(0.00061) = (3.4 \times 10^5)(61 \times 10^{-5})$
$= (3.4)(61) \times (10^5)(10^{-5})$
$= 207.4 \times 10^0$
$= \mathbf{207.4}$

3- **Division**

$$\frac{A \times 10^n}{B \times 10^m} = \frac{A}{B} \times 10^{n-m}$$

EXAMPLE

a. $$\frac{0.00047}{0.002} = \frac{47 \times 10^{-5}}{2 \times 10^{-3}} = \left(\frac{47}{2}\right) \times \left(\frac{10^{-5}}{10^{-3}}\right)$$
$$= \mathbf{23.5 \times 10^{-2}}$$

b. $$\frac{690{,}000}{0.00000013} = \frac{69 \times 10^4}{13 \times 10^{-8}} = \left(\frac{69}{13}\right) \times \left(\frac{10^4}{10^{-8}}\right)$$
$$= \mathbf{5.31 \times 10^{12}}$$

4- **Powers**

$$(A \times 10^n)^m = A^m \times 10^{nm}$$

EXAMPLE

a. $(0.00003)^3 = (3 \times 10^{-5})^3 = (3)^3 \times (10^{-5})^3$
$= \mathbf{27 \times 10^{-15}}$

b. $(90{,}800{,}000)^2 = (9.08 \times 10^7)^2 = (9.08)^2 \times (10^7)^2$
$= \mathbf{82.4464 \times 10^{14}}$

Prefixes

Multiplication Factors	SI Prefix	SI Symbol
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1\ 000\ 000\ 000 = 10^{9}$	giga	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p

EXAMPLE

a. $1{,}000{,}000$ ohms $= 1 \times 10^6$ ohms
$= 1$ megohm (MΩ)

b. $100{,}000$ meters $= 100 \times 10^3$ meters
$= 100$ kilometers (km)

c. 0.0001 second $= 0.1 \times 10^{-3}$ second
$= 0.1$ millisecond (ms)

d. 0.000001 farad $= 1 \times 10^{-6}$ farad
$= 1$ microfarad (μF)

EXAMPLE

a. 41,200 m is equivalent to 41.2×10^3 m = 41.2 kilometers = **41.2 km.**

b. 0.00956 J is equivalent to 9.56×10^{-3} J = 9.56 millijoules = **9.56 mJ.**

c. 0.000768 s is equivalent to 768×10^{-6} s = 768 microseconds = **768 μs.**

d. $$\frac{8400\text{ m}}{0.06} = \frac{8.4 \times 10^3\text{ m}}{6 \times 10^{-2}} = \left(\frac{8.4}{6}\right) \times \left(\frac{10^3}{10^{-2}}\right)\text{ m}$$
$$= 1.4 \times 10^5\text{ m} = 140 \times 10^3\text{ m} = 140\text{ kilometers} = \mathbf{140\ km}$$

e. $$(0.0003)^4\text{ s} = (3 \times 10^{-4})^4\text{ s} = 81 \times 10^{-16}\text{ s}$$
$$= 0.0081 \times 10^{-12}\text{ s} = 0.008\text{ picosecond} = \mathbf{0.0081\ ps}$$

الوحدة الثانية - الزمن: 90 دقيقة

أهداف المحاضرة الاولى:

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

التعرف على التيار والفولتية

موضوعات

الأساليب والأنشطة والوسائل التعليمية

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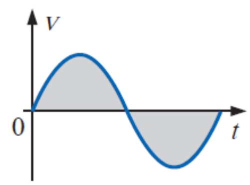
Current and Voltage

Charge: the electrical charge is an electrical property of atomic particles of which matter consists, measured in coulombs (C). The charge of an electron is ($-1.602\times10^{-19}\ C$).

Electrical current: is the rate of change of charge, measured in amperes (A). The current (I) is defined mathematically as:

$$I = \frac{Q}{t}$$

- Direct current (DC): is the current that remains constant with time. The symbol (I) is usually used to represent such a constant current.
- Alternating current (AC): is a current that is varying sinusoidally with time. A time varying current is represented by the symbol (i).



Sinusoidal

Voltage: the voltage (or potential difference) is the energy required to move a unit of charge through an element, measured in volts (V).

* For the voltage **Vab**, this mean that the potential of point **a** is higher than that of point **b**.

$$Vab = Va - Vb$$

Power: is the time rate of expending or absorbing energy, measured in watt (W).

$$P = \frac{w}{t}$$

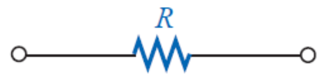
Where P is the power in watt (W), w is the energy in joules (J), and t is the time in seconds (s).
The power (P) is defined mathematically as:

$$P = VI$$

$$P = \frac{V^2}{R}$$

$$P = I^2R$$

Resistance: the resistance R denotes the ability of an element to resist the flow of electrical current, it is measured in Ohms (Ω).



For the material, the resistance R depends of the physical dimensions as follows:

$$R = \rho \frac{l}{A}$$

Where ρ is the receptivity of material.

Resistivity (ρ) of various materials in ohm-centimeters.

Silver	1.645×10^{-6}
Copper	$\mathbf{1.723 \times 10^{-6}}$
Gold	2.443×10^{-6}
Aluminum	2.825×10^{-6}
Tungsten	5.485×10^{-6}
Nickel	7.811×10^{-6}
Iron	12.299×10^{-6}
Tantalum	15.54×10^{-6}
Nichrome	99.72×10^{-6}
Tin oxide	250×10^{-6}
Carbon	3500×10^{-6}

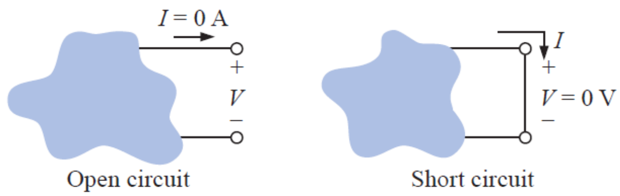
EXAMPLE: Determine the resistance of 30.48 m of copper telephone wire if the diameter is 0.032 cm.

Solution:

$$A = \frac{\pi d^2}{4} = \frac{(3.1416)(0.032\ \text{cm})^2}{4} = 8.04 \times 10^{-4}\ \text{cm}^2$$

$$R = \rho\frac{l}{A} = \frac{(1.723 \times 10^{-6}\ \Omega\cdot\text{cm})(3048\ \text{cm})}{8.04 \times 10^{-4}\ \text{cm}^2} \cong \mathbf{6.5\ \Omega}$$

- The resistance of a short circuit element is approaching zero.
- The resistance of an open circuit element is approaching infinity.



Conductance: the conductance can be explained as the ability of an element to conduct electrical current, it is measured in siemens (S).

$$G = \frac{1}{R} \qquad G = \frac{A}{\rho l}$$

OHM'S LAW: Ohm's low states that the voltage V across a resistor is directly proportional to the current I flowing through the resistor.

$$V = IR \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

EXAMPLE: Determine the current resulting from the application of a 9-V battery across a network with a resistance of 2.2 Ω.

Solution:

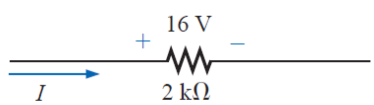
$$I = \frac{V}{R} = \frac{9V}{2.2\Omega} = 4.09\,A$$

EXAMPLE: Calculate the resistance of a 60-W bulb if a current of 500 mA results from an applied voltage of 120 V.

Solution:

$$R = \frac{V}{I} = \frac{120}{500\times10^{-3}} = 240\Omega$$

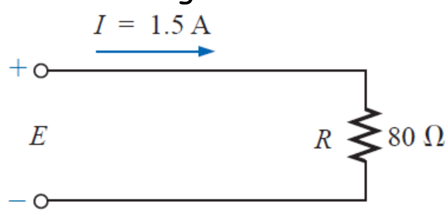
EXAMPLE: Calculate the current through the 2-kΩ resistor of Figure below if the voltage drop across it is 16 V.



Solution:

$$I = \frac{V}{R} = \frac{16\text{ V}}{2\times10^{3}\ \Omega} = \mathbf{8\ mA}$$

EXAMPLE: Calculate the voltage that must be applied across the soldering iron of Figure below to establish a current of 1.5 A through the iron if its internal resistance is 80Ω.



Solution:

$$E = IR = (1.5\text{ A})(80\ \Omega) = \mathbf{120\ V}$$

EXAMPLE: What is the power dissipated by a 5Ω resistor if the current is 4 A?

Solution:

$$P = I^2R = (4\text{ A})^2(5\ \Omega) = \mathbf{80\ W}$$

EXAMPLE: Determine the current through a 5-kΩ resistor when the power dissipated by the element is 20 mW.

Solution:

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{20 \times 10^{-3}\ \text{W}}{5 \times 10^{3}\ \Omega}} = \sqrt{4 \times 10^{-6}} = 2 \times 10^{-3}\ \text{A}$$
$$= \mathbf{2\ mA}$$

الوحدة الثالثة -الزمن: 90 دقيقة

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التعرف على الدوائر المتسلسلة

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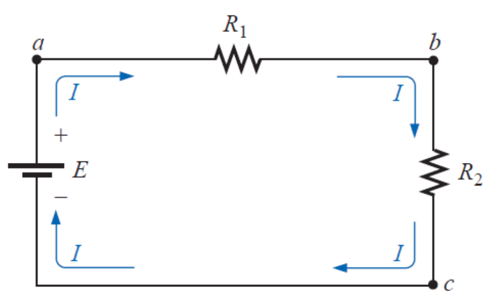
Series Circuits:

Two elements are in series if

1. They have only one terminal in common (i.e., one lead of one is connected to only one lead of the other).
2. The common point between the two elements is not connected to another current-carrying element.



- The current is the same through series elements, but the voltage is different.
- The total resistance of a series circuit is the sum of the resistance levels.

$$R_T = R_1 + R_2 + R_3 + \cdots + R_N$$

$$V_1 = IR_1,\ V_2 = IR_2,\ V_3 = IR_3,\ \ldots,\ V_N = IR_N$$

EXAMPLE: for the figure below

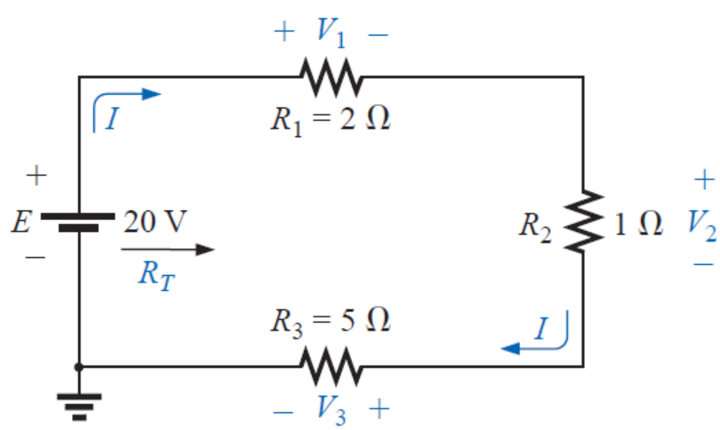
a. Find the total resistance for the series circuit.

b. Calculate the source current Is.

c. Determine the voltages V1, V2, and V3.

d. Calculate the power dissipated by R1, R2, and R3.

e. Determine the power delivered by the source, and compare it to the sum of the power levels of part (d).



Solution:

a. $R_T = R_1 + R_2 + R_3 = 2\ \Omega + 1\ \Omega + 5\ \Omega = \mathbf{8\ \Omega}$

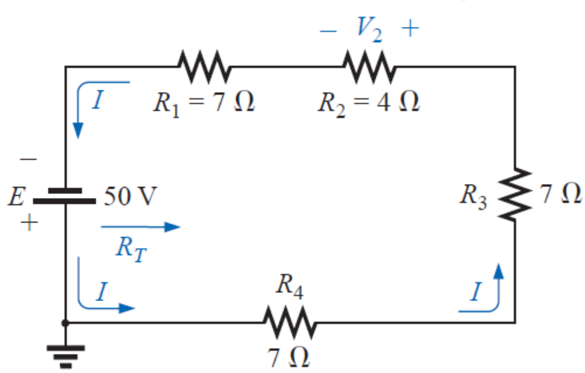
b. $I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{8\ \Omega} = \mathbf{2.5\ A}$

c. $V_1 = IR_1 = (2.5\text{ A})(2\ \Omega) = \mathbf{5\ V}$
$V_2 = IR_2 = (2.5\text{ A})(1\ \Omega) = \mathbf{2.5\ V}$
$V_3 = IR_3 = (2.5\text{ A})(5\ \Omega) = \mathbf{12.5\ V}$

d. $P_1 = V_1I_1 = (5\text{ V})(2.5\text{ A}) = \mathbf{12.5\ W}$
$P_2 = I_2^2R_2 = (2.5\text{ A})^2(1\ \Omega) = \mathbf{6.25\ W}$
$P_3 = V_3^2/R_3 = (12.5\text{ V})^2/5\ \Omega = \mathbf{31.25\ W}$

e. $P_{\text{del}} = EI = (20\text{ V})(2.5\text{ A}) = \mathbf{50\ W}$
$P_{\text{del}} = P_1 + P_2 + P_3$
$50\text{ W} = 12.5\text{ W} + 6.25\text{ W} + 31.25\text{ W}$
$50\text{ W} = 50\text{ W}$ (checks)

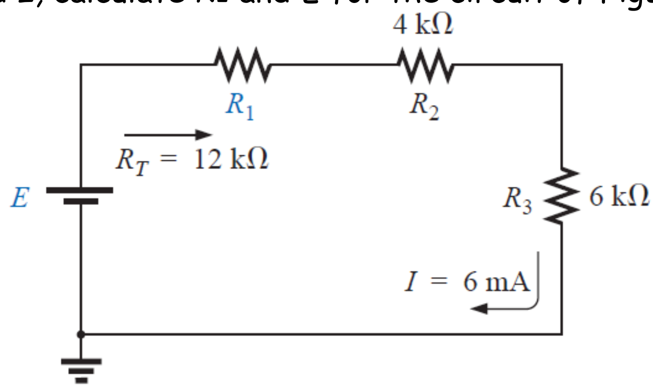
EXAMPLE: Determine *RT*, *I*, and *V2* for the circuit of Figure below.



Solution: Note the current direction as established by the battery and the polarity of the voltage drops across *R2* as determined by the current direction. Since *R1* = *R3* = *R4*,

$$R_T = NR_1 + R_2 = (3)(7\ \Omega) + 4\ \Omega = 21\ \Omega + 4\ \Omega = \mathbf{25\ \Omega}$$
$$I = \frac{E}{R_T} = \frac{50\text{ V}}{25\ \Omega} = \mathbf{2\ A}$$
$$V_2 = IR_2 = (2\text{ A})(4\ \Omega) = \mathbf{8\ V}$$

EXAMPLE: Given *RT* and *I*, calculate *R1* and *E* for the circuit of Figure below.



Solution:

$$R_T = R_1 + R_2 + R_3$$

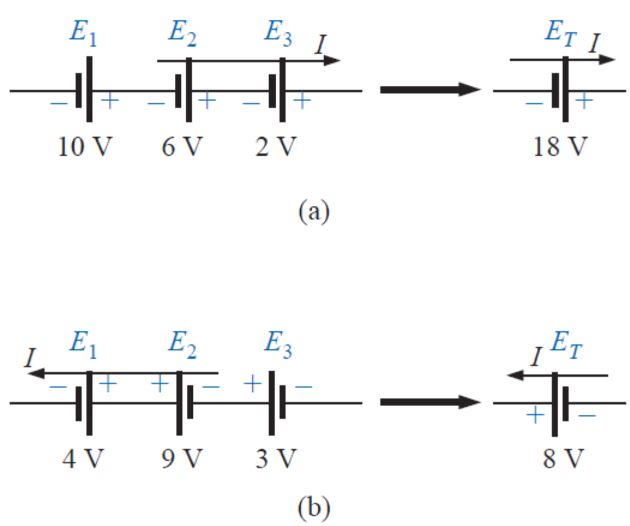
$$12\ \text{k}\Omega = R_1 + 4\ \text{k}\Omega + 6\ \text{k}\Omega$$

$$R_1 = 12\ \text{k}\Omega - 10\ \text{k}\Omega = \mathbf{2\ k\Omega}$$

$$E = IR_T = (6 \times 10^{-3}\ \text{A})(12 \times 10^{3}\ \Omega) = \mathbf{72\ V}$$

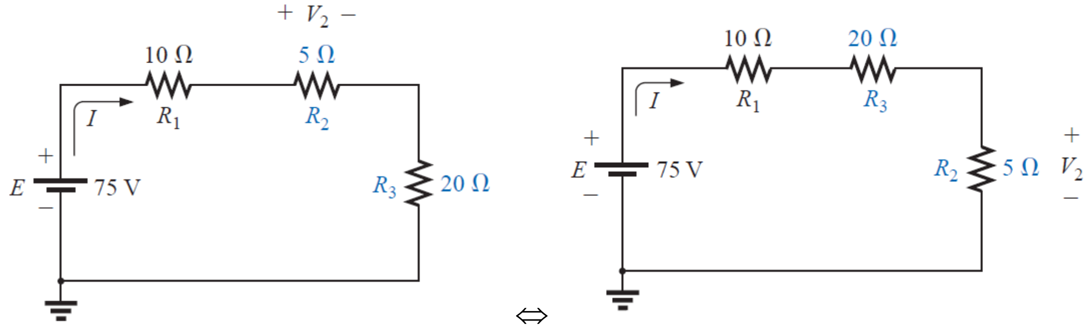
Voltage Sources in Series:

Voltage sources can be connected in series as shown in figure below. The net voltage is determined simply by summing the sources with the same polarity and subtracting the total of the sources with the opposite.



Interchanging Series Elements:

The elements of a series circuit can be interchanged without affecting the total resistance, current, or power to each element.



الوحدة الرابعة -الزمن: 90 دقيقة

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التعرف على قوانين الفولتية في الدوائر المتسلسلة

الأساليب والأنشطة والوسائل التعليمية

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VOLTAGE DIVIDER RULE:

In a series circuit,

the voltage across a resistor in a series circuit is equal to the value of that resistor times the total impressed voltage across the series elements divided by the total resistance of the series elements.

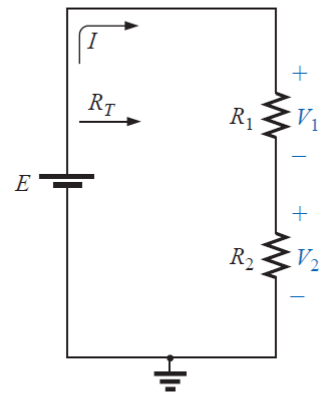
$$V_x = \frac{R_x E}{R_T}$$

Where *Vx* is the voltage across *Rx*.

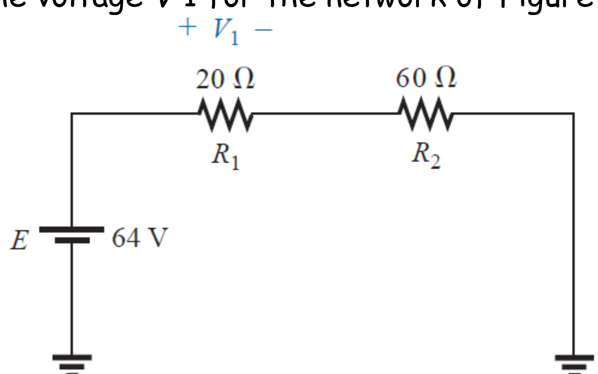
For example:

$$V_1 = IR_1 = \left(\frac{E}{R_T}\right)R_1 = \frac{R_1E}{R_T}$$

$$V_2 = IR_2 = \left(\frac{E}{R_T}\right)R_2 = \frac{R_2E}{R_T}$$



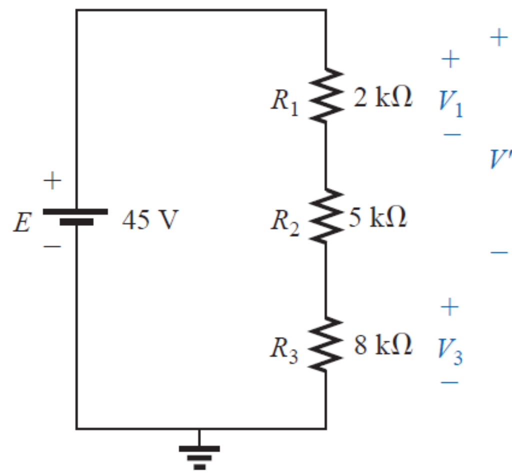
EXAMPLE: Determine the voltage V_1 for the network of Figure below.



Solution:

$$V_1 = \frac{R_1E}{R_T} = \frac{R_1E}{R_1 + R_2} = \frac{(20\ \Omega)(64\ \text{V})}{20\ \Omega + 60\ \Omega} = \frac{1280\ \text{V}}{80} = \mathbf{16\ V}$$

EXAMPLE: Using the voltage divider rule, determine the voltages V_1 and V_3 for the series circuit of Figure below.



Solution:

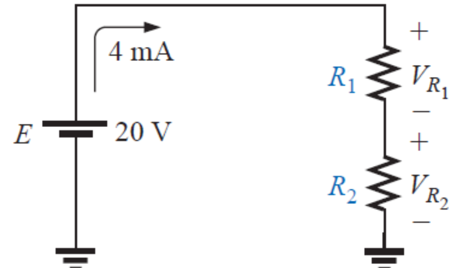
$$V_1 = \frac{R_1E}{R_T} = \frac{(2\ \text{k}\Omega)(45\ \text{V})}{2\ \text{k}\Omega + 5\ \text{k}\Omega + 8\ \text{k}\Omega} = \frac{(2\ \text{k}\Omega)(45\ \text{V})}{15\ \text{k}\Omega}$$

$$= \frac{(2\times10^3\ \Omega)(45\ \text{V})}{15\times10^3\ \Omega} = \frac{90\ \text{V}}{15} = \mathbf{6\ V}$$

$$V_3 = \frac{R_3E}{R_T} = \frac{(8\ \text{k}\Omega)(45\ \text{V})}{15\ \text{k}\Omega} = \frac{(8\times10^3\ \Omega)(45\ \text{V})}{15\times10^3\ \Omega}$$

$$= \frac{360\ \text{V}}{15} = \mathbf{24\ V}$$

EXAMPLE: Design the voltage divider of Figure below such that $V_{R1} = 4V_{R2}$.



Solution: The total resistance is defined by

$$R_T = \frac{E}{I} = \frac{20\ \text{V}}{4\ \text{mA}} = 5\ \text{k}\Omega$$

Since $V_{R_1} = 4V_{R_2}$,

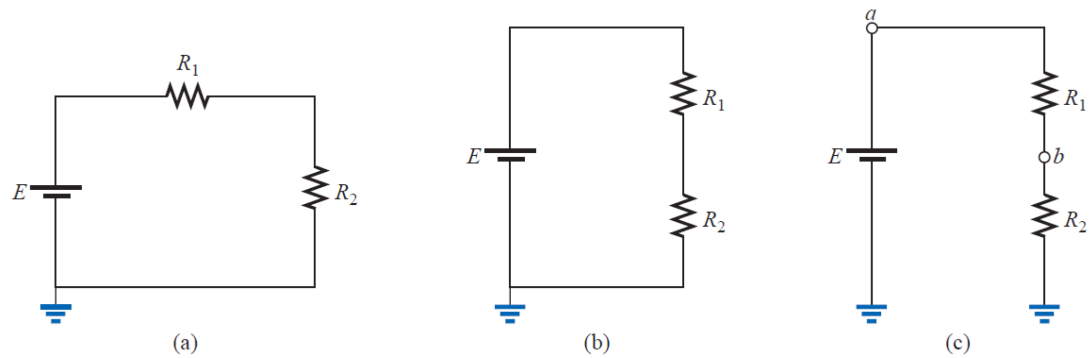
$$R_1 = 4R_2$$

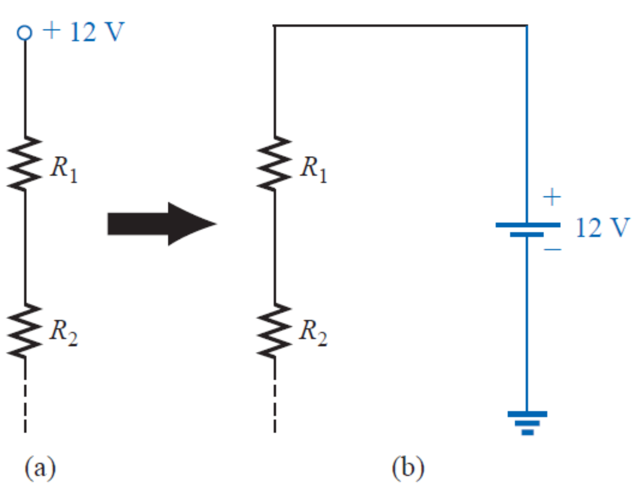
Thus $$R_T = R_1 + R_2 = 4R_2 + R_2 = 5R_2$$

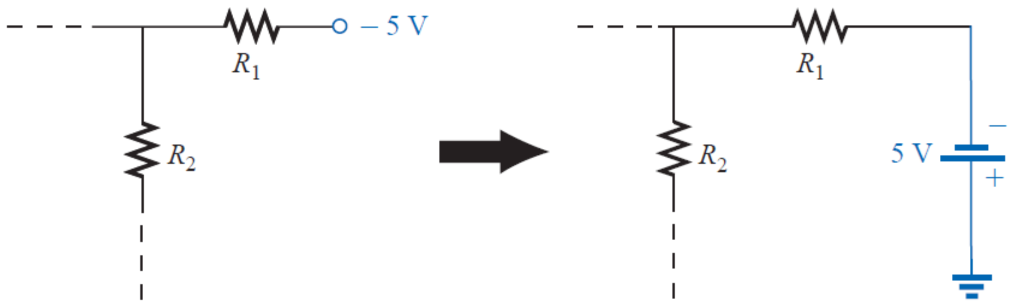
and $$5R_2 = 5\ \text{k}\Omega$$
$$R_2 = \mathbf{1\ k\Omega}$$

and $$R_1 = 4R_2 = \mathbf{4\ k\Omega}$$

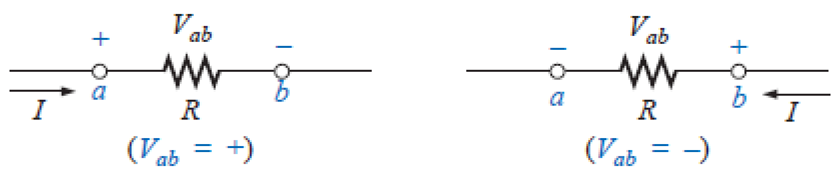
NOTATION:





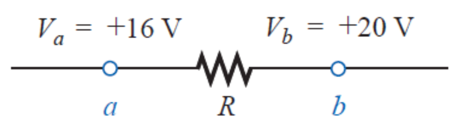


(a) (b)



(a) (b)

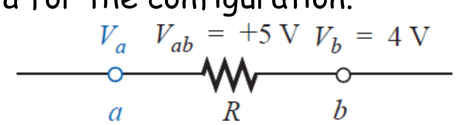
EXAMPLE: Find the voltage *Vab* for the conditions.



Solution:

$$V_{ab} = V_a - V_b = 16\text{ V} - 20\text{ V}$$
$$= \mathbf{-4\ V}$$

EXAMPLE: Find the voltage *Va* for the configuration.

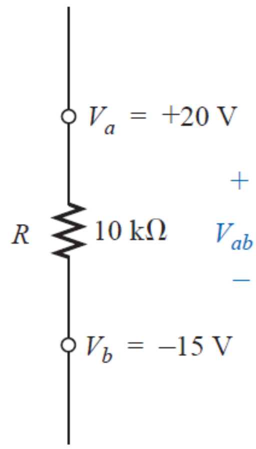


Solution:

$$V_{ab} = V_a - V_b$$

$$V_a = V_{ab} + V_b = 5\text{ V} + 4\text{ V}$$
$$= \mathbf{9\ V}$$

EXAMPLE: Find the voltage *Vab* for the configuration.



Solution:

$$V_{ab} = V_a - V_b = 20\text{ V} - (-15\text{ V}) = 20\text{ V} + 15\text{ V}$$
$$= \mathbf{35\ V}$$

الوحدة الخامسة - الزمن: 90 دقيقة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

التعرف على الدوائر المتوازية

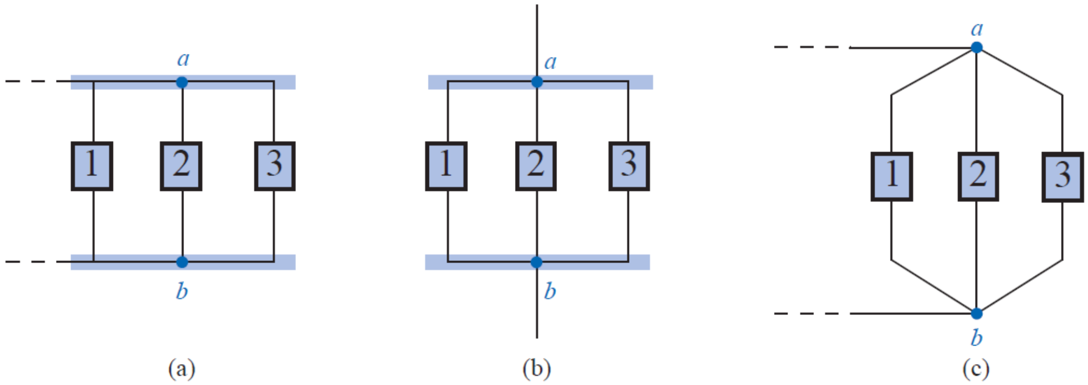
موضوعات المحاضرة

امثلة
الأساليب والأنشطة والوسائل التعليمية

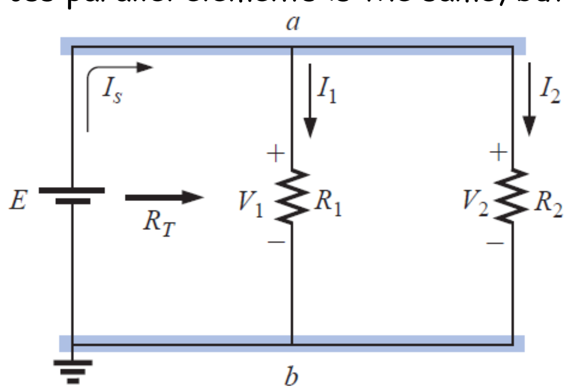
م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
5	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

Parallel Circuits:

Two elements, branches, or networks are in parallel if they have two points in common.



- The voltage across parallel elements is the same, but the current is different.

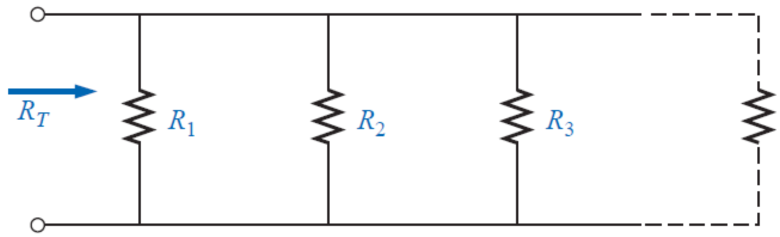


$E = V1 = V2$

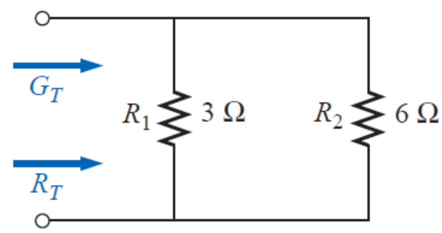
- For parallel elements, the total conductance is the sum of the individual conductances.
- The total resistance of parallel resistors is always less than the value of the smallest resistor.

$$G_T = G_1 + G_2 + G_3 + \cdots + G_N$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}$$



EXAMPLE: Determine the total conductance and resistance for the parallel network.

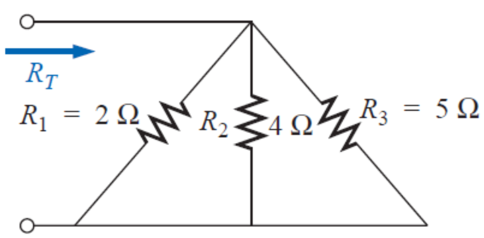


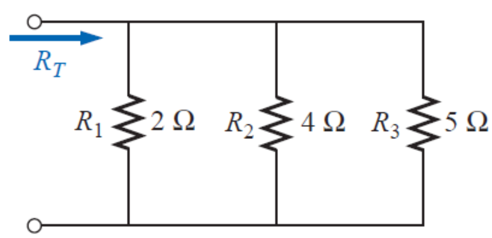
Solution:

$$G_T = G_1 + G_2 = \frac{1}{3\ \Omega} + \frac{1}{6\ \Omega} = 0.333\ \text{S} + 0.167\ \text{S} = \mathbf{0.5\ S}$$

and
$$R_T = \frac{1}{G_T} = \frac{1}{0.5\ \text{S}} = \mathbf{2\ \Omega}$$

EXAMPLE: Determine the total resistance for the network.





Solution:

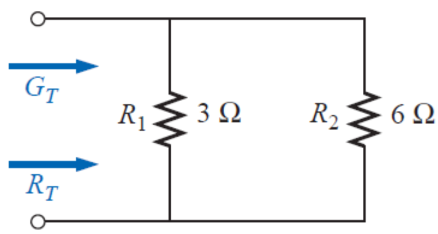
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
$$= \frac{1}{2\,\Omega} + \frac{1}{4\,\Omega} + \frac{1}{5\,\Omega} = 0.5\text{ S} + 0.25\text{ S} + 0.2\text{ S}$$
$$= 0.95\text{ S}$$

and $$R_T = \frac{1}{0.95\text{ S}} = \mathbf{1.053\ \Omega}$$

* The total resistance of two parallel resistors is the product of the two divided by their sum.

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

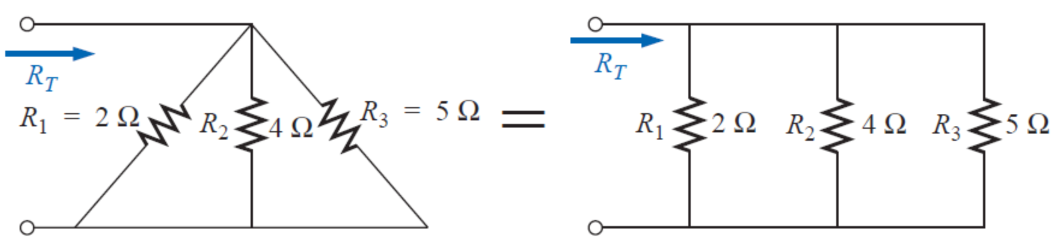
EXAMPLE: Determine the total conductance and resistance for the parallel network.



Solution:

$$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{(3\,\Omega)(6\,\Omega)}{3\,\Omega + 6\,\Omega} = \frac{18\,\Omega}{9} = \mathbf{2\ \Omega}$$

EXAMPLE: Determine the total resistance for the network.

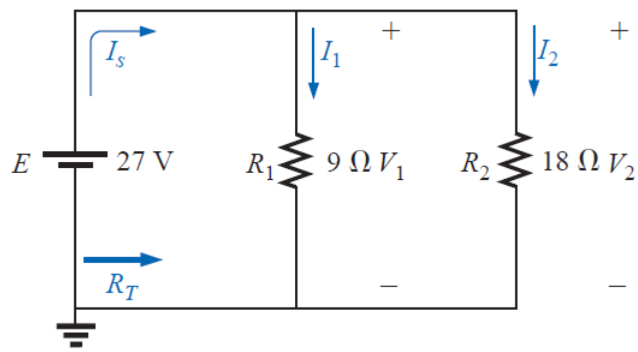


Solution:

$$R'_T = 2\,\Omega \parallel 4\,\Omega = \frac{(2\,\Omega)(4\,\Omega)}{2\,\Omega + 4\,\Omega} = \frac{4}{3}\,\Omega$$

$$R_T = R'_T \parallel 5\,\Omega = \frac{\left(\frac{4}{3}\,\Omega\right)(5\,\Omega)}{\frac{4}{3}\,\Omega + 5\,\Omega} = \mathbf{1.053\,\Omega}$$

EXAMPLE: For the parallel network.



a. Calculate *RT*.
b. Determine *Is*.
c. Calculate *I1* and *I2*, and demonstrate that *Is* = *I1* + *I2*.
d. Determine the power to each resistive load.
e. Determine the power delivered by the source, and compare it to the total power dissipated by the resistive elements.

Solution:

a. $R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{(9\ \Omega)(18\ \Omega)}{9\ \Omega + 18\ \Omega} = \frac{162\ \Omega}{27} = \mathbf{6\ \Omega}$

b. $I_s = \frac{E}{R_T} = \frac{27\ \text{V}}{6\ \Omega} = \mathbf{4.5\ A}$

c. $I_1 = \frac{V_1}{R_1} = \frac{E}{R_1} = \frac{27\ \text{V}}{9\ \Omega} = \mathbf{3\ A}$

$I_2 = \frac{V_2}{R_2} = \frac{E}{R_2} = \frac{27\ \text{V}}{18\ \Omega} = \mathbf{1.5\ A}$

$I_s = I_1 + I_2$

$4.5\ \text{A} = 3\ \text{A} + 1.5\ \text{A}$

$\mathbf{4.5\ A = 4.5\ A}$ (checks)

d. $P_1 = V_1 I_1 = E I_1 = (27\ \text{V})(3\ \text{A}) = \mathbf{81\ W}$

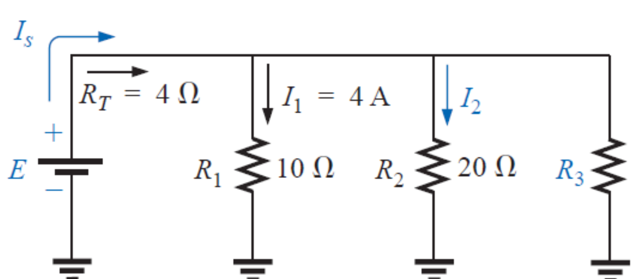
$P_2 = V_2 I_2 = E I_2 = (27\ \text{V})(1.5\ \text{A}) = \mathbf{40.5\ W}$

e. $P_s = E I_s = (27\ \text{V})(4.5\ \text{A}) = \mathbf{121.5\ W}$

$= P_1 + P_2 = 81\ \text{W} + 40.5\ \text{W} = \mathbf{121.5\ W}$

EXAMPLE: Given the information provided.

a. Determine *R3*.
b. Calculate *E*.
c. Find *Is*.
d. Find *I2*.
e. Determine *P2*.



Solution:

a. $$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{4\ \Omega} = \frac{1}{10\ \Omega} + \frac{1}{20\ \Omega} + \frac{1}{R_3}$$

$$0.25\ \text{S} = 0.1\ \text{S} + 0.05\ \text{S} + \frac{1}{R_3}$$

$$0.25\ \text{S} = 0.15\ \text{S} + \frac{1}{R_3}$$

$$\frac{1}{R_3} = 0.1\ \text{S}$$

$$R_3 = \frac{1}{0.1\ \text{S}} = \mathbf{10\ \Omega}$$

b. $E = V_1 = I_1R_1 = (4\ \text{A})(10\ \Omega) = \mathbf{40\ V}$

c. $I_s = \dfrac{E}{R_T} = \dfrac{40\ \text{V}}{4\ \Omega} = \mathbf{10\ A}$

d. $I_2 = \dfrac{V_2}{R_2} = \dfrac{E}{R_2} = \dfrac{40\ \text{V}}{20\ \Omega} = \mathbf{2\ A}$

e. $P_2 = I_2^2R_2 = (2\ \text{A})^2(20\ \Omega) = \mathbf{80\ W}$

الوحدة السادسة - الزمن: .90 دقيقة

أهداف المحاضرة الثانية:

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

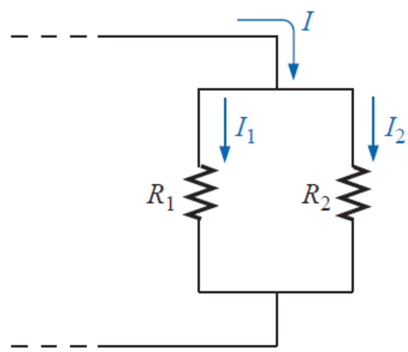
التعرف على قوانين التيار
موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
6	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

CURRENT DIVIDER RULE:

- For two parallel elements of equal value, the current will divide equally.
- For parallel elements with different values, the smaller the resistance, the greater the share of input current.
- For parallel elements of different values, the current will split with a ratio equal to the inverse of their resistor values.

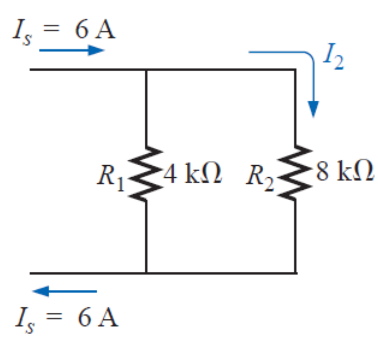


Note difference in subscripts.

$$I_1 = \frac{R_2 I}{R_1 + R_2}$$

$$I_2 = \frac{R_1 I}{R_1 + R_2}$$

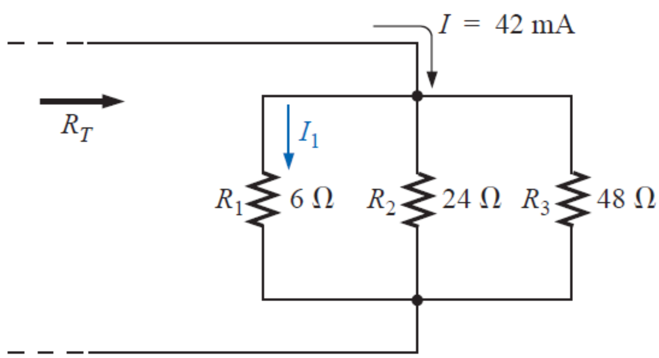
EXAMPLE: Determine the current I_2 for the network using the current divider rule.



Solution:

$$I_2 = \frac{R_1 I_s}{R_1 + R_2} = \frac{(4\ \text{k}\Omega)(6\ \text{A})}{4\ \text{k}\Omega + 8\ \text{k}\Omega} = \frac{4}{12}(6\ \text{A}) = \frac{1}{3}(6\ \text{A})$$
$$= \mathbf{2\ A}$$

EXAMPLE: Find the current I_1 for the network.

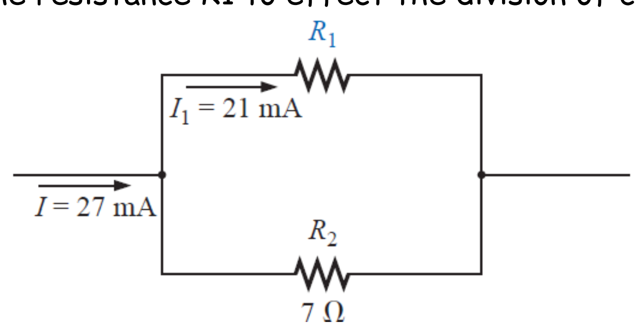


Solution:

$$24\ \Omega \parallel 48\ \Omega = \frac{(24\ \Omega)(48\ \Omega)}{24\ \Omega + 48\ \Omega} = 16\ \Omega$$

$$I_1 = \frac{16\ \Omega(42\ \text{mA})}{16\ \Omega + 6\ \Omega} = \mathbf{30.54\ mA}$$

EXAMPLE: Determine the resistance R1 to effect the division of current.



Solution:

$$I_1 = \frac{R_2 I}{R_1 + R_2}$$

$$(R_1 + R_2)I_1 = R_2 I$$
$$R_1 I_1 + R_2 I_1 = R_2 I$$
$$R_1 I_1 = R_2 I - R_2 I_1$$
$$R_1 = \frac{R_2(I - I_1)}{I_1}$$
$$R_1 = \frac{7\ \Omega(27\ \text{mA} - 21\ \text{mA})}{21\ \text{mA}}$$
$$= 7\ \Omega\left(\frac{6}{21}\right) = \frac{42\ \Omega}{21} = \mathbf{2\ \Omega}$$

الوحدة السابعة - الزمن: 90 دقيقة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

التعرف على الدوائر القصيرة المفتوحة

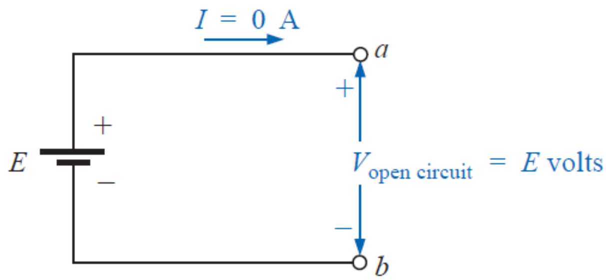
موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

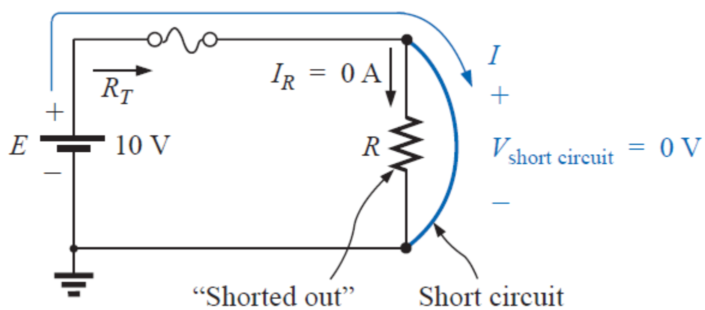
م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
7	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

Open and Short Circuits:

An open circuit can have a potential difference (voltage) across its terminals, but the current is always zero amperes.

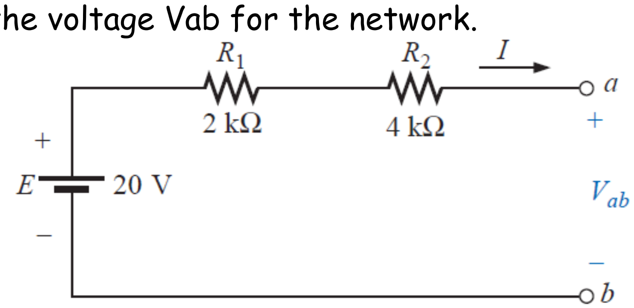


A short circuit can carry a current of a level determined by the external circuit, but the potential difference (voltage) across its terminals is always zero volts.



$$I = \frac{E}{R} = \frac{10\text{ V}}{0\ \Omega} \longrightarrow \infty\text{ A}$$

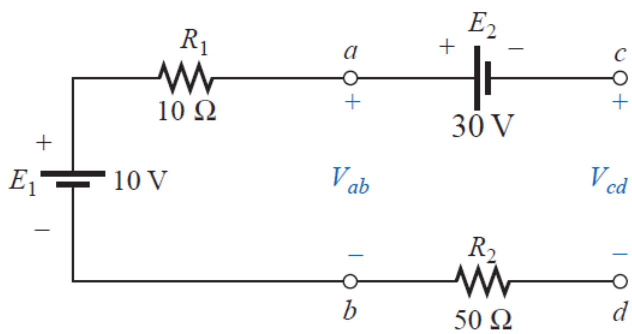
EXAMPLE: Determine the voltage Vab for the network.



Solution:

$$V_{ab} = E = \mathbf{20\ V}$$

EXAMPLE: Determine the voltages Vab and Vcd for the network.



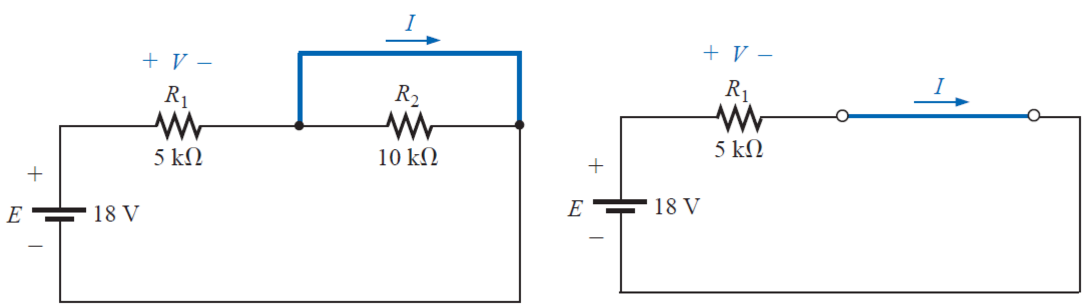
Solution:

$$V_{ab} = E_1 = \mathbf{10\ V}$$

$$+E_1 - E_2 - V_{cd} = 0$$

$$V_{cd} = E_1 - E_2 = 10\text{ V} - 30\text{ V} = \mathbf{-20\ V}$$

EXAMPLE: Calculate the current I and the voltage V for the network.



Solution:

$$I = \frac{E}{R_1} = \frac{18\text{ V}}{5\text{ k}\Omega} = \mathbf{3.6\ mA}$$

$$V = E = \mathbf{18\ V}$$

الوحدة الثامنة- الزمن: 90 دقيقة

أهداف المحاضرة الثانية:

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Series-parallel networks are networks that contain both series and parallel circuit configurations

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
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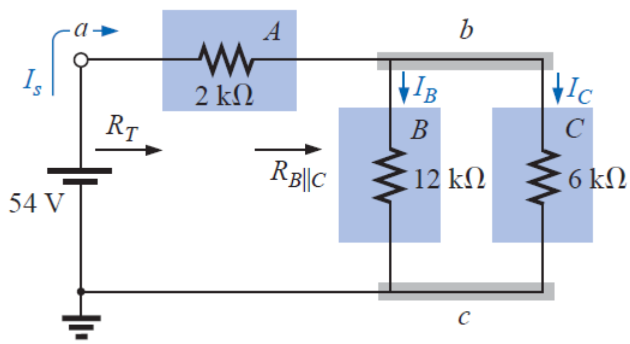
Series-Parallel Networks:

Series-parallel networks are networks that contain both series and parallel circuit configurations.

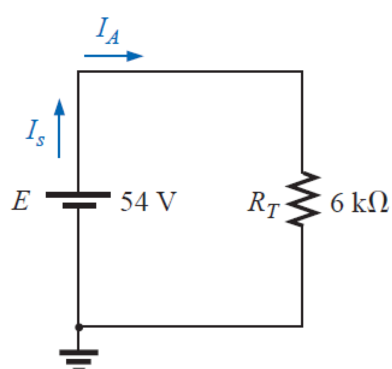
EXAMPLE: for the network find R_T, Is, IA, IB, and IC.



Solution:

$$R_{B\|C} = R_B \,\|\, R_C = \frac{(12\text{ k}\Omega)(6\text{ k}\Omega)}{12\text{ k}\Omega + 6\text{ k}\Omega} = 4\text{ k}\Omega$$

$$R_T = R_A + R_{B\|C} = 2\text{ k}\Omega + 4\text{ k}\Omega = \mathbf{6\text{ k}\Omega}$$

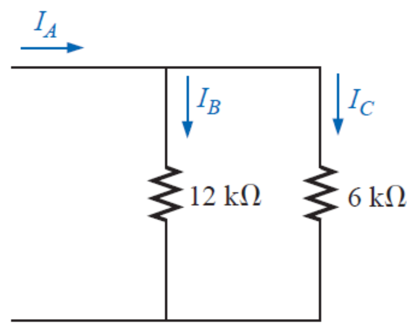


$$I_s = \frac{E}{R_T} = \frac{54\text{ V}}{6\text{ k}\Omega} = \mathbf{9\text{ mA}}$$

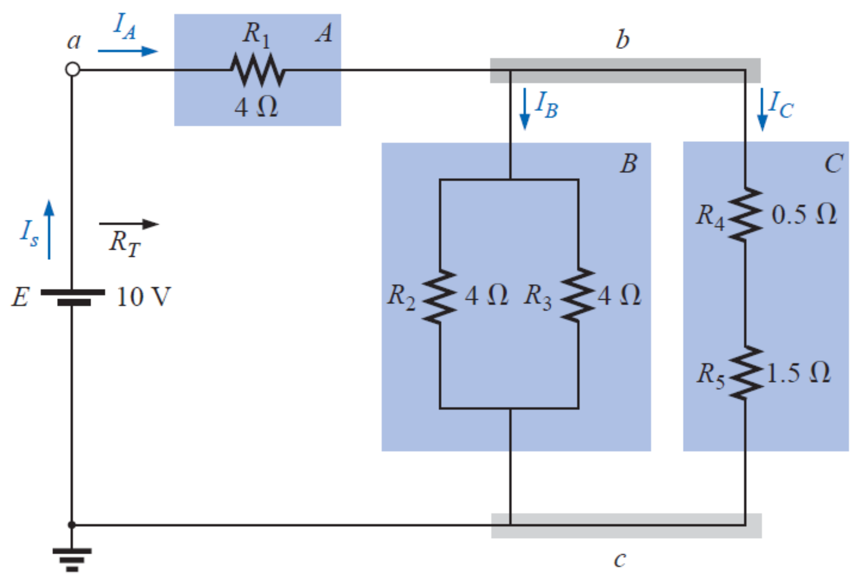
$$I_A = I_s = 9\text{ mA}$$

$$I_B = \frac{6\,k\Omega(I_s)}{6\,k\Omega + 12\,k\Omega} = \frac{6}{18}I_s = \frac{1}{3}(9\text{ mA}) = \mathbf{3\text{ mA}}$$

$$I_C = \frac{12\,k\Omega(I_s)}{12\,k\Omega + 6\,k\Omega} = \frac{12}{18}I_s = \frac{2}{3}(9\text{ mA}) = \mathbf{6\text{ mA}}$$



EXAMPLE: for the network find the currents and voltage for each element.

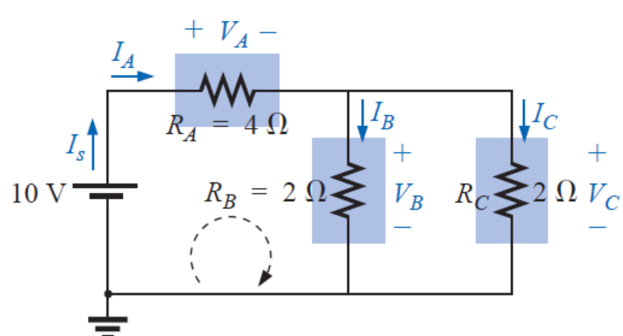


Solution:

$$A: \quad R_A = 4\,\Omega$$

$$B: \quad R_B = R_2 \parallel R_3 = R_{2\parallel 3} = \frac{R}{N} = \frac{4\,\Omega}{2} = 2\,\Omega$$

$$C: \quad R_C = R_4 + R_5 = R_{4,5} = 0.5\,\Omega + 1.5\,\Omega = 2\,\Omega$$



$$R_{B\parallel C} = \frac{R}{N} = \frac{2\ \Omega}{2} = 1\ \Omega$$

$$R_T = R_A + R_{B\parallel C} = 4\ \Omega + 1\ \Omega = \mathbf{5\ \Omega}$$

$$I_s = \frac{E}{R_T} = \frac{10\ \text{V}}{5\ \Omega} = \mathbf{2\ A}$$

$$I_A = I_s = \mathbf{2\ A}$$

$$I_B = I_C = \frac{I_A}{2} = \frac{I_s}{2} = \frac{2\ \text{A}}{2} = \mathbf{1\ A}$$

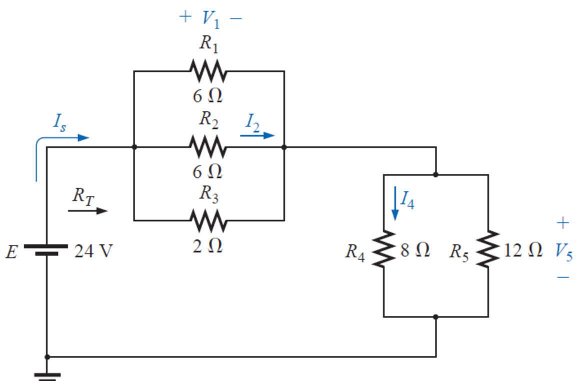
$$I_{R_2} = I_{R_3} = \frac{I_B}{2} = \mathbf{0.5\ A}$$

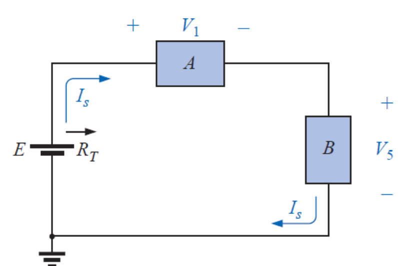
$$V_A = I_A R_A = (2\ \text{A})(4\ \Omega) = \mathbf{8\ V}$$

$$V_B = I_B R_B = (1\ \text{A})(2\ \Omega) = \mathbf{2\ V}$$

$$V_C = V_B = \mathbf{2\ V}$$

EXAMPLE: for the network find the currents and voltage for each element.



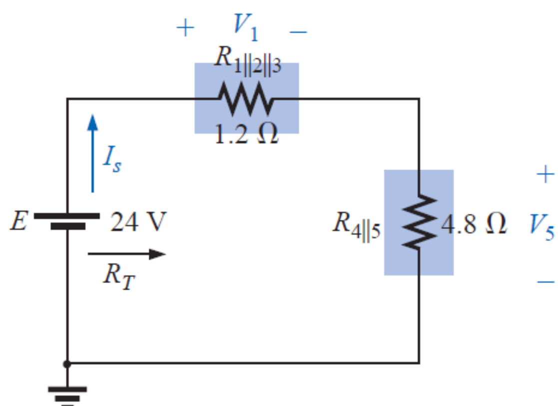


Solution:

$$R_{1\|2} = \frac{R}{N} = \frac{6\ \Omega}{2} = 3\ \Omega$$

$$R_A = R_{1\|2\|3} = \frac{(3\ \Omega)(2\ \Omega)}{3\ \Omega + 2\ \Omega} = \frac{6\ \Omega}{5} = 1.2\ \Omega$$

$$R_B = R_{4\|5} = \frac{(8\ \Omega)(12\ \Omega)}{8\ \Omega + 12\ \Omega} = \frac{96\ \Omega}{20} = 4.8\ \Omega$$



$$R_T = R_{1\|2\|3} + R_{4\|5} = 1.2\ \Omega + 4.8\ \Omega = \mathbf{6\ \Omega}$$

$$I_s = \frac{E}{R_T} = \frac{24\text{ V}}{6\ \Omega} = \mathbf{4\ A}$$

$$V_1 = I_s R_{1\|2\|3} = (4\text{ A})(1.2\ \Omega) = \mathbf{4.8\ V}$$

$$V_5 = I_s R_{4\|5} = (4\text{ A})(4.8\ \Omega) = \mathbf{19.2\ V}$$

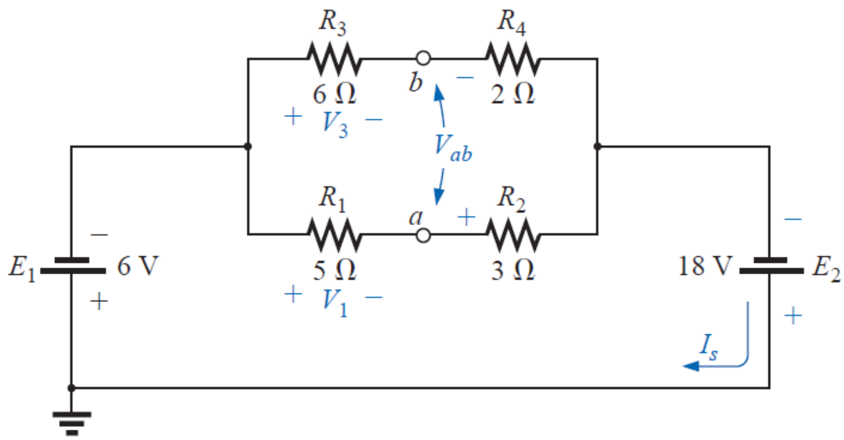
$$I_4 = \frac{V_5}{R_4} = \frac{19.2\text{ V}}{8\ \Omega} = \mathbf{2.4\ A}$$

$$I_2 = \frac{V_2}{R_2} = \frac{V_1}{R_2} = \frac{4.8\text{ V}}{6\ \Omega} = \mathbf{0.8\ A}$$

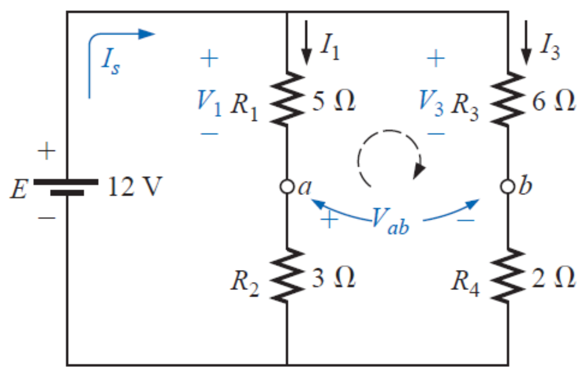
EXAMPLE:

a. Find the voltages *V1*, *V3*, and *Vab* for the network.

b. Calculate the source current *Is*.



Solution:



$$V_1 = \frac{R_1 E}{R_1 + R_2} = \frac{(5\ \Omega)(12\ \text{V})}{5\ \Omega + 3\ \Omega} = \frac{60\ \text{V}}{8} = \mathbf{7.5\ V}$$

$$V_3 = \frac{R_3 E}{R_3 + R_4} = \frac{(6\ \Omega)(12\ \text{V})}{6\ \Omega + 2\ \Omega} = \frac{72\ \text{V}}{8} = \mathbf{9\ V}$$

$$+V_1 - V_3 + V_{ab} = 0$$

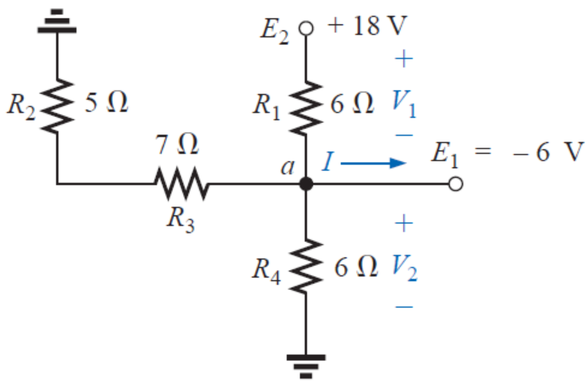
$$V_{ab} = V_3 - V_1 = 9\ \text{V} - 7.5\ \text{V} = \mathbf{1.5\ V}$$

$$I_1 = \frac{V_1}{R_1} = \frac{7.5\ \text{V}}{5\ \Omega} = 1.5\ \text{A}$$

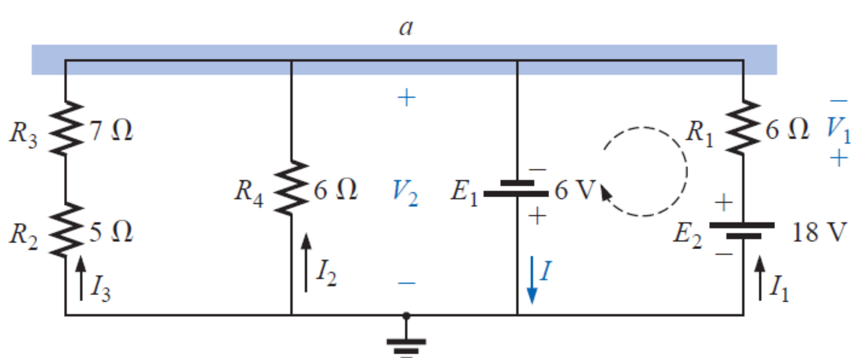
$$I_3 = \frac{V_3}{R_3} = \frac{9\ \text{V}}{6\ \Omega} = 1.5\ \text{A}$$

$$I_s = I_1 + I_3 = 1.5\ \text{A} + 1.5\ \text{A} = \mathbf{3\ A}$$

EXAMPLE: For the network, determine the voltages *V1* and *V2* and the current *I*.



Solution:



$$V_2 = -E_1 = \mathbf{-6\ V}$$

$$-E_1 + V_1 - E_2 = 0$$

$$V_1 = E_2 + E_1 = 18\ \text{V} + 6\ \text{V} = \mathbf{24\ V}$$

$$
\begin{aligned}
I &= I_1 + I_2 + I_3 \\
&= \frac{V_1}{R_1} + \frac{E_1}{R_4} + \frac{E_1}{R_2 + R_3} \\
&= \frac{24\,\text{V}}{6\,\Omega} + \frac{6\,\text{V}}{6\,\Omega} + \frac{6\,\text{V}}{12\,\Omega} \\
&= 4\,\text{A} + 1\,\text{A} + 0.5\,\text{A} \\
I &= \mathbf{5.5\,A}
\end{aligned}
$$

الوحدة التاسعة- الزمن: 90 دقيقة

أهداف المحاضرة الثانية:

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

* Kirchhoff's current law (KCL) states that the algebraic sum of the currents entering and leaving an area, system, or junction is zero.

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

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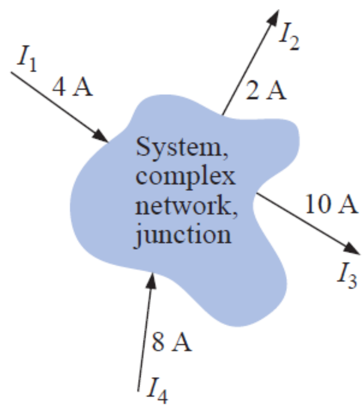
Kirchoff's Laws

* Kirchhoff's current law (KCL) states that the algebraic sum of the currents entering and leaving an area, system, or junction is zero.

Or,

* The sum of the currents entering an area, system, or junction must equal the sum of the currents leaving the area, system, or junction.

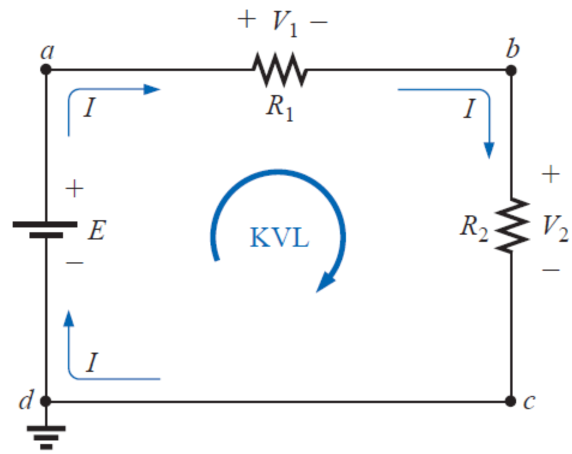
$$\Sigma I_{\text{entering}} = \Sigma I_{\text{leaving}}$$



$$I_1 + I_4 = I_2 + I_3$$
$$4\text{ A} + 8\text{ A} = 2\text{ A} + 10\text{ A}$$
$$12\text{ A} = 12\text{ A}$$

* Kirchhoff's voltage law (KVL) states that the algebraic sum of the potential rises and drops around a closed loop (or path) is zero.

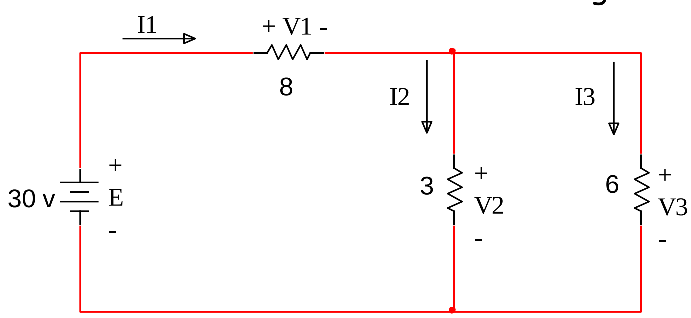
$$\Sigma_{\circlearrowright} V = 0$$



$$+E - V_1 - V_2 = 0$$

$$E = V_1 + V_2$$

EXAMPLE: using Kirchhoff's lows. Find the currents and voltages in the circuit shown.



Solution:

$E - V1 - V2 = 0 \quad \Rightarrow \quad 30 - V1 - V2 = 0$

$30 - 8I1 - 3I2 = 0 \quad \Rightarrow \quad I1 = \dfrac{30 - 3I2}{8}$

$V2 - V3 = 0 \quad \Rightarrow \quad V2 = V3$

$6I3 = 3I2 \quad \Rightarrow \quad I3 = \dfrac{I2}{3}$

$I1 = I2 + I3 \quad \Rightarrow \quad I1 - I2 - I3 = 0$

By substitute I1 and I3

$$\frac{30-3I2}{8}-I2-\frac{I2}{2}=0 \quad \Rightarrow I2=2A$$

$$I1=\frac{30-3I2}{8}=\frac{30-3(2)}{8}=3A$$

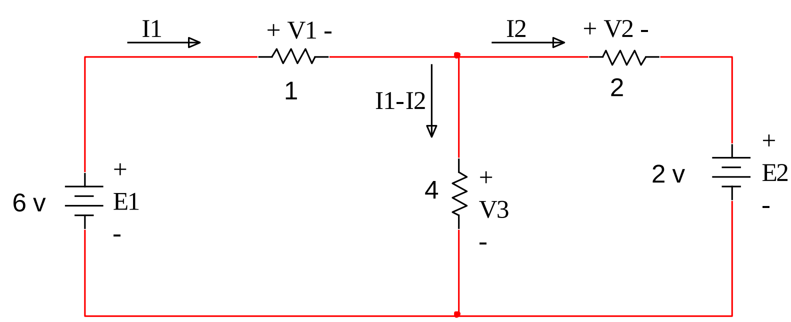
$$I3=\frac{I2}{2}=\frac{2}{2}=1A$$

$$V1=8I1 \quad \Rightarrow V1=8(3)=24V$$

$$V2=3I2 \quad \Rightarrow V2=3(2)=6V$$

$$V3=6I3 \quad \Rightarrow V3=6(1)=6V$$

EXAMPLE: using Kirchhoff's lows. Find the currents and voltages in the circuit shown.



Solution:

$$I1+4(I1-I2)-E1=0 \quad ....(1)$$

$$I1+4I1-4I2=E1 \quad \Rightarrow 5I1-4I2=6 \quad \Rightarrow I1=\frac{6+4I2}{5}$$

$$2I2+E2-4(I1-I2)=0 \; ....(2)$$

$$2I2-4I1+4I2=-E \quad \Rightarrow 6I2-4I1=-2$$

By substitute I1

$$6I2-4(\frac{6+4I2}{5})=-2 \Rightarrow 6I2-\frac{24}{5}-\frac{16I2}{5}=-2 \Rightarrow 30I2-24-16I2=-10$$

$$14I2=14 \Rightarrow I2=\frac{14}{14}=1A$$

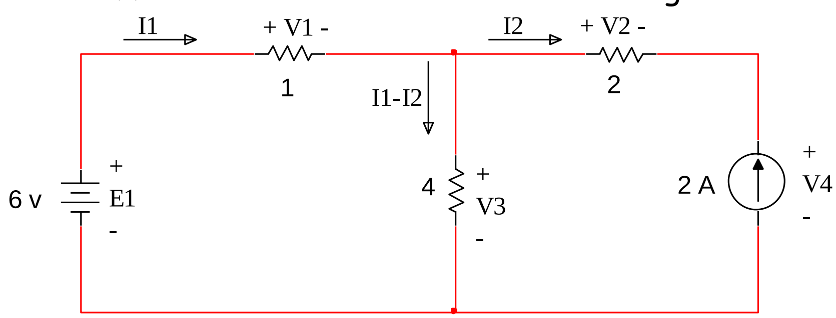
$$I1=\frac{6+4(1)}{5}=2A$$

$$V1=1I1=2V$$

$$V2=2I2=2(1)=2V$$

$$V3=4(I1-I2)=4(2-1)=4V$$

EXAMPLE: using Kirchhoff's lows. Find the currents and voltages in the circuit shown.



Solution:

From the circuit I2=-2 A

$$I1+4(I1-I2)-E1=0 \quad ....(1)$$

$$I1+4I1-4I2=E1 \Rightarrow 5I1-4I2=6 \Rightarrow I1=\frac{6+4I2}{5}=\frac{6+4(-2)}{5}=-0.4A$$

$$2I2+V4-4(I1-I2)=0 \quad ....(2)$$

$$2I2-4I1+4I2+V4=0 \Rightarrow 6I2-4I1+V4=0 \Rightarrow V4=4I1-6I2=4(-0.4)-6(-2)=10.4V$$

$$V1=1I1=-0.4V$$

$$V2=2I2=2(-2)=-4V$$

$$V3=4(I1-I2)=4(-0.4+2)=6.4V$$

الوحدة العاشرة- الزمن: 90 دقيقة

أهداف المحاضرة الثانية:

If two or more current sources are in parallel, they may all be replaced by one current source having the magnitude and direction of the resultant

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

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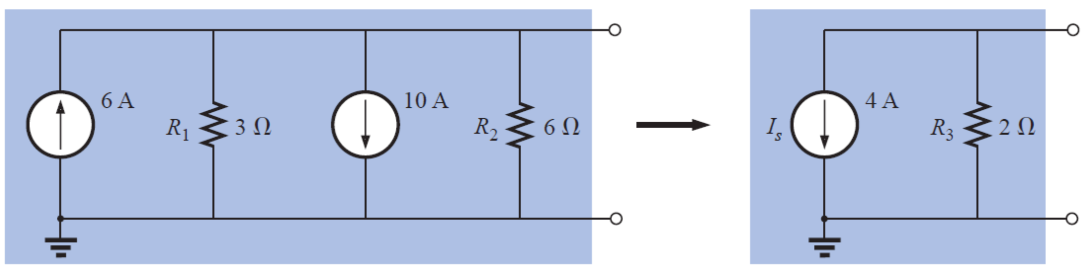
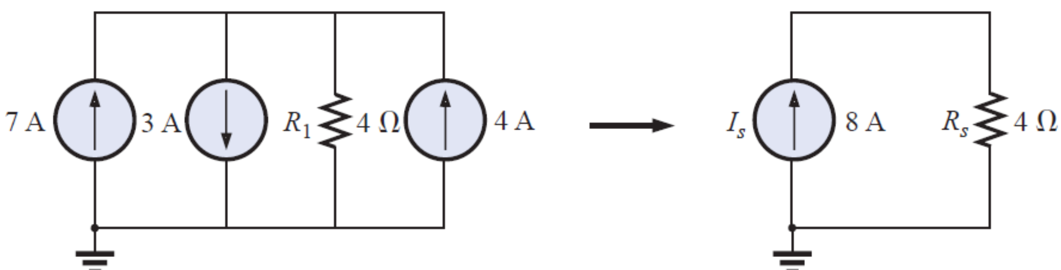
Current Sources in Parallel

If two or more current sources are in parallel, they may all be replaced by one current source having the magnitude and direction of the resultant



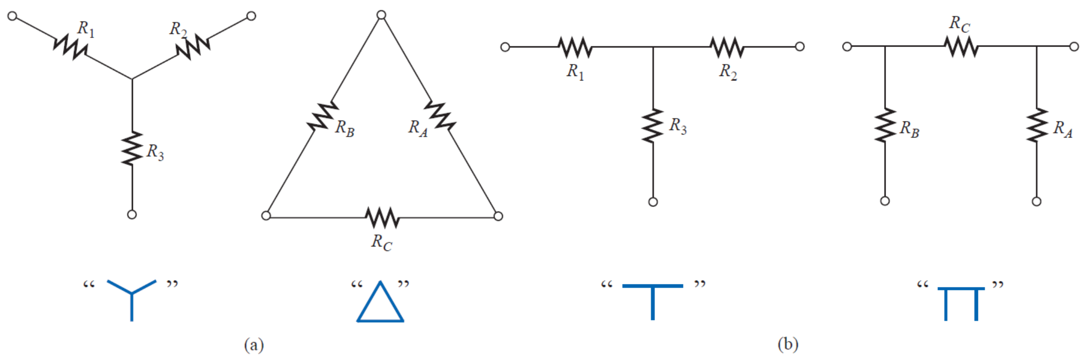
$I_s = 10\,A - 6\,A = \mathbf{4\,A}$
$R_s = 3\,\Omega \parallel 6\,\Omega = \mathbf{2\,\Omega}$

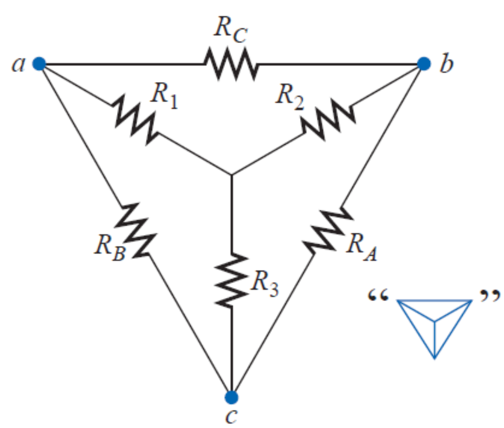


$I_s = 7\,A + 4\,A - 3\,A = \mathbf{8\,A}$
$R_s = R_1 = \mathbf{4\,\Omega}$

Y-D (T-p) and D-Y (p-T) Conversions

Circuit configurations are often encountered in which the resistors do not appear to be in series or parallel. Under these conditions, it may be necessary to convert the circuit from one form to another.





$\Delta \rightarrow Y$

$$R_1 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_A R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A R_B}{R_A + R_B + R_C}$$

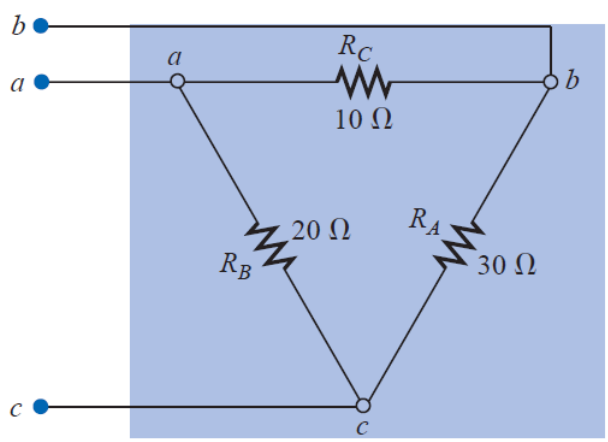
$Y \rightarrow \Delta$

$$R_A = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

$$R_B = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

$$R_C = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3}$$

EXAMPLE: Convert the Δ to a Y .

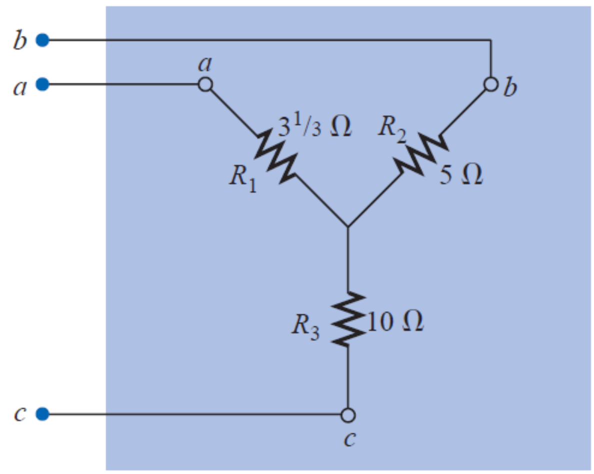


Solution:

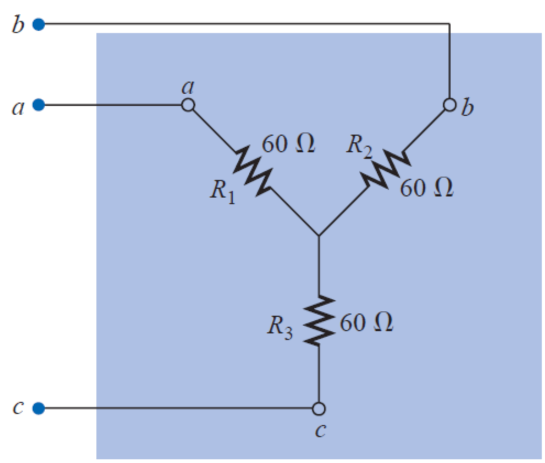
$$R_1 = \frac{R_B R_C}{R_A + R_B + R_C} = \frac{(20\ \Omega)(10\ \Omega)}{30\ \Omega + 20\ \Omega + 10\ \Omega} = \frac{200\ \Omega}{60} = \mathbf{3\tfrac{1}{3}\ \Omega}$$

$$R_2 = \frac{R_A R_C}{R_A + R_B + R_C} = \frac{(30\ \Omega)(10\ \Omega)}{60\ \Omega} = \frac{300\ \Omega}{60} = \mathbf{5\ \Omega}$$

$$R_3 = \frac{R_A R_B}{R_A + R_B + R_C} = \frac{(20\ \Omega)(30\ \Omega)}{60\ \Omega} = \frac{600\ \Omega}{60} = \mathbf{10\ \Omega}$$



EXAMPLE: Convert the Y to a Δ.



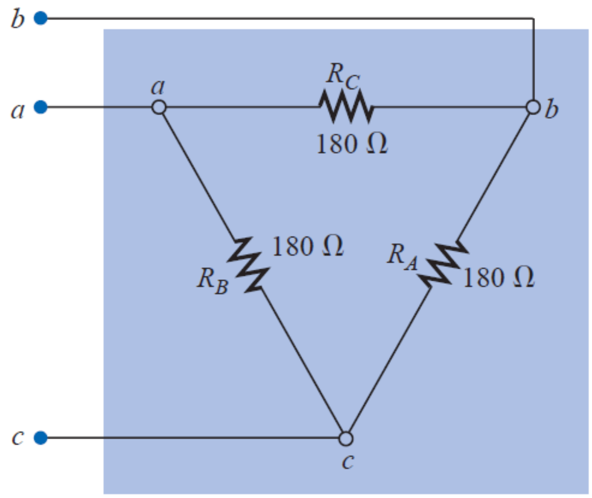
Solution:

$$R_\Delta = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

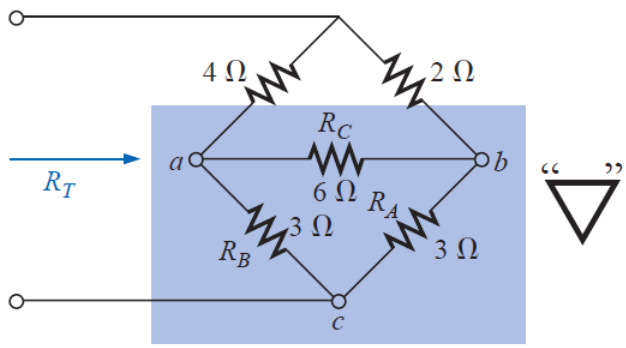
$$= \frac{(60\ \Omega)(60\ \Omega) + (60\ \Omega)(60\ \Omega) + (60\ \Omega)(60\ \Omega)}{60\ \Omega}$$

$$= \frac{3600\ \Omega + 3600\ \Omega + 3600\ \Omega}{60} = \frac{10{,}800\ \Omega}{60}$$

$$R_\Delta = \mathbf{180\ \Omega}$$



EXAMPLE: Find the total resistance of the network



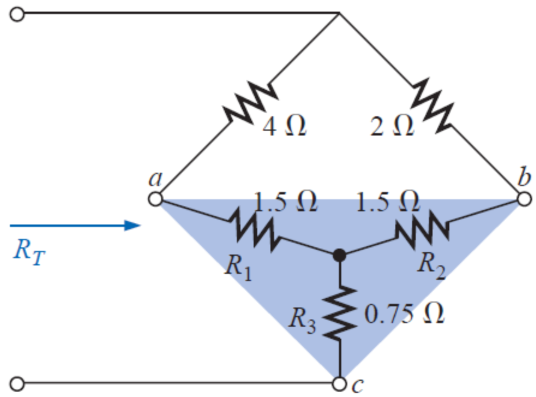
Solution:

Two resistors of the Δ were equal; therefore, two resistors of the Y will be equal.

$$R_1 = \frac{R_B R_C}{R_A + R_B + R_C} = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 3\ \Omega + 6\ \Omega} = \frac{18\ \Omega}{12} = \mathbf{1.5\ \Omega}$$

$$R_2 = \frac{R_A R_C}{R_A + R_B + R_C} = \frac{(3\ \Omega)(6\ \Omega)}{12\ \Omega} = \frac{18\ \Omega}{12} = \mathbf{1.5\ \Omega}$$

$$R_3 = \frac{R_A R_B}{R_A + R_B + R_C} = \frac{(3\ \Omega)(3\ \Omega)}{12\ \Omega} = \frac{9\ \Omega}{12} = \mathbf{0.75\ \Omega}$$



$$R_T = 0.75\ \Omega + \frac{(4\ \Omega + 1.5\ \Omega)(2\ \Omega + 1.5\ \Omega)}{(4\ \Omega + 1.5\ \Omega) + (2\ \Omega + 1.5\ \Omega)}$$

$$= 0.75\ \Omega + \frac{(5.5\ \Omega)(3.5\ \Omega)}{5.5\ \Omega + 3.5\ \Omega}$$

$$= 0.75\ \Omega + 2.139\ \Omega$$

$$R_T = \mathbf{2.889\ \Omega}$$

الوحدة الحادية عشر الزمن: 90 دقيقة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Methods of Analysis

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

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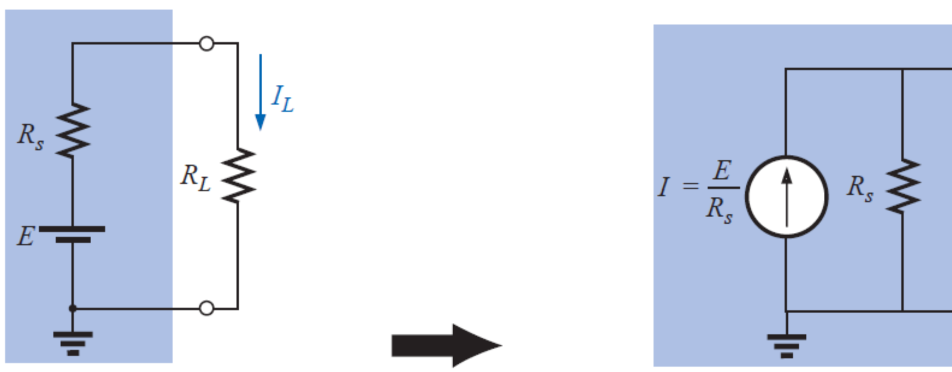
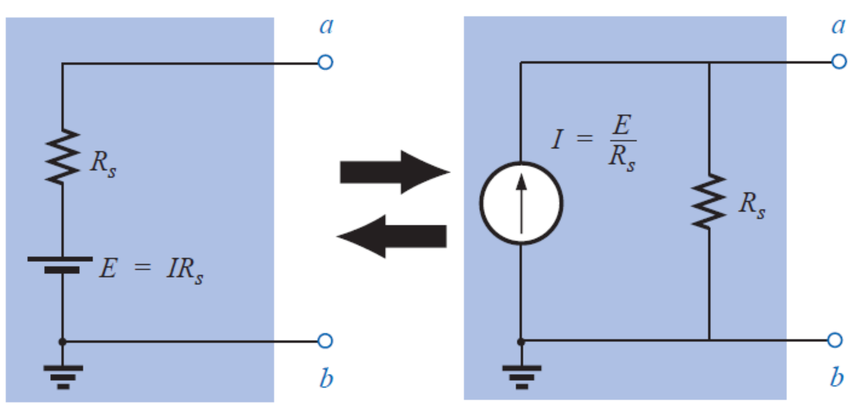
Methods of Analysis

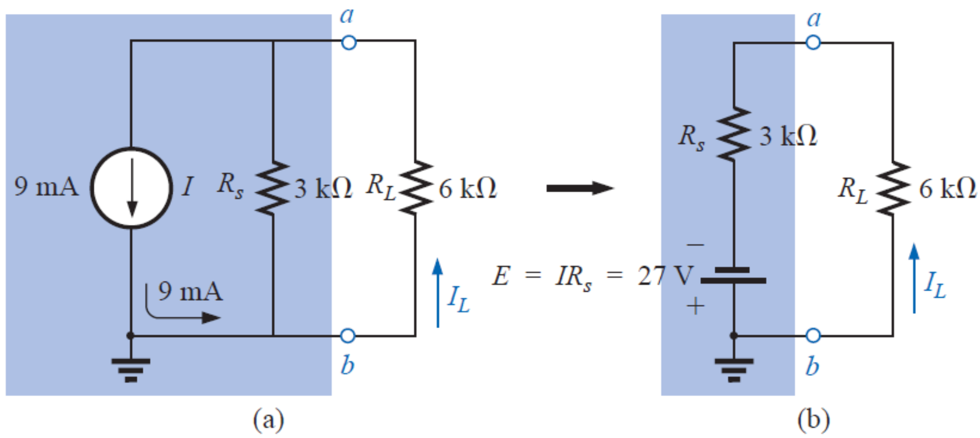
Source Conversions

To perform a conversion from one type of source to another, a voltage source must have a resistor in series with it, and a current source must have a resistor in parallel.





EXAMPLE: Convert the current source of the circuit below to a voltage source, and find the load current for each source.



Solution:

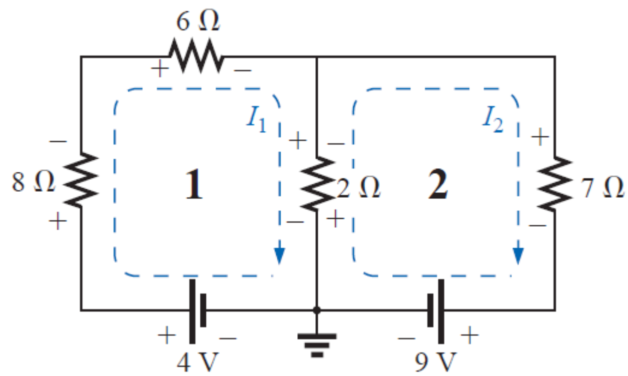
(a): $$I_L = \frac{R_s I}{R_s + R_L} = \frac{(3\text{ k}\Omega)(9\text{ mA})}{3\text{ k}\Omega + 6\text{ k}\Omega} = \mathbf{3\text{ mA}}$$

(b): $$I_L = \frac{E}{R_s + R_L} = \frac{27\text{ V}}{3\text{ k}\Omega + 6\text{ k}\Omega} = \frac{27\text{ V}}{9\text{ k}\Omega} = \mathbf{3\text{ mA}}$$

Mesh Analysis (Loop)

- Assign a distinct current in the clockwise direction to each independent, closed loop of the network.
- Indicate the polarities within each loop for each resistor as determined by the assumed direction of loop current for that loop.
- Write the linear equations for each loop.
- Solve the resulting linear equations for the assumed loop currents.

EXAMPLE: Write the mesh equations for the network, and find the current through the 7-Ω resistor.



Solution:

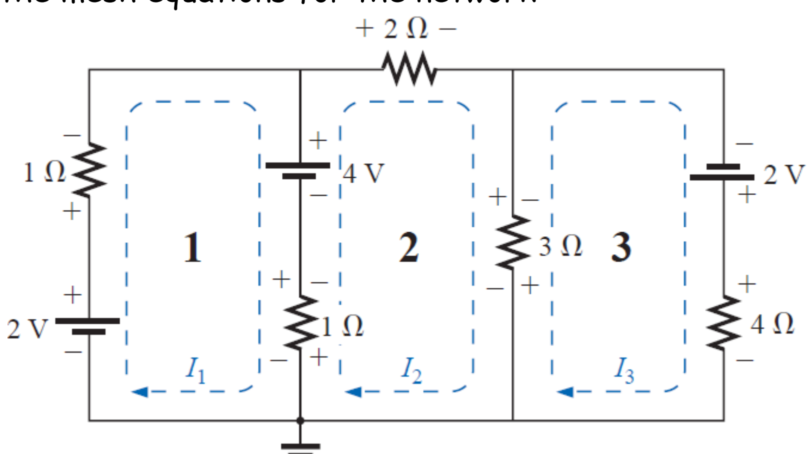
$$I_1:\quad (8\,\Omega + 6\,\Omega + 2\,\Omega)I_1 - (2\,\Omega)I_2 = 4\text{ V}$$
$$I_2:\quad (7\,\Omega + 2\,\Omega)I_2 - (2\,\Omega)I_1 = -9\text{ V}$$

$$16I_1 - 2I_2 = 4$$
$$9I_2 - 2I_1 = -9$$

$$16I_1 - 2I_2 = 4$$
$$-2I_1 + 9I_2 = -9$$

$$I_2 = I_{7\Omega} = \frac{\begin{vmatrix} 16 & 4 \\ -2 & -9 \end{vmatrix}}{\begin{vmatrix} 16 & -2 \\ -2 & 9 \end{vmatrix}} = \frac{-144 + 8}{144 - 4} = \frac{-136}{140}$$
$$= \mathbf{-0.971\ A}$$

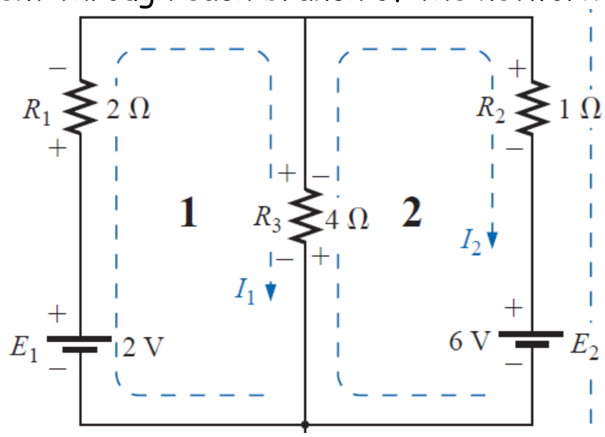
EXAMPLE: Write the mesh equations for the network



Solution:

$$2I_1 - I_2 + 0 = -2$$
$$6I_2 - I_1 - 3I_3 = 4$$
$$7I_3 - 3I_2 + 0 = 2$$

EXAMPLE: Find the current through each branch of the network



Solution:

$$6I1 - 4I2 = 2 \text{ ....(1)}$$
$$5I2 - 4I1 = -6 \text{ ....(2)}$$

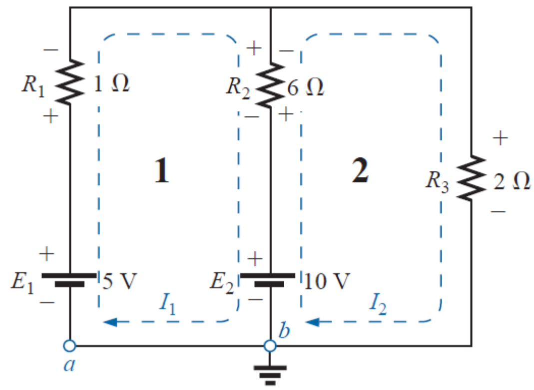
$$6I1 \quad -4I2 = 2$$
$$-4I1 + 5I2 = -6$$

$$I1 = \frac{\begin{bmatrix} 2 & -4 \\ -6 & 5 \end{bmatrix}}{\begin{bmatrix} 6 & -4 \\ -4 & 5 \end{bmatrix}} = \frac{(2\times 5)-(-4\times -6)}{(6\times 5)-(-4\times -4)} = \frac{10-24}{30-16} = \frac{-14}{14} = -1\,A$$

$$I2 = \frac{\begin{bmatrix} 6 & 2 \\ -4 & 6 \end{bmatrix}}{\begin{bmatrix} 6 & -4 \\ -4 & 5 \end{bmatrix}} = -2\,A$$

$$I_{4\Omega} = I_1 - I_2 = -1\text{ A} - (-2\text{ A}) = -1\text{ A} + 2\text{ A}$$
$$= \mathbf{1\ A} \quad \text{(in the direction of } I_1\text{)}$$

EXAMPLE: Find the current through each branch of the network



Solution:

$7I1 - 6I2 = 5 - 10$ ....(1)

$8I2 - 6I1 = 10$ ....(2)

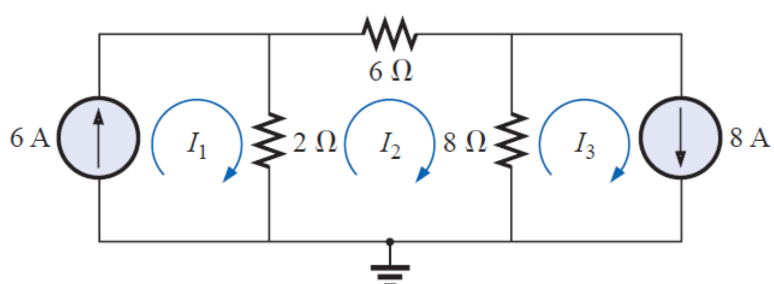
$$-7I_1 + 6I_2 = 5$$
$$+6I_1 - 8I_2 = -10$$

$$I_1 = \frac{\begin{vmatrix} 5 & 6 \\ -10 & -8 \end{vmatrix}}{\begin{vmatrix} -7 & 6 \\ 6 & -8 \end{vmatrix}} = \frac{-40 + 60}{56 - 36} = \frac{20}{20} = \mathbf{1\ A}$$

$$I_2 = \frac{\begin{vmatrix} -7 & 5 \\ 6 & -10 \end{vmatrix}}{20} = \frac{70 - 30}{20} = \frac{40}{20} = \mathbf{2\ A}$$

$I_{R_2} = I_2 - I_1 = 2\text{ A} - 1\text{ A} = \mathbf{1\ A}$ in the direction of I_2

EXAMPLE: Using mesh analysis, determine the currents of the network



Solution:

$I_1 = 6\text{ A}$

$I_3 = 8\text{ A}$

$2I_1 - 16I_2 + 8I_3 = 0$

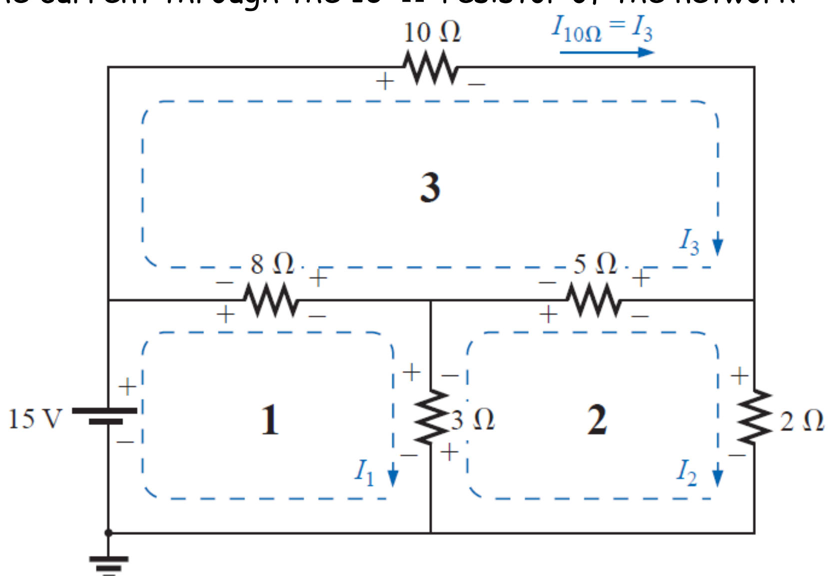
$2(6\text{ A}) - 16I_2 + 8(8\text{ A}) = 0$

$$I_2 = \frac{76\text{ A}}{16} = \mathbf{4.75\text{ A}}$$

$I_{2\Omega}\downarrow = I_1 - I_2 = 6\text{ A} - 4.75\text{ A} = \mathbf{1.25\text{ A}}$

$I_{8\Omega}\uparrow = I_3 - I_2 = 8\text{ A} - 4.75\text{ A} = \mathbf{3.25\text{ A}}$

EXAMPLE: Find the current through the 10-Ω resistor of the network



Solution:

I_1: $(8\ \Omega + 3\ \Omega)I_1 - (8\ \Omega)I_3 - (3\ \Omega)I_2 = 15\text{ V}$

I_2: $(3\ \Omega + 5\ \Omega + 2\ \Omega)I_2 - (3\ \Omega)I_1 - (5\ \Omega)I_3 = 0$

I_3: $(8\ \Omega + 10\ \Omega + 5\ \Omega)I_3 - (8\ \Omega)I_1 - (5\ \Omega)I_2 = 0$

$$\begin{aligned} 11I_1 - 8I_3 - 3I_2 &= 15 \\ 10I_2 - 3I_1 - 5I_3 &= 0 \\ 23I_3 - 8I_1 - 5I_2 &= 0 \end{aligned}$$

$$\begin{aligned} 11I_1 - \ \ 3I_2 - \ \ 8I_3 &= 15 \\ -3I_1 + 10I_2 - \ \ 5I_3 &= 0 \\ -8I_1 - \ \ 5I_2 + 23I_3 &= 0 \end{aligned}$$

$$I_3 = I_{10\Omega} = \frac{\begin{vmatrix} 11 & -3 & 15 \\ -3 & 10 & 0 \\ -8 & -5 & 0 \end{vmatrix}}{\begin{vmatrix} 11 & -3 & -8 \\ -3 & 10 & -5 \\ -8 & -5 & 23 \end{vmatrix}} = \mathbf{1.220\ A}$$

الوحدة الثانية عشر الزمن: 90 دقيقة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Nodal Analysis

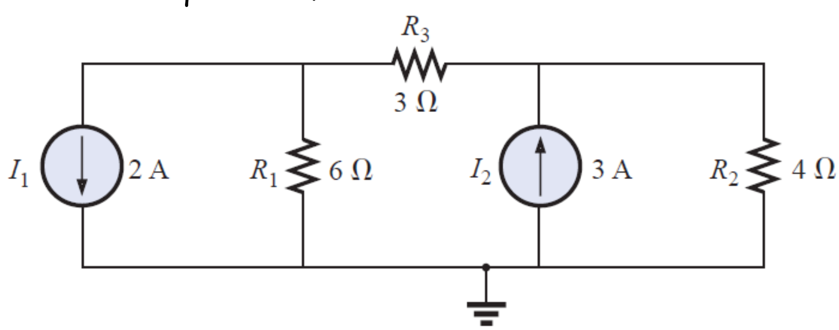
موضوعات المحاضرة
الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
12	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

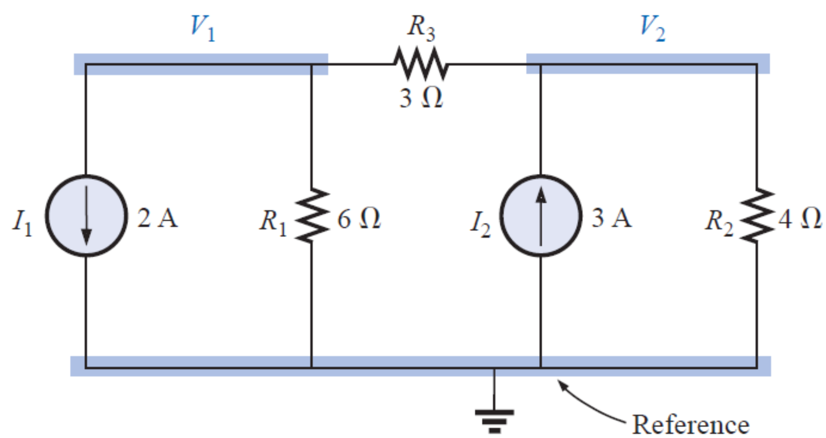
Nodal Analysis

- Choose a reference node and assign a subscripted voltage label to the (N _ 1) remaining nodes of the network.
- Writ the equations of node so that the column to the right of the equality sign is the algebraic sum of the current sources tied to the node of interest. A current source is assigned a positive sign if it supplies current to a node and a negative sign if it draws current from the node.
- Solve the resulting equations for the desired voltages.

EXAMPLE: Write the nodal equations for the network.



Solution:



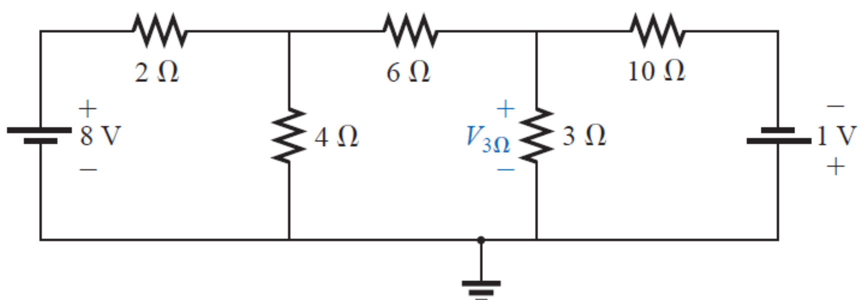
$$V_1:\ \underbrace{\left(\frac{1}{6\ \Omega}+\frac{1}{3\ \Omega}\right)}_{\substack{\text{Sum of}\\ \text{conductances}\\ \text{connected}\\ \text{to node 1}}}V_1-\underbrace{\left(\frac{1}{3\ \Omega}\right)}_{\substack{\text{Mutual}\\ \text{conductance}}}V_2=\overset{\substack{\text{Drawing current}\\ \text{from node 1}\\ \downarrow}}{-2\ \text{A}}$$

$$V_2:\ \underbrace{\left(\frac{1}{4\ \Omega}+\frac{1}{3\ \Omega}\right)}_{\substack{\text{Sum of}\\ \text{conductances}\\ \text{connected}\\ \text{to node 2}}}V_2-\underbrace{\left(\frac{1}{3\ \Omega}\right)}_{\substack{\text{Mutual}\\ \text{conductance}}}V_1=\overset{\substack{\text{Supplying current}\\ \text{to node 2}\\ \downarrow}}{+3\ \text{A}}$$

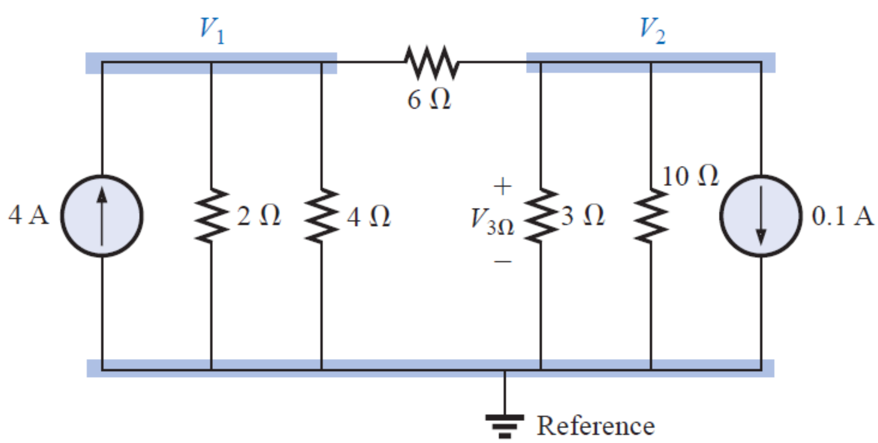
$$\frac{1}{2}V_1-\frac{1}{3}V_2=-2$$

$$-\frac{1}{3}V_1+\frac{7}{12}V_2=3$$

EXAMPLE: Find the voltage across the 3-Ω resistor by nodal analysis.



Solution:



$$\left(\frac{1}{2\,\Omega}+\frac{1}{4\,\Omega}+\frac{1}{6\,\Omega}\right)V_1-\left(\frac{1}{6\,\Omega}\right)V_2=+4\text{ A}$$

$$\left(\frac{1}{10\,\Omega}+\frac{1}{3\,\Omega}+\frac{1}{6\,\Omega}\right)V_2-\left(\frac{1}{6\,\Omega}\right)V_1=-0.1\text{ A}$$

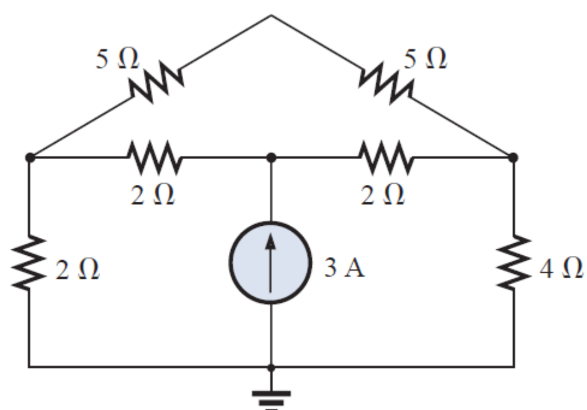
$$\frac{11}{12}V_1-\frac{1}{6}V_2=4$$

$$-\frac{1}{6}V_1+\frac{3}{5}V_2=-0.1$$

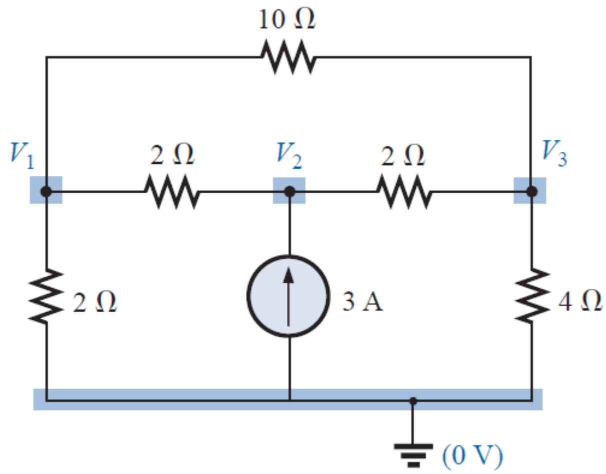
$$11V_1-2V_2=+48$$
$$-5V_1+18V_2=-3$$

$$V_2=V_{3\Omega}=\frac{\begin{vmatrix}11 & 48\\ -5 & -3\end{vmatrix}}{\begin{vmatrix}11 & -2\\ -5 & 18\end{vmatrix}}=\frac{-33+240}{198-10}=\frac{207}{188}=\mathbf{1.101\ V}$$

EXAMPLE: Using nodal analysis, determine the potential across the 4-Ω resistor and it's current.



Solution:



$$V_1: \quad \left(\frac{1}{2\,\Omega} + \frac{1}{2\,\Omega} + \frac{1}{10\,\Omega}\right)V_1 - \left(\frac{1}{2\,\Omega}\right)V_2 - \left(\frac{1}{10\,\Omega}\right)V_3 = 0$$

$$V_2: \quad \left(\frac{1}{2\,\Omega} + \frac{1}{2\,\Omega}\right)V_2 - \left(\frac{1}{2\,\Omega}\right)V_1 - \left(\frac{1}{2\,\Omega}\right)V_3 = 3\text{ A}$$

$$V_3: \quad \left(\frac{1}{10\,\Omega} + \frac{1}{2\,\Omega} + \frac{1}{4\,\Omega}\right)V_3 - \left(\frac{1}{2\,\Omega}\right)V_2 - \left(\frac{1}{10\,\Omega}\right)V_1 = 0$$

$$1.1V_1 - 0.5V_2 - 0.1V_3 = 0$$
$$V_2 - 0.5V_1 - 0.5V_3 = 3$$
$$0.85V_3 - 0.5V_2 - 0.1V_1 = 0$$

$$V_3 = V_{4\Omega} = \frac{\begin{vmatrix} 1.1 & -0.5 & 0 \\ -0.5 & +1 & 3 \\ -0.1 & -0.5 & 0 \end{vmatrix}}{\begin{vmatrix} 1.1 & -0.5 & -0.1 \\ -0.5 & +1 & -0.5 \\ -0.1 & -0.5 & +0.85 \end{vmatrix}} = \mathbf{4.645\ V}$$

$$I_{4\Omega} = \frac{V3}{4} = \frac{4.645}{4} = 1.16\,A$$

الوحدة الثالثة عشر- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Superposition Theorem

The current through, or voltage across, an element in a linear bilateral network is equal to the algebraic sum of the currents or voltages produced independently by each source.

موضوعات المحاضرة

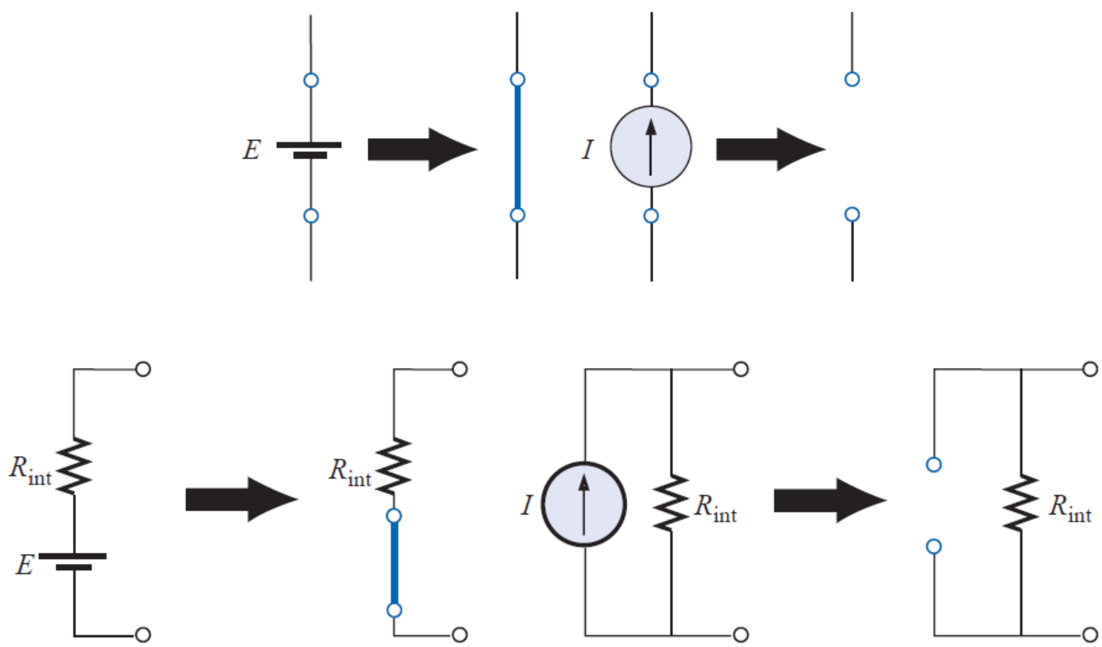
الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
13	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

Superposition Theorem

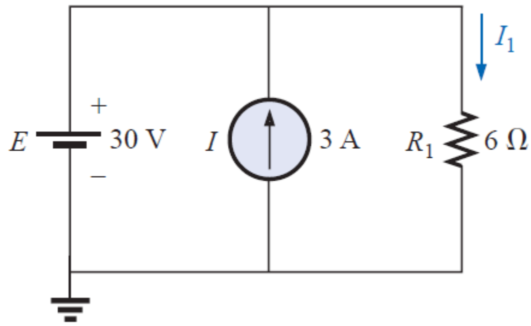
The current through, or voltage across, an element in a linear bilateral network is equal to the algebraic sum of the currents or voltages produced independently by each source.

Number of networks to be analyzed = Number of independent sources



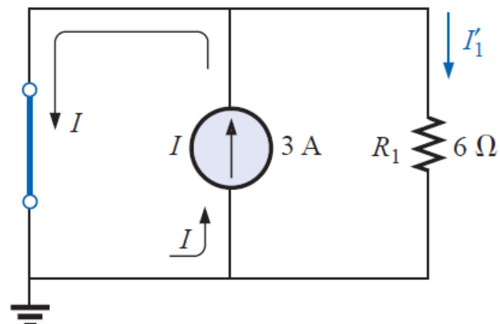
The total power delivered to a resistive element must be determined using the total current through or the total voltage across the element and cannot be determined by a simple sum of the power levels established by each source.

EXAMPLE: Determine I1 for the network.



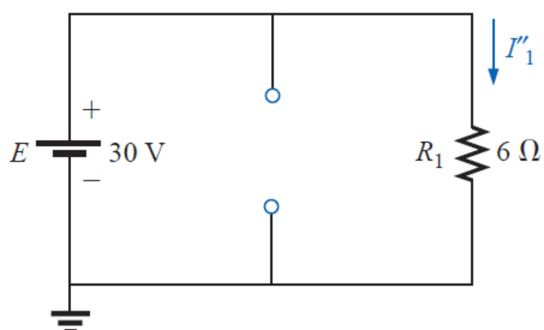
Solution:

1) Setting E = 0 V



$$I'_1 = \frac{R_{sc}I}{R_{sc} + R_1} = \frac{(0\ \Omega)I}{0\ \Omega + 6\ \Omega} = 0\ \text{A}$$

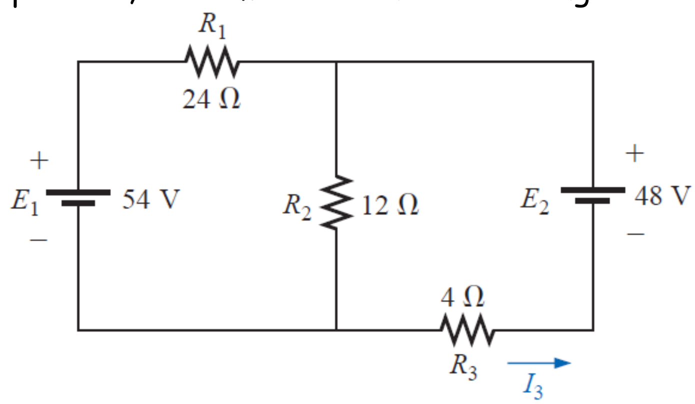
2) Setting I = zero



$$I''_1 = \frac{E}{R_1} = \frac{30\ \text{V}}{6\ \Omega} = 5\ \text{A}$$

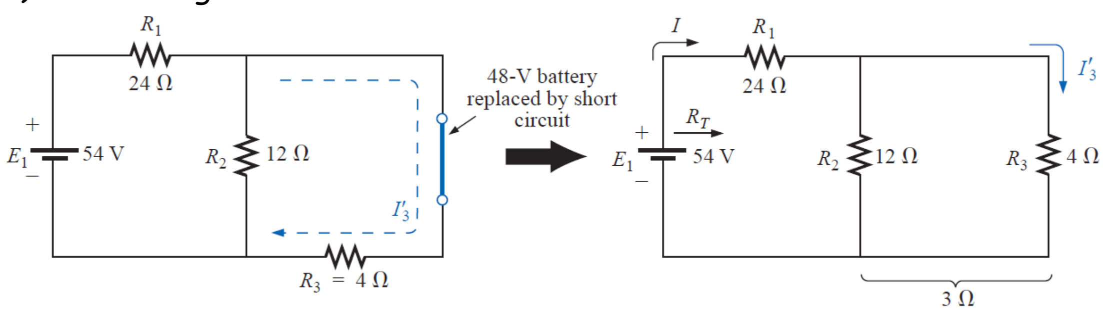
$$I_1 = I'_1 + I''_1 = 0\ \text{A} + 5\ \text{A} = \mathbf{5\ A}$$

EXAMPLE: Using superposition, determine the current through the 4-Ω resistor



Solution:

1) *Considering the effects of a 54-V source*

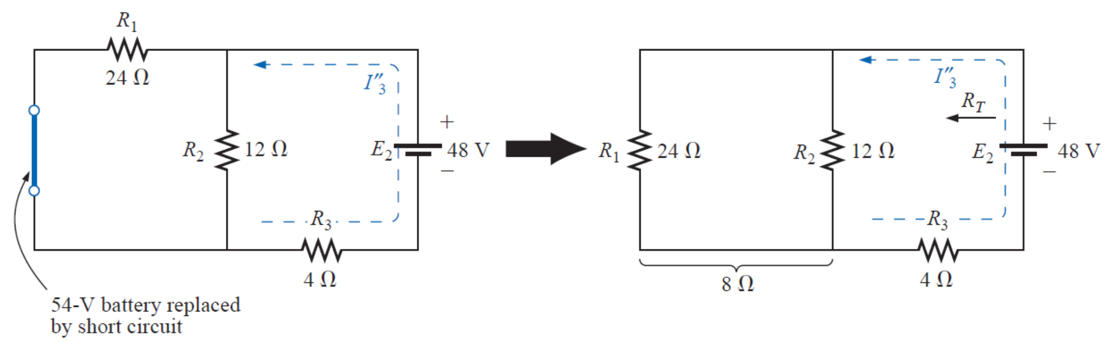


$$R_T = R_1 + R_2 \,||\, R_3 = 24\,\Omega + 12\,\Omega \,||\, 4\,\Omega = 24\,\Omega + 3\,\Omega = 27\,\Omega$$

$$I = \frac{E_1}{R_T} = \frac{54\text{ V}}{27\,\Omega} = 2\text{ A}$$

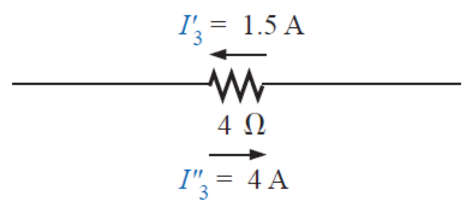
$$I'_3 = \frac{R_2 I}{R_2 + R_3} = \frac{(12\,\Omega)(2\text{ A})}{12\,\Omega + 4\,\Omega} = \frac{24\text{ A}}{16} = 1.5\text{ A}$$

2) *Considering the effects of the 48-V source*



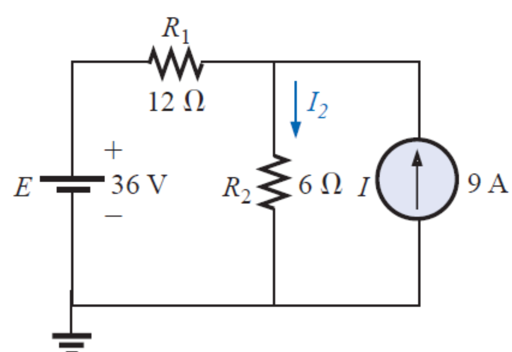
$$R_T = R_3 + R_1 \parallel R_2 = 4\ \Omega + 24\ \Omega \parallel 12\ \Omega = 4\ \Omega + 8\ \Omega = 12\ \Omega$$

$$I''_3 = \frac{E_2}{R_T} = \frac{48\ \text{V}}{12\ \Omega} = 4\ \text{A}$$



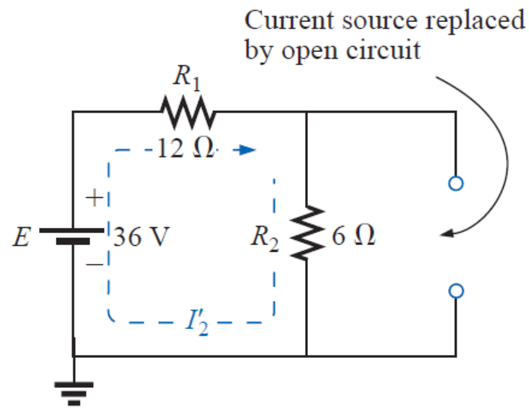
$$I_3 = I''_3 - I'_3 = 4\ \text{A} - 1.5\ \text{A} = \mathbf{2.5\ A}$$

EXAMPLE: Using superposition, find the current through the 6-Ω resistor of the network, and find it's power.



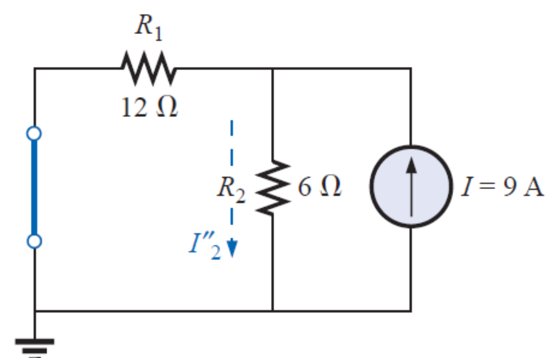
Solution:

1) *Considering the effect of the 36-V source*



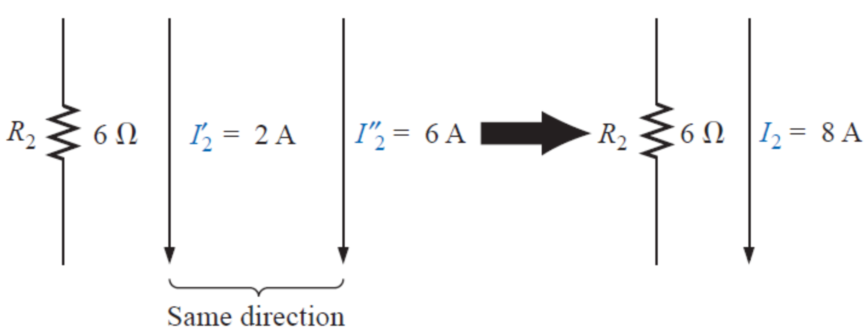
$$I'_2 = \frac{E}{R_T} = \frac{E}{R_1 + R_2} = \frac{36\ \text{V}}{12\ \Omega + 6\ \Omega} = 2\ \text{A}$$

2) *Considering the effect of the 9-A source*



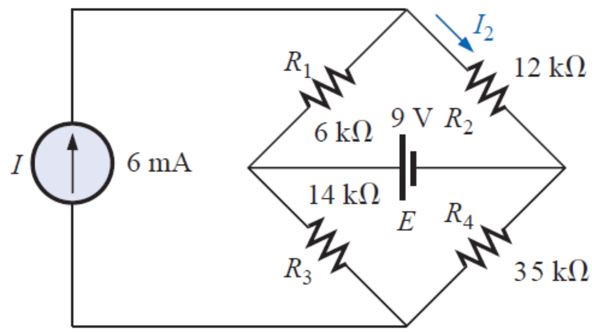
$$I''_2 = \frac{R_1 I}{R_1 + R_2} = \frac{(12\ \Omega)(9\ \text{A})}{12\ \Omega + 6\ \Omega} = \frac{108\ \text{A}}{18} = 6\ \text{A}$$

$$I_2 = I'_2 + I''_2 = 2\ \text{A} + 6\ \text{A} = \mathbf{8\ A}$$



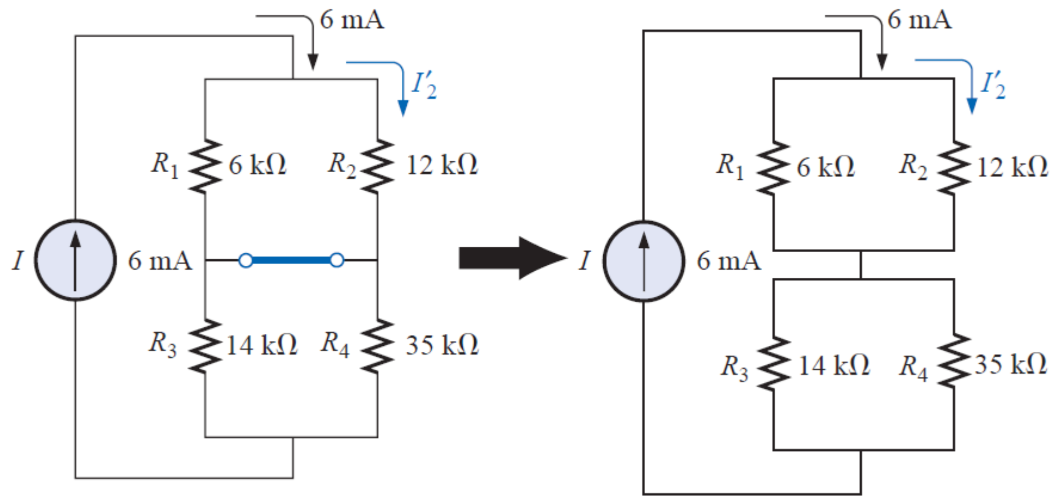
$$\text{Power} = I^2R = (8\ \text{A})^2(6\ \Omega) = \mathbf{384\ W}$$

EXAMPLE: Using the principle of superposition, find the current I2 through the 12-kΩ resistor.



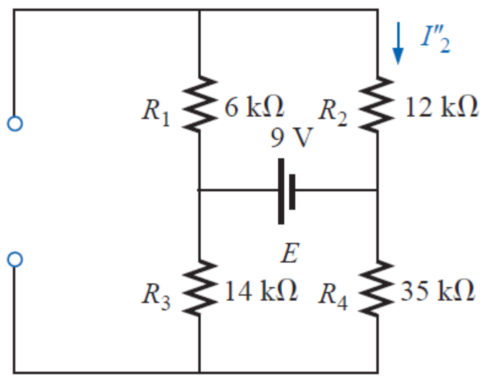
Solution:

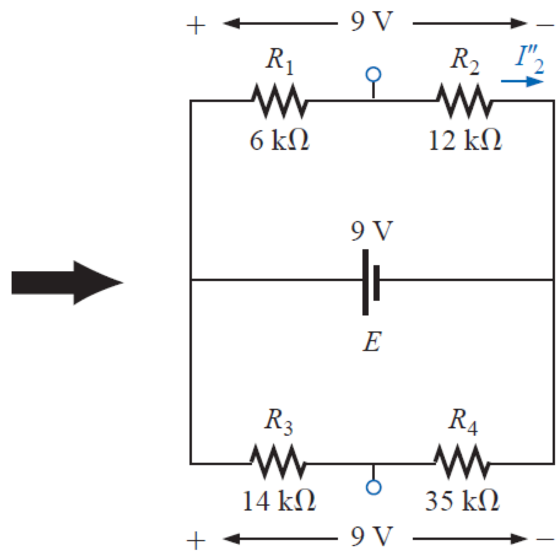
1) *Considering the effect of the 6-mA*



$$I'_2 = \frac{R_1 I}{R_1 + R_2} = \frac{(6\text{ k}\Omega)(6\text{ mA})}{6\text{ k}\Omega + 12\text{ k}\Omega} = 2\text{ mA}$$

2) *Considering the effect of the 9-V voltage source*





$$I''_2 = \frac{E}{R_1 + R_2} = \frac{9\text{ V}}{6\text{ k}\Omega + 12\text{ k}\Omega} = 0.5\text{ mA}$$

$$\begin{aligned} I_2 &= I'_2 + I''_2 \\ &= 2\text{ mA} + 0.5\text{ mA} \\ &= \mathbf{2.5\text{ mA}} \end{aligned}$$

الوحدة الرابعة عشر- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Thevenin's Theorem

Any two-terminal, linear bilateral dc network can be replaced by an equivalent circuit consisting of a voltage source and a series resistor,

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
14	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

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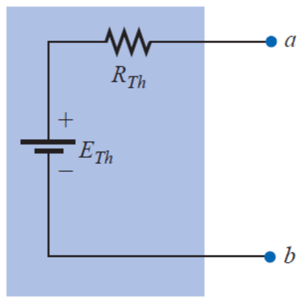
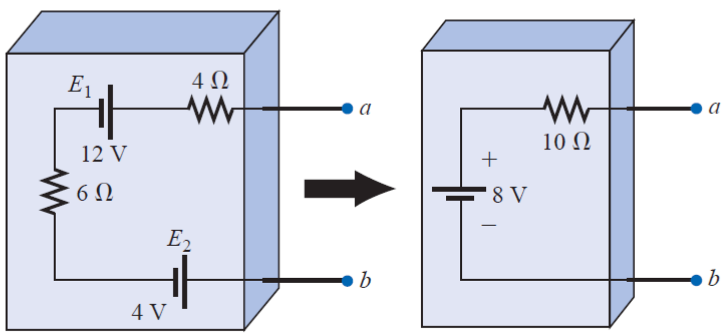




(a) (b)

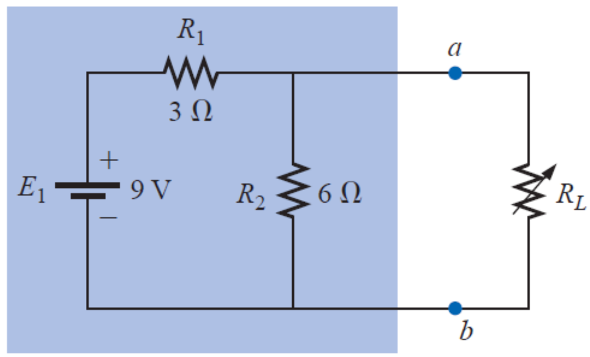
The following sequence of steps will lead to the proper value of *RTh* and *ETh*.

1) Remove that portion of the network across which the Thévenin equivalent circuit is to be found.
2) Mark the terminals of the remaining two-terminal network.
3) Calculate RTh by first setting all sources to zero (voltage sources are replaced by short circuits and current sources by open circuits) and then finding the resultant resistance between the two marked terminals.
4) Calculate ETh by first returning all sources to their original position and finding the open-circuit voltage between the marked terminals.
5) Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.

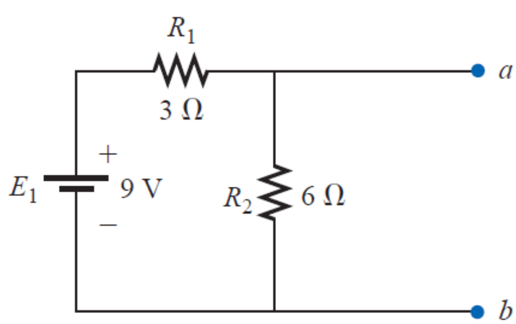
So the load current will be equal to

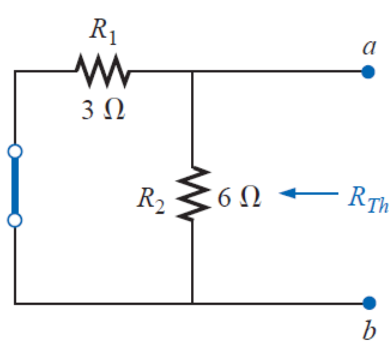
$$I_L = \frac{E_{th}}{R_{th} + R_L}$$

EXAMPLE: Find the Thévenin equivalent circuit for the network in the shaded area of the network. Then find the current through *RL* for values of 2Ω , 10Ω , and 100Ω .

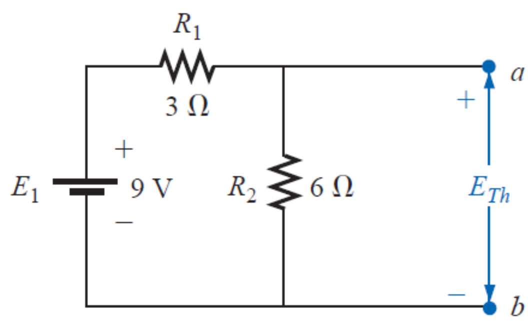


Solution:

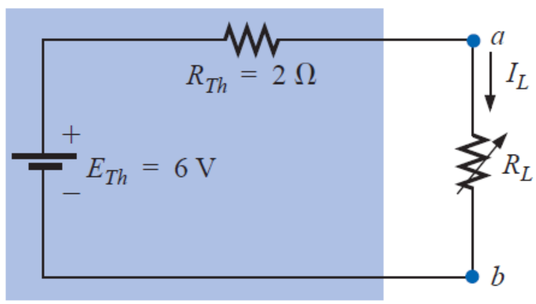




$$R_{Th} = R_1 \parallel R_2 = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = \mathbf{2\ \Omega}$$



$$E_{Th} = \frac{R_2E_1}{R_2 + R_1} = \frac{(6\ \Omega)(9\ \text{V})}{6\ \Omega + 3\ \Omega} = \frac{54\ \text{V}}{9} = \mathbf{6\ V}$$



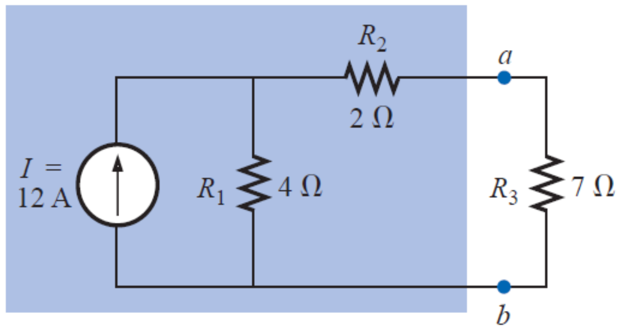
$$I_L = \frac{E_{Th}}{R_{Th} + R_L}$$

$$R_L = 2\ \Omega: \quad I_L = \frac{6\ \text{V}}{2\ \Omega + 2\ \Omega} = \mathbf{1.5\ A}$$

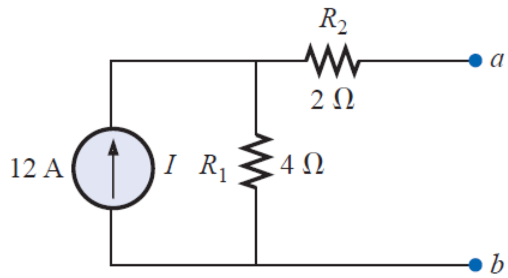
$$R_L = 10\ \Omega: \quad I_L = \frac{6\ \text{V}}{2\ \Omega + 10\ \Omega} = \mathbf{0.5\ A}$$

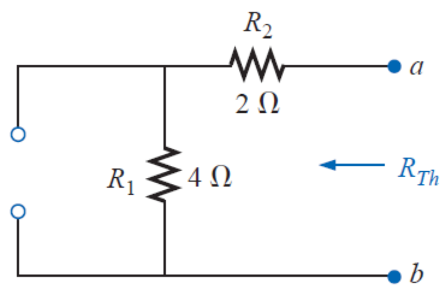
$$R_L = 100\ \Omega: \quad I_L = \frac{6\ \text{V}}{2\ \Omega + 100\ \Omega} = \mathbf{0.059\ A}$$

EXAMPLE: Find the Thévenin equivalent circuit for the network in the shaded area of the network

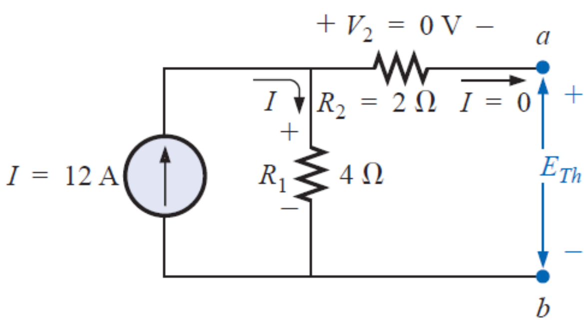


Solution:



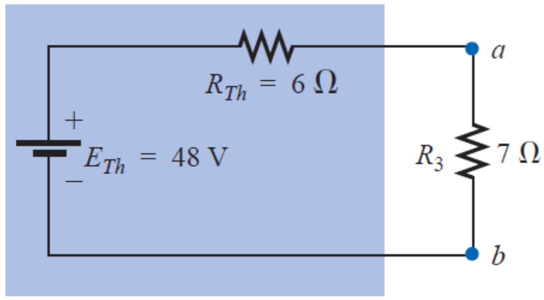


$$R_{Th} = R_1 + R_2 = 4\ \Omega + 2\ \Omega = \mathbf{6\ \Omega}$$

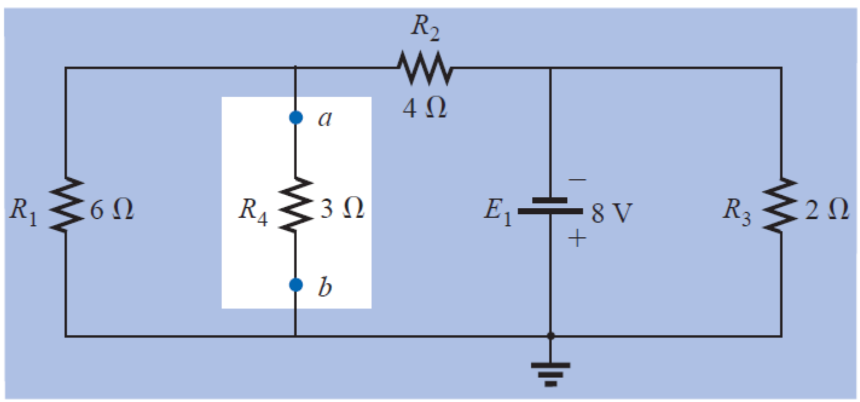


$$V_2 = I_2R_2 = (0)R_2 = 0\text{ V}$$

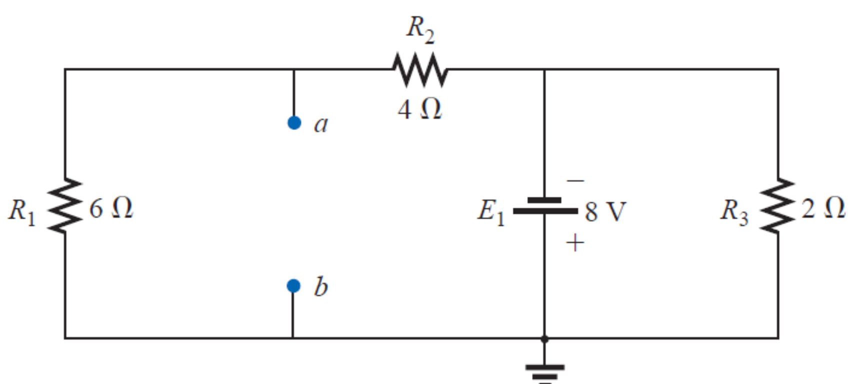
$$E_{Th} = V_1 = I_1R_1 = IR_1 = (12\text{ A})(4\ \Omega) = \mathbf{48\ V}$$

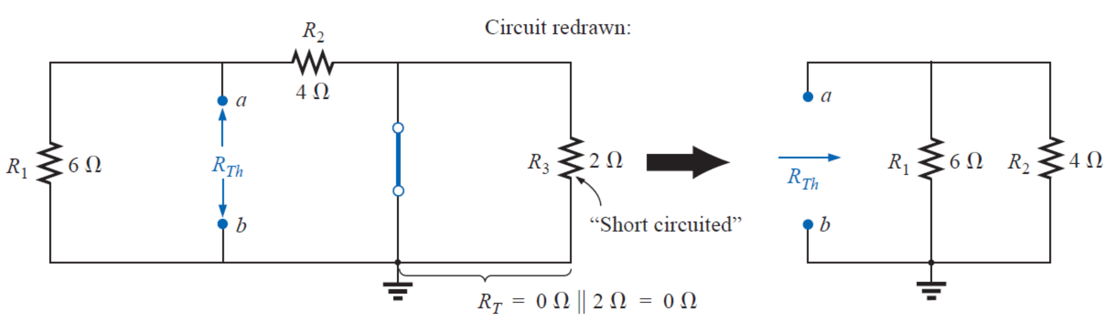


EXAMPLE: Find the Thévenin equivalent circuit for the network in the shaded area of the network

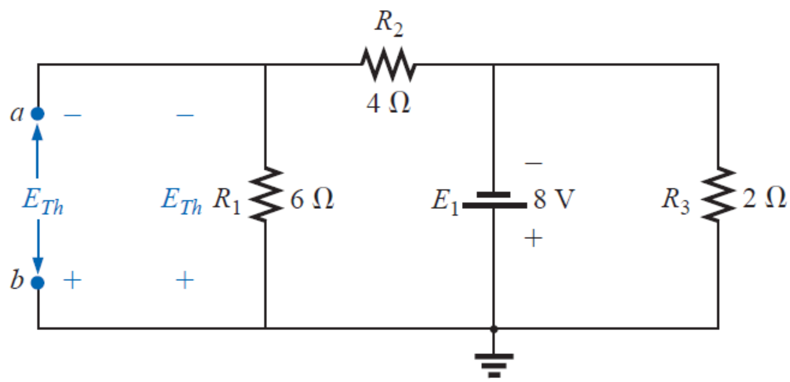


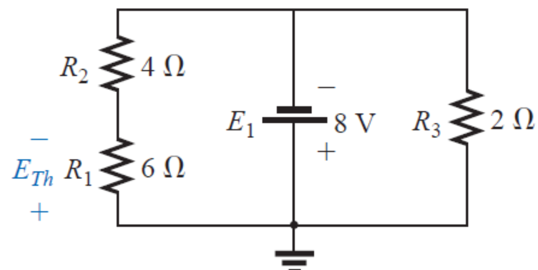
Solution:



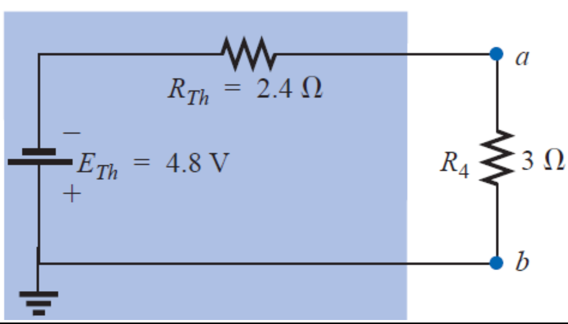


$$R_{Th} = R_1 \parallel R_2 = \frac{(6\ \Omega)(4\ \Omega)}{6\ \Omega + 4\ \Omega} = \frac{24\ \Omega}{10} = \mathbf{2.4\ \Omega}$$

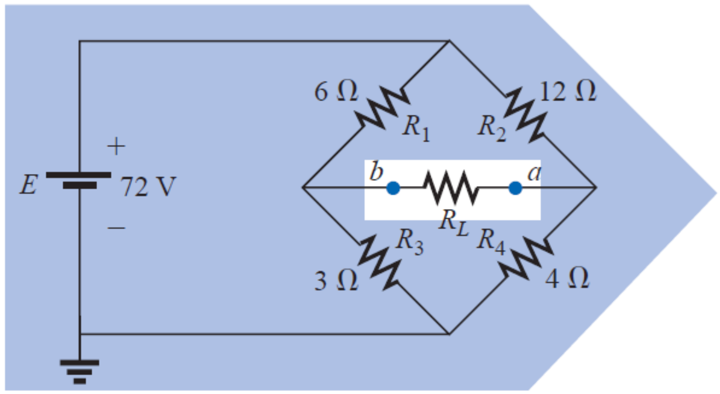




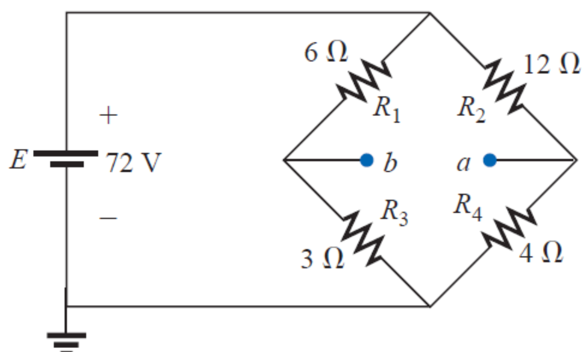
$$E_{Th} = \frac{R_1 E_1}{R_1 + R_2} = \frac{(6\ \Omega)(8\ \text{V})}{6\ \Omega + 4\ \Omega} = \frac{48\ \text{V}}{10} = \mathbf{4.8\ V}$$

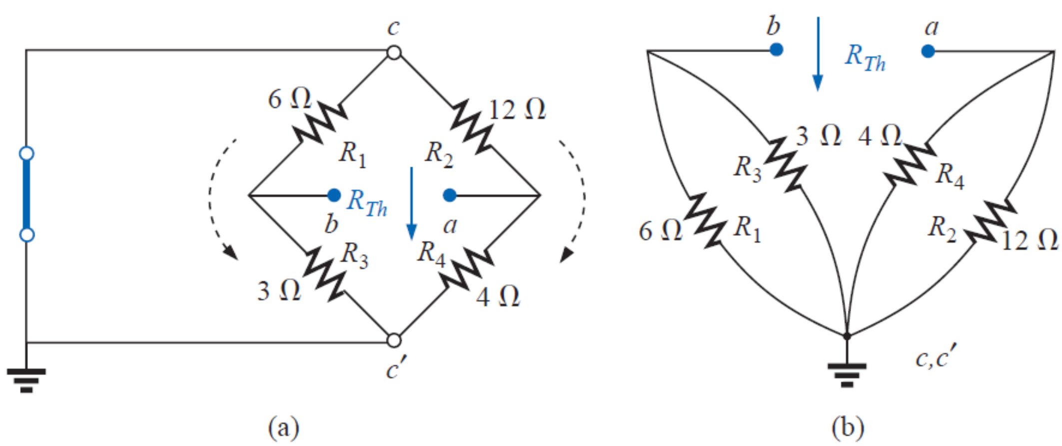


EXAMPLE: Find the Thévenin equivalent circuit for the network in the shaded area of the bridge network

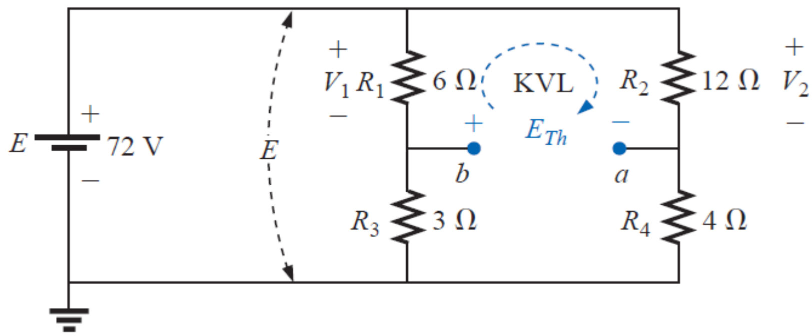

E
+
72 V
–
6 Ω
R1
12 Ω
R2
b
a
RL
R3
R4
3 Ω
4 Ω

Solution:


E
+
72 V
–
6 Ω
R1
12 Ω
R2
b
a
R3
R4
3 Ω
4 Ω

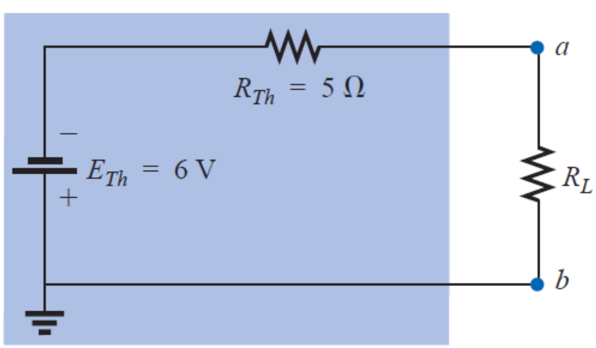

c
6 Ω
R1
12 Ω
R2
RTh
b
a
R3
R4
3 Ω
4 Ω
c′
(a)
b
RTh
a
3 Ω
4 Ω
R3
R4
6 Ω
R1
R2
12 Ω
c,c′
(b)

$$R_{Th} = R_{a\text{-}b} = R_1 \parallel R_3 + R_2 \parallel R_4$$
$$= 6\ \Omega \parallel 3\ \Omega + 4\ \Omega \parallel 12\ \Omega$$
$$= 2\ \Omega + 3\ \Omega = \mathbf{5\ \Omega}$$



$$V_1 = \frac{R_1 E}{R_1 + R_3} = \frac{(6\ \Omega)(72\ \text{V})}{6\ \Omega + 3\ \Omega} = \frac{432\ \text{V}}{9} = 48\ \text{V}$$
$$V_2 = \frac{R_2 E}{R_2 + R_4} = \frac{(12\ \Omega)(72\ \text{V})}{12\ \Omega + 4\ \Omega} = \frac{864\ \text{V}}{16} = 54\ \text{V}$$

$$\Sigma_{\circlearrowright} V = +E_{Th} + V_1 - V_2 = 0$$
$$E_{Th} = V_2 - V_1 = 54\ \text{V} - 48\ \text{V} = \mathbf{6\ V}$$



الوحدة الخامسة عشر- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Norton's Theorem

Any two-terminal linear bilateral dc network can be replaced by an equivalent circuit consisting of a current source and a parallel resistor

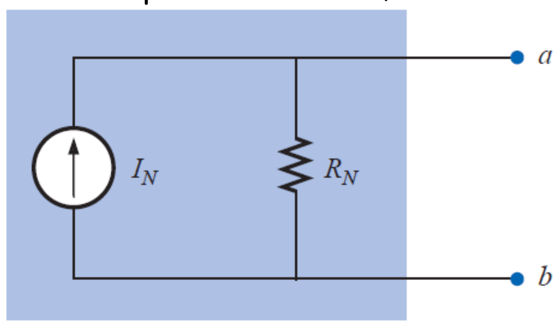
موضوعات المحاضرة

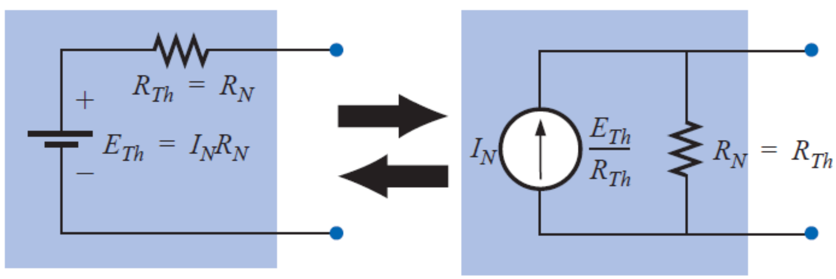
الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
15	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

Norton's Theorem

Any two-terminal linear bilateral dc network can be replaced by an equivalent circuit consisting of a current source and a parallel resistor,





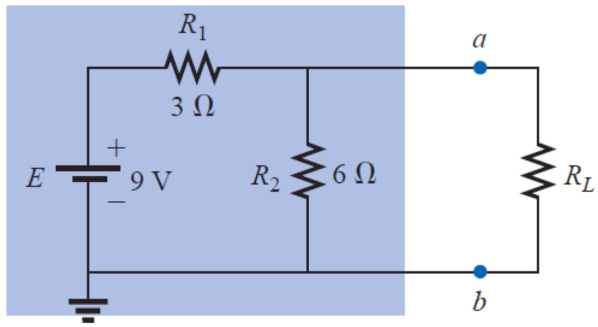
The steps leading to the proper values of *IN* and *RN* are now listed.

1) Remove that portion of the network across which the Norton equivalent circuit is found.
2) Mark the terminals of the remaining two-terminal network.
3) Calculate RN by first setting all sources to zero (voltage sources are replaced with short circuits and current sources with open circuits) and then finding the resultant resistance between the two marked terminals.
4) Calculate IN by first returning all sources to their original position and then finding the short-circuit current between the marked terminals.
5) Draw the Norton equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.

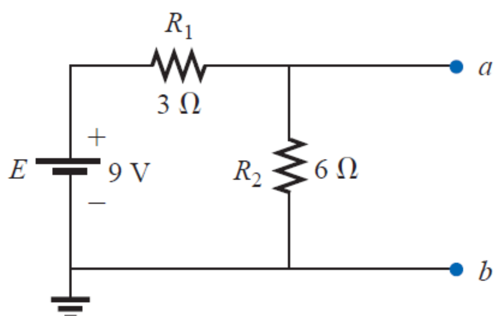
Then

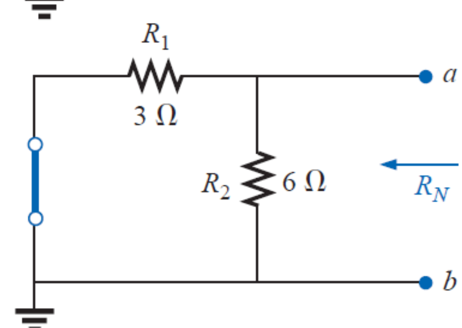
$$I_L = I_N \frac{R_N}{R_N + R_L}$$

EXAMPLE: Find the Norton equivalent circuit for the network.

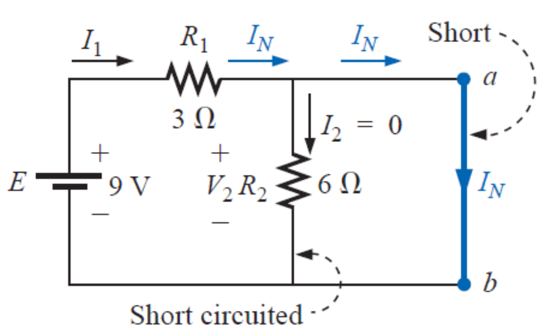


Solution:



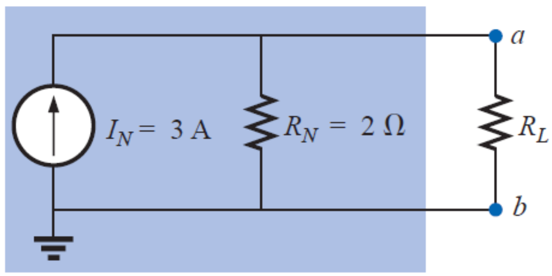


$$R_N = R_1 \parallel R_2 = 3\ \Omega \parallel 6\ \Omega = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = \frac{18\ \Omega}{9} = \mathbf{2\ \Omega}$$

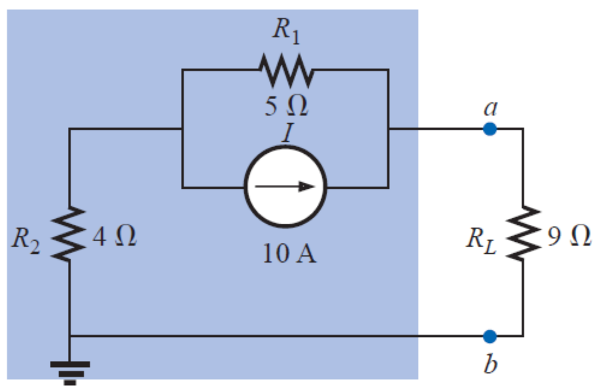


$$V_2 = I_2R_2 = (0)6\ \Omega = 0\ \text{V}$$

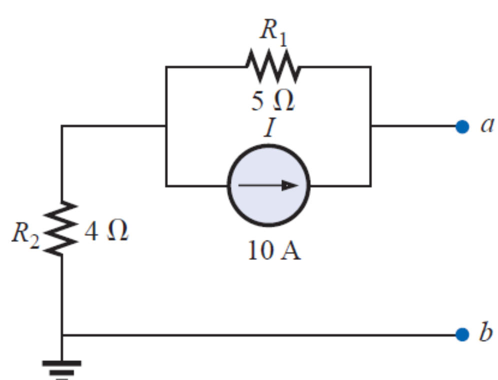
$$I_N = \frac{E}{R_1} = \frac{9\ \text{V}}{3\ \Omega} = \mathbf{3\ A}$$

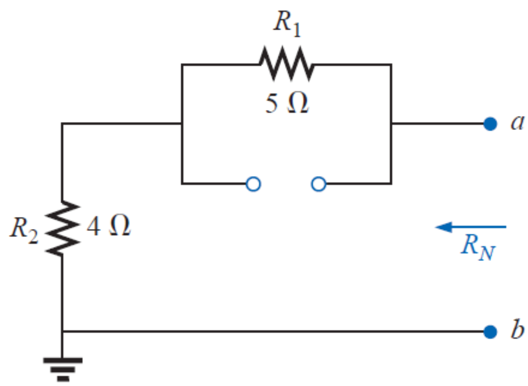


EXAMPLE: Find the Norton equivalent circuit for the network external to the 9-Ω resistor.

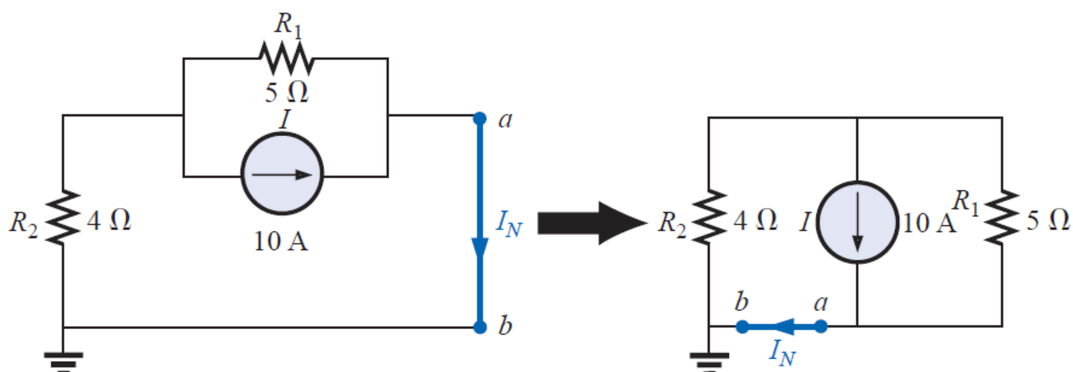


Solution:

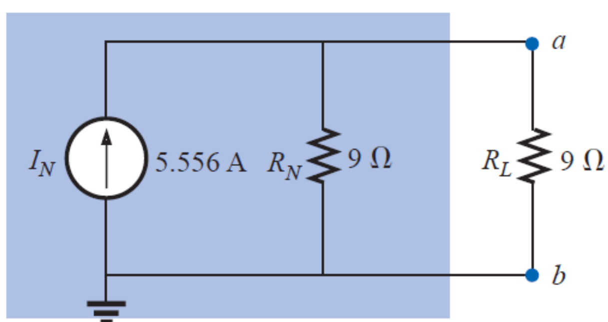




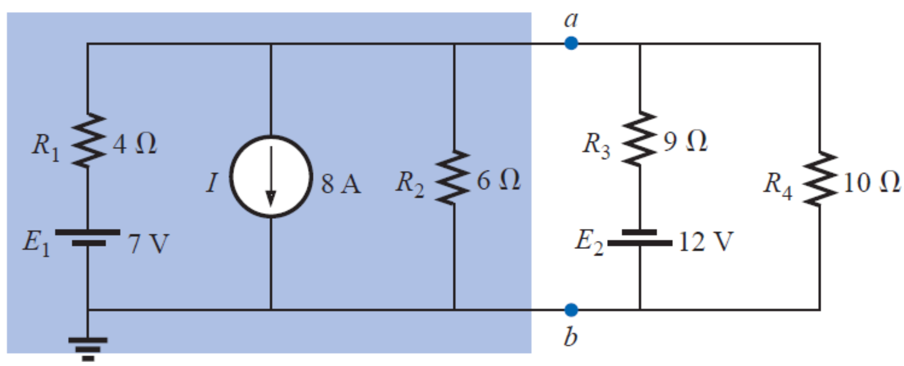
$$R_N = R_1 + R_2 = 5\ \Omega + 4\ \Omega = \mathbf{9\ \Omega}$$



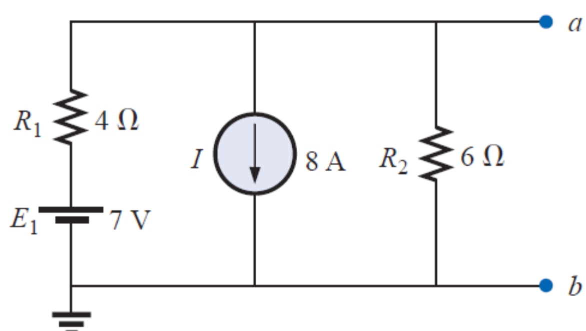
$$I_N = \frac{R_1 I}{R_1 + R_2} = \frac{(5\ \Omega)(10\ \text{A})}{5\ \Omega + 4\ \Omega} = \frac{50\ \text{A}}{9} = \mathbf{5.556\ A}$$

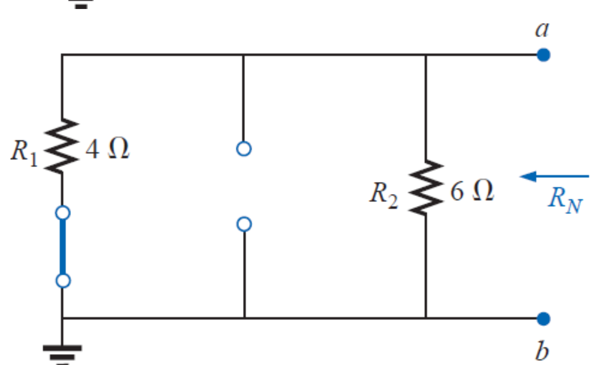


EXAMPLE: Find the Norton equivalent circuit for the portion of the network to the left of a-b.



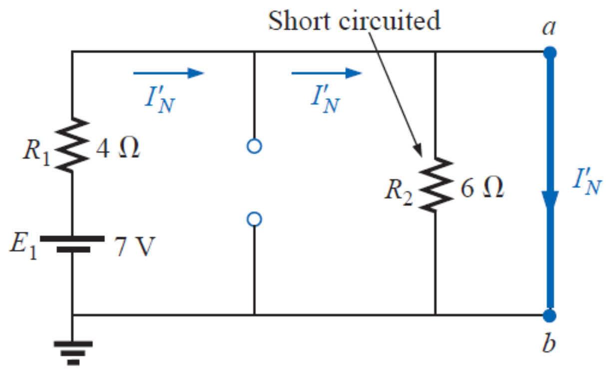
Solution:





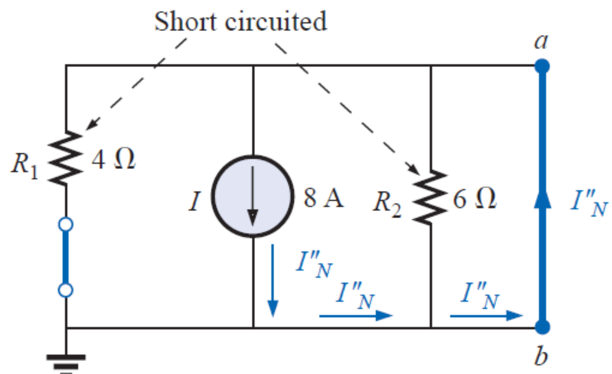
$$R_N = R_1 \parallel R_2 = 4\ \Omega \parallel 6\ \Omega = \frac{(4\ \Omega)(6\ \Omega)}{4\ \Omega + 6\ \Omega} = \frac{24\ \Omega}{10} = \mathbf{2.4\ \Omega}$$

1) (Using superposition) for the 7-V battery



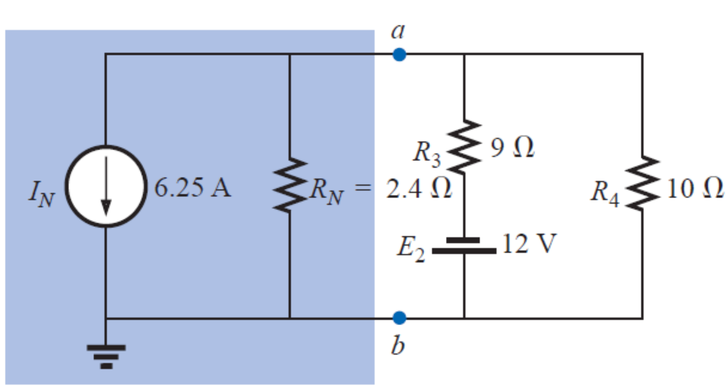
$$I'_N = \frac{E_1}{R_1} = \frac{7\text{ V}}{4\ \Omega} = 1.75\text{ A}$$

2) (Using superposition) for the 8-A source



$$I''_N = I = 8\text{ A}$$

$$I_N = I''_N - I'_N = 8\text{ A} - 1.75\text{ A} = \mathbf{6.25\ A}$$



الوحدة السادسة عشر- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Maximum Power Transfer Theorem

A load will receive maximum power from a linear bilateral dc network when its total resistive value is exactly equal to the Thévenin resistance of the network as "seen" by the load

موضوعات المحاضرة

Examples

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
16	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

Maximum Power Transfer Theorem

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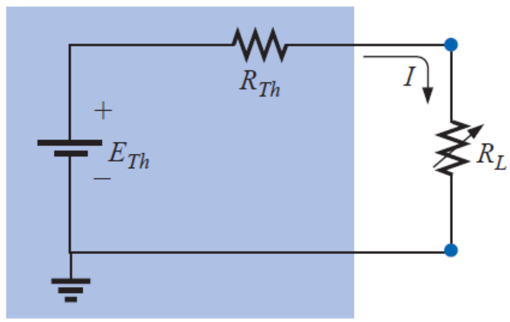


$$R_L = R_{Th}$$

$$I = \frac{E_{Th}}{R_{Th} + R_L} = \frac{E_{Th}}{2R_{Th}}$$

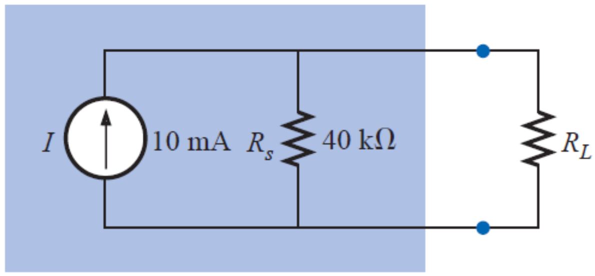
$$P_L = I^2 R_L = \left(\frac{E_{Th}}{2R_{Th}}\right)^2 R_{Th} = \frac{E_{Th}^2 R_{Th}}{4R_{Th}^2}$$

$$P_{L_{max}} = \frac{E_{Th}^2}{4R_{Th}}$$

Or

$$P_{L_{max}} = \frac{I_N^2 R_N}{4}$$

EXAMPLE: Determine the *RL* necessary to transfer maximum power to *RL*, and calculate the power of *RL* under these conditions.

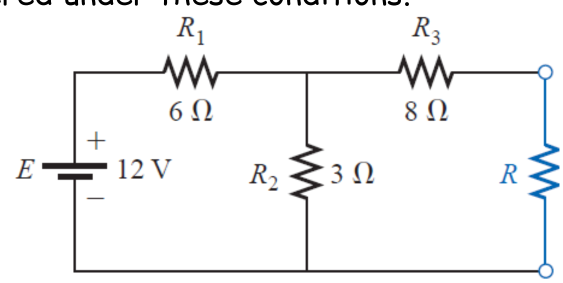


Solution:

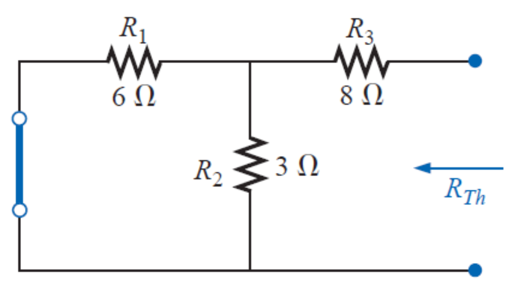
$$R_L = R_s = \mathbf{40\ k\Omega}$$

$$P_{L_{max}} = \frac{I_N^2 R_N}{4} = \frac{(10\text{ mA})^2(40\text{ k}\Omega)}{4} = \mathbf{1\ W}$$

EXAMPLE: For the network. Determine the value of *R* for maximum power to *R*, and calculate the power delivered under these conditions.

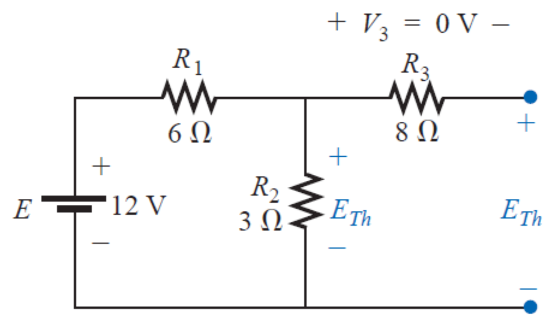


Solution:



$$R_{Th} = R_3 + R_1 \parallel R_2 = 8\ \Omega + \frac{(6\ \Omega)(3\ \Omega)}{6\ \Omega + 3\ \Omega} = 8\ \Omega + 2\ \Omega$$

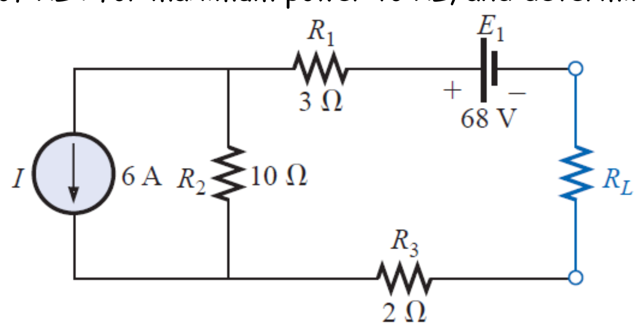
$$R = R_{Th} = \mathbf{10\ \Omega}$$



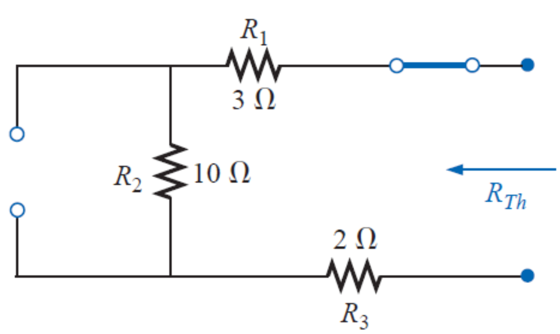
$$E_{Th} = \frac{R_2 E}{R_2 + R_1} = \frac{(3\,\Omega)(12\,\text{V})}{3\,\Omega + 6\,\Omega} = \frac{36\,\text{V}}{9} = \mathbf{4\,V}$$

$$P_{L_{\max}} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(4\,\text{V})^2}{4(10\,\Omega)} = \mathbf{0.4\,W}$$

EXAMPLE: Find the value of *RL* i for maximum power to *RL*, and determine the maximum power.

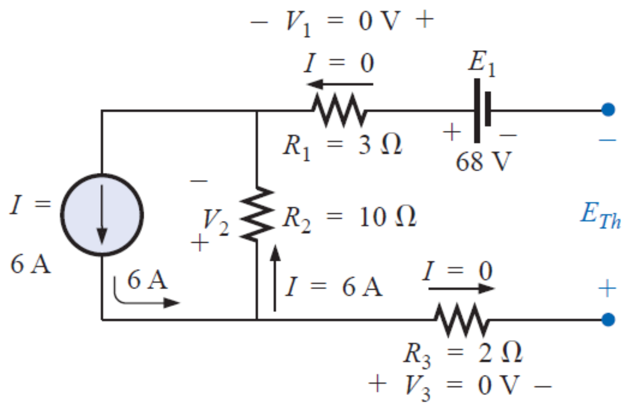


Solution:



$$R_{Th} = R_1 + R_2 + R_3 = 3\,\Omega + 10\,\Omega + 2\,\Omega = 15\,\Omega$$

$$R_L = R_{Th} = \mathbf{15\,\Omega}$$



$$V_1 = V_3 = 0\text{ V}$$

$$V_2 = I_2R_2 = IR_2 = (6\text{ A})(10\ \Omega) = 60\text{ V}$$

$$\Sigma_{\circlearrowright} V = -V_2 - E_1 + E_{Th} = 0$$

$$E_{Th} = V_2 + E_1 = 60\text{ V} + 68\text{ V} = 128\text{ V}$$

$$P_{L_{\max}} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(128\text{ V})^2}{4(15\ \Omega)} = \mathbf{273.07\ W}$$

الوحدة السابعة عشر - الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Magnetic Circuits

موضوعات المحاضرة

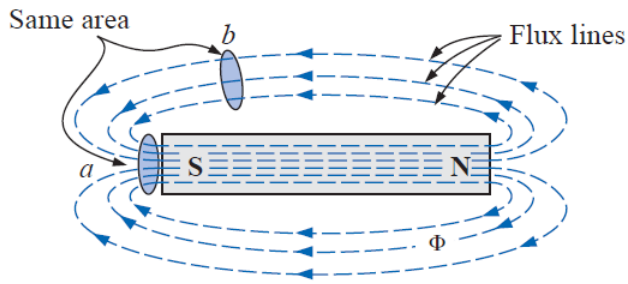
الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
17	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

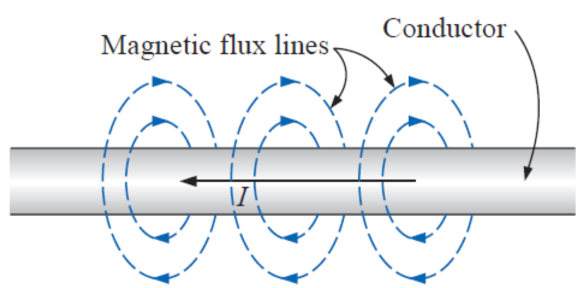
Magnetic Circuits

Magnetic Fields: is a field of force produced by a magnetic object or particle, or by a changing electric field.

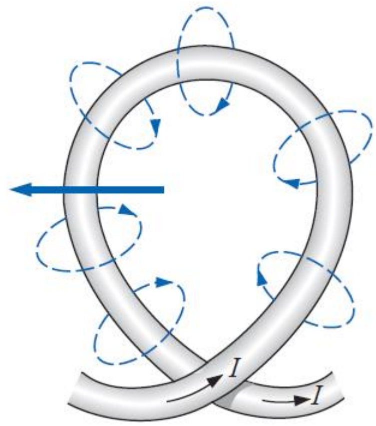
Magnetic Flux Lines: is a measure of the magnetic field strength existing on a two dimensional surface, the unit of magnetic flux is the (weber). The symbol for magnetic flux is (Φ).



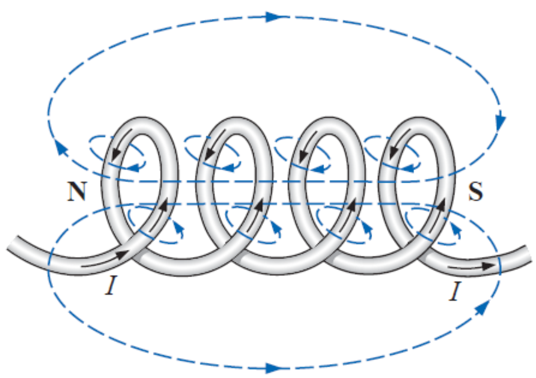
* The magnetic flux lines around a current-carrying conductor (*right-hand rule).*



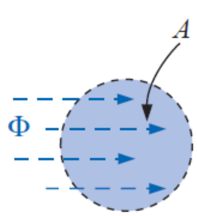
* The Flux distribution of a single-turn coil.



* The Flux distribution of a current-carrying coil.



Flux Density: The number of flux lines per unit area, is denoted by the capital letter ***B***, and is measured in *teslas (T).*



$$B = \frac{\Phi}{A}$$

Where

B : is flux density in teslas (T)

Φ : is magnetic flux in webers (Wb)

A : is cross-sectional area in sequre meters (m^2)

EXAMPLE: determine the flux density *B* in teslas for the figure below.

$\Phi = 6 \times 10^{-5}$ Wb
$A = 1.2 \times 10^{-3}$ m^2

Solution:

$$B = \frac{\Phi}{A} = \frac{6 \times 10^{-5}\ \text{Wb}}{1.2 \times 10^{-3}\ \text{m}^2} = \mathbf{5 \times 10^{-2}\ T}$$

Permeability: is a measure of the ease with which magnetic flux lines can be established in the material, the symbol for Permeability is (μ), the units of Permeability is Wb/A· m.

* The permeability of free space μ_0 (vacuum) is

$$\mu_o = 4\pi \times 10^{-7} \frac{\text{Wb}}{\text{A} \cdot \text{m}}$$

* The permeability of material μ is

$$\mu = \mu_0 \mu_r$$

Where μ_r is the relative permeability of material.

Reluctance: It is analogous to resistance in an electrical circuit, but rather than dissipating magnetic energy it stores magnetic energy. the symbol for Reluctance is ($\Re$), the units of Reluctance is (At/Wb).

$$\Re = \frac{l}{\mu A}$$

Where

l : is the length in meters (m).

μ : is Permeability

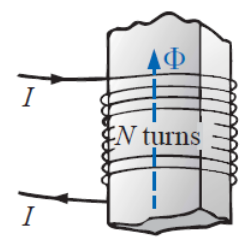
A : is cross-sectional area in sequre meters (m^2)

Ohm's Law for Magnetic Circuits: the **magnetomotive force (mmf)** $\mathscr{F}$, which is the external force (or "pressure") required to set up the magnetic flux lines within the magnetic material. The opposition to the setting up of the flux Φ is the reluctance $\Re$.

$$\Phi = \frac{\mathscr{F}}{\mathscr{R}}$$

* The magnetomotive force $\mathscr{F}$ is proportional to the product of the number of turns around the core is

$$\mathscr{F} = NI \quad \text{(ampere-turns, At)}$$



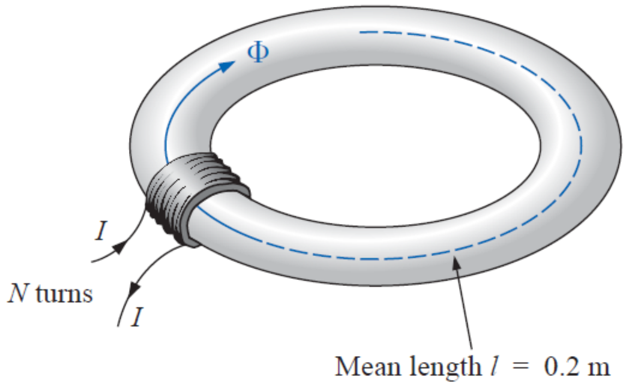
Magnetizing Force: The magnetomotive force per unit length.

$$H = \frac{\mathscr{F}}{l} \quad \text{(At/m)}$$

The magnetic force H of the number of turns around the core is

$$H = \frac{NI}{l} \quad \text{(At/m)}$$

EXAMPLE: determine the magnetic force if NI= 40 At and l = 0.2 m.



Solution:

الوحدة الثامنة عشر - الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

موضوعات المحاضرة

Sinusoidal Alternating Waveforms

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
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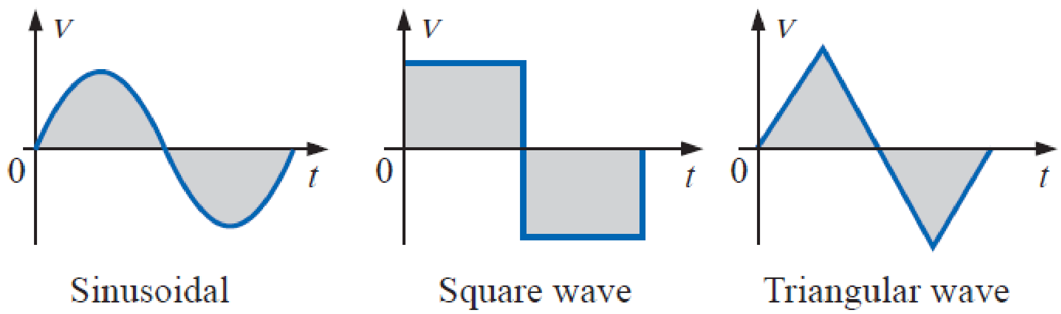
Sinusoidal Alternating Waveforms

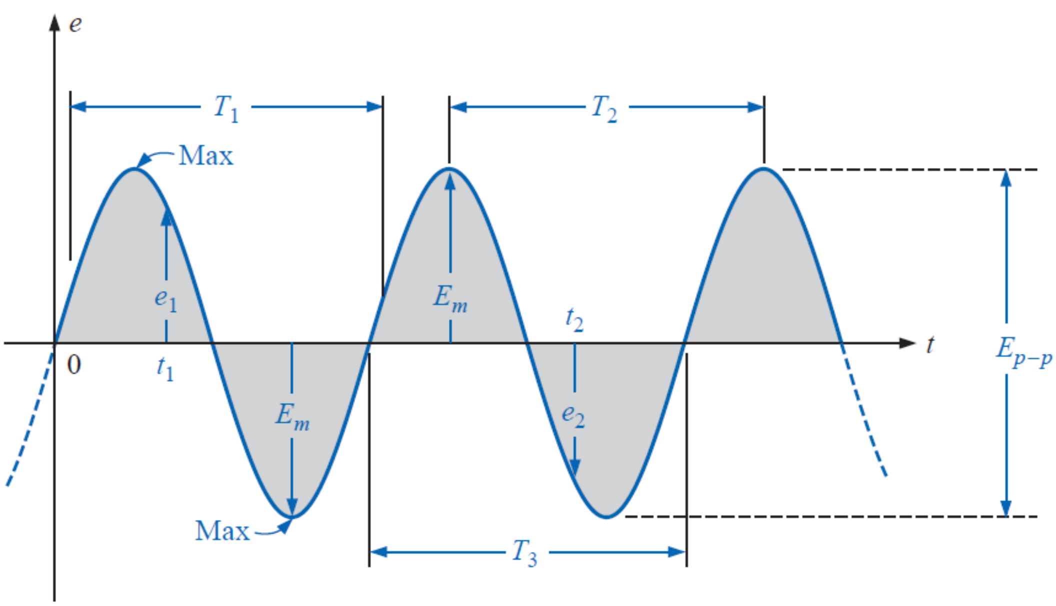
The terminology **(ac)** voltage or **(ac)** current refers to alternating voltage or current. The term alternating indicates only that waveforms alternate between two prescribed levels in a set time sequence. To be absolutely correct the term sinusoidal, square, triangular must be also applied.



The pattern of particular interest is the **sinusoidal ac** waveform voltage.

SINUSOIDAL ac VOLTAGE DEFINITIONS

The vertical scaling is in volts or amperes and the horizontal scaling is always in units of time.



Waveform: The path traced by a quantity, such as the voltage plotted as a function of some variable such as time (as above), position, degrees, radians, temperature, and so on.

Instantaneous value: The magnitude of a waveform at any instant of time; denoted by lowercase letters ($e1$, $e2$).

Peak amplitude: The maximum value of a waveform as measured from its *average*, or *mean*, value, denoted by uppercase letters (such as Em for sources of voltage and Vm for the voltage drop across a load).

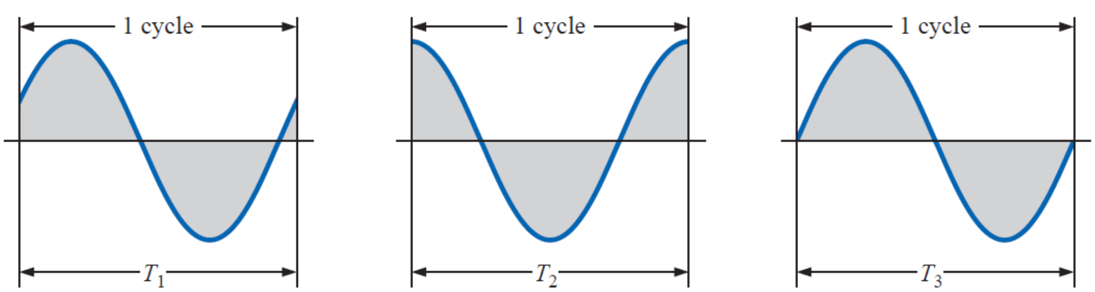
Peak value: The maximum instantaneous value of a function as measured from the zero-volt level.

Peak-to-peak value: Denoted by $Ep\text{-}p$ or $Vp\text{-}p$, the full voltage between positive and negative peaks of the waveform, that is, the sum of the magnitude of the positive and negative peaks.

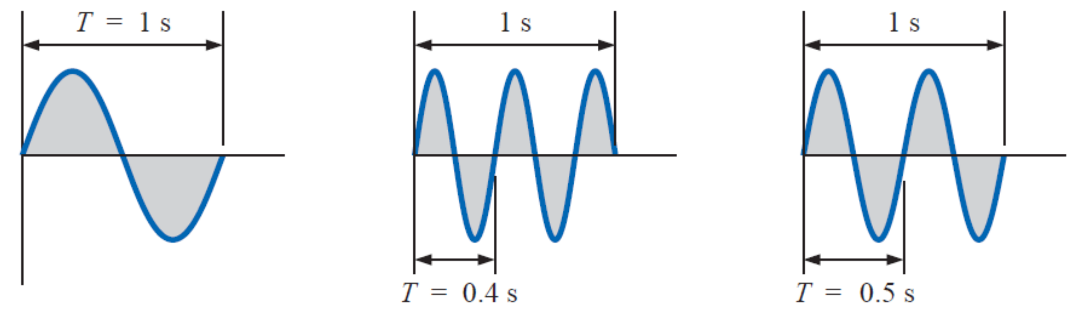
Periodic waveform: A waveform that continually repeats itself after the same time interval.

Period (T): The time interval between successive repetitions of a periodic waveform (the period $T1 = T2 = T3$),

Cycle: The portion of a waveform contained in *one period* of time.



Frequency (f): The number of cycles that occur in 1 s.



(a) is 1 cycle per second, and for (b), 2 1/2 cycles per second. If a waveform of similar shape had a period of 0.5 s (c), the frequency would be 2 cycles per second.

1 hertz (Hz) = 1 cycle per second (c/s)

$$f = \frac{1}{T}$$

f = Hz
T = seconds (s)

$$T = \frac{1}{f}$$

EXAMPLE: Find the period of a periodic waveform with a frequency of

a. 60 Hz.
b. 1000 Hz.

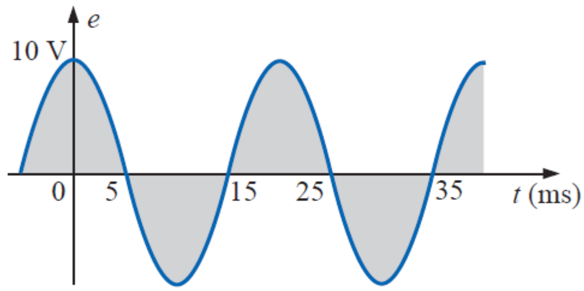
Solutions:

a. $T = \dfrac{1}{f} = \dfrac{1}{60\text{ Hz}} \cong 0.01667\text{ s or } \mathbf{16.67\ ms}$

(a recurring value since 60 Hz is so prevalent)

b. $T = \dfrac{1}{f} = \dfrac{1}{1000\text{ Hz}} = 10^{-3}\text{ s} = \mathbf{1\ ms}$

EXAMPLE: Determine the frequency of the waveform



Solutions:

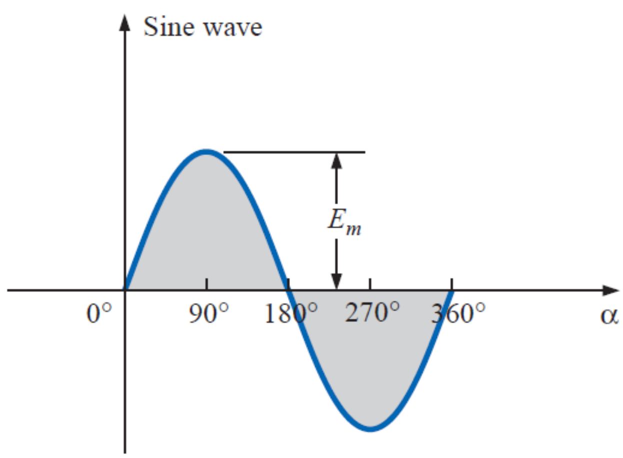
From the figure, $T = (25 \text{ ms} - 5 \text{ ms}) = 20 \text{ ms}$, and

$$f = \frac{1}{T} = \frac{1}{20 \times 10^{-3} \text{ s}} = \mathbf{50 \text{ Hz}}$$

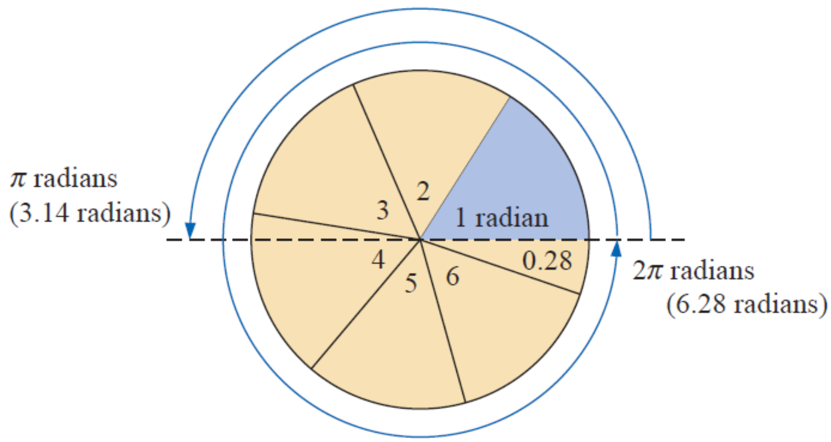
THE SINE WAVE

The sinusoidal waveform is the only alternating waveform whose shape is unaffected by the response characteristics of R, L, and C elements.

In other words, if the voltage across (or current through) a resistor, coil, or capacitor is sinusoidal in nature, the resulting current (or voltage, respectively) for each will also have sinusoidal characteristics.



$$2\pi \text{ rad} = 360°$$



$$\text{Radians} = \left(\frac{\pi}{180^\circ}\right) \times (\text{degrees})$$

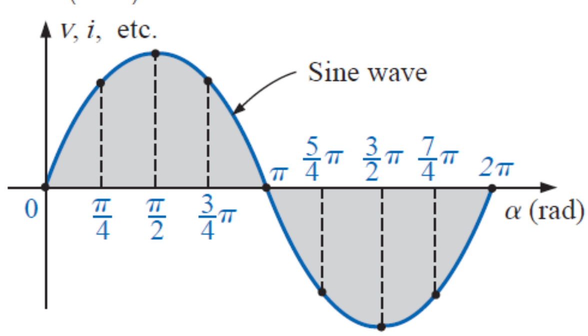
$$\text{Degrees} = \left(\frac{180^\circ}{\pi}\right) \times (\text{radians})$$

$$\mathbf{90^\circ:}\quad \text{Radians} = \frac{\pi}{180^\circ}(90^\circ) = \frac{\pi}{2}\ \textbf{rad}$$

$$\mathbf{30^\circ:}\quad \text{Radians} = \frac{\pi}{180^\circ}(30^\circ) = \frac{\pi}{6}\ \textbf{rad}$$

$$\frac{\pi}{3}\ \textbf{rad:}\quad \text{Degrees} = \frac{180^\circ}{\pi}\left(\frac{\pi}{3}\right) = \mathbf{60^\circ}$$

$$\frac{3\pi}{2}\ \textbf{rad:}\quad \text{Degrees} = \frac{180^\circ}{\pi}\left(\frac{3\pi}{2}\right) = \mathbf{270^\circ}$$



Angular velocity: The velocity, with which the radius vector rotates about the center, can be determined from the following equation:

$$\text{Angular velocity} = \frac{\text{distance (degrees or radians)}}{\text{time (seconds)}}$$

$$\omega = \frac{2\pi}{T} \qquad \text{(rad/s)}$$

$$\omega = 2\pi f \qquad \text{(rad/s)}$$

الوحدة التاسعة عشر - الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

GENERAL FORMAT FOR THE SINUSOIDAL VOLTAGE OR CURRENT

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

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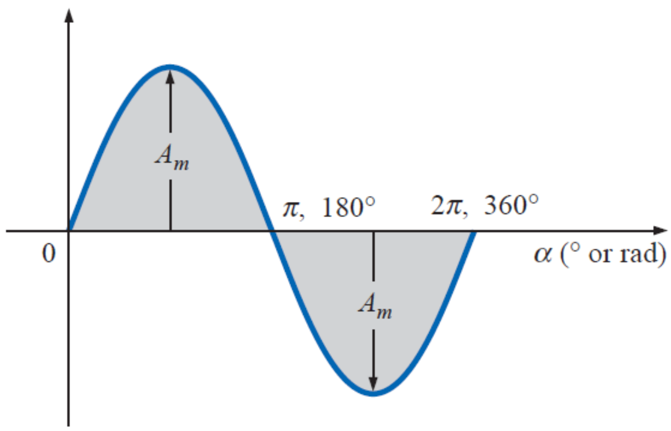
GENERAL FORMAT FOR THE SINUSOIDAL VOLTAGE OR CURRENT

The basic mathematical format for the sinusoidal waveform is:

$$A_m \sin \alpha$$

where ***Am*** is the peak value of the waveform and α is the unit of measure for the horizontal axis.

$$\alpha = \omega t$$



$$A_m \sin \omega t$$

For electrical quantities such as current and voltage, the general format is:

$$i = I_m \sin \omega t = I_m \sin \alpha$$

$$e = E_m \sin \omega t = E_m \sin \alpha$$

EXAMPLE: Given e = 5 sin α , determine e at α = 40° and α = 0.8 π .

Solution:

For $\alpha = 40°$,

$$e = 5 \sin 40° = 5(0.6428) = \mathbf{3.214\ V}$$

For $\alpha = 0.8\pi$,

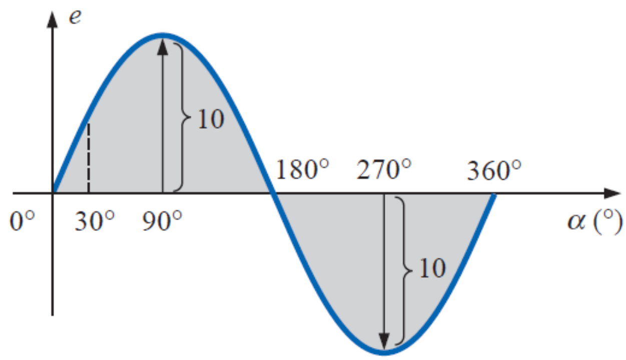
$$\alpha\,(^\circ) = \frac{180^\circ}{\pi}(0.8\pi) = 144^\circ$$

and $$e = 5\sin 144^\circ = 5(0.5878) = \mathbf{2.939\ V}$$

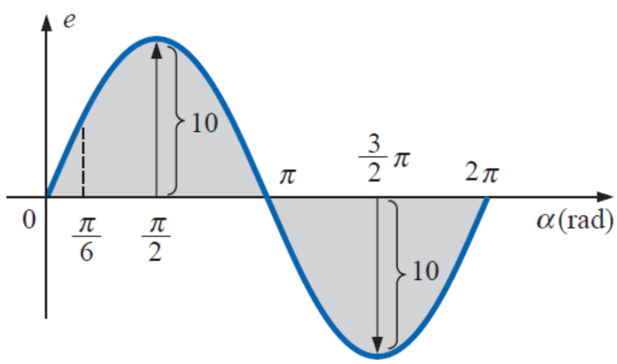
EXAMPLE: Sketch $e = 10 \sin 314\, t$ with the abscissa

a. angle (α) in degrees.
b. angle (α) in radians.
c. time (t) in seconds.

Solution:



(a)



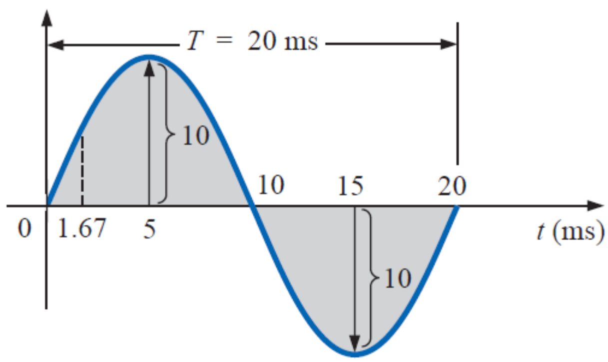
(b)

c. 360°: $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{314} = 20 \text{ ms}$

180°: $\dfrac{T}{2} = \dfrac{20 \text{ ms}}{2} = 10 \text{ ms}$

90°: $\dfrac{T}{4} = \dfrac{20 \text{ ms}}{4} = 5 \text{ ms}$

30°: $\dfrac{T}{12} = \dfrac{20 \text{ ms}}{12} = 1.67 \text{ ms}$



EXAMPLE: Given $i = 6 * 10^{-3} \sin 1000\, t$, determine i at $t = 2$ ms.

Solution:

$$\alpha = \omega t = 1000t = (1000 \text{ rad/s})(2 \times 10^{-3} \text{ s}) = 2 \text{ rad}$$

$$\alpha\ (°) = \frac{180°}{\pi \text{ rad}}(2 \text{ rad}) = 114.59°$$

$$i = (6 \times 10^{-3})(\sin 114.59°)$$
$$= (6 \text{ mA})(0.9093) = \mathbf{5.46\ mA}$$

الوحدة العشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

PHASE RELATIONS

موضوعات المحاضرة

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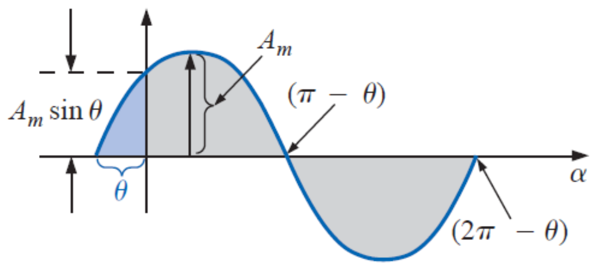
PHASE RELATIONS

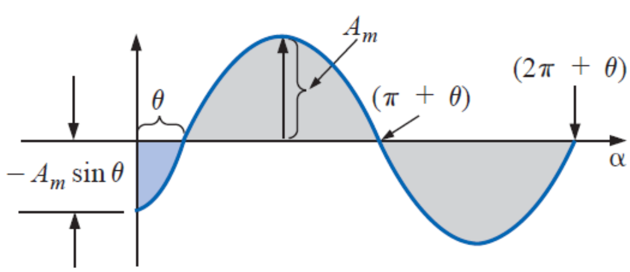
* If the waveform passes through the horizontal axis with a *positive going* (increasing with time) slope *before* 0°.

$$A_m \sin(\omega t + \theta)$$



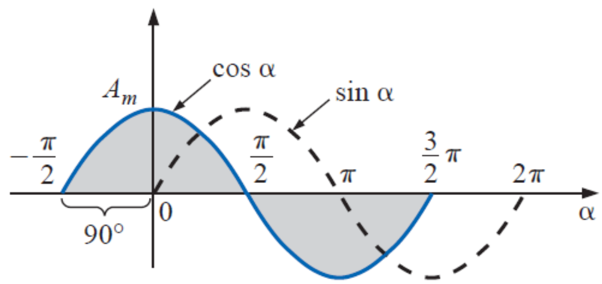
* If the waveform passes through the horizontal axis with a positive-going slope *after* 0°,

$$A_m \sin(\omega t - \theta)$$



* If the waveform crosses the horizontal axis with a positive-going slope 90° (π/2) sooner, it is called a *cosine wave.*

$$\sin(\omega t + 90°) = \sin\left(\omega t + \frac{\pi}{2}\right) = \cos \omega t$$



EXAMPLE 13.12 What is the phase relationship between the sinusoidal waveforms of each of the following sets?

a. $v = 10\sin(\omega t + 30^\circ)$
   $i = 5\sin(\omega t + 70^\circ)$

b. $i = 15\sin(\omega t + 60^\circ)$
   $v = 10\sin(\omega t - 20^\circ)$

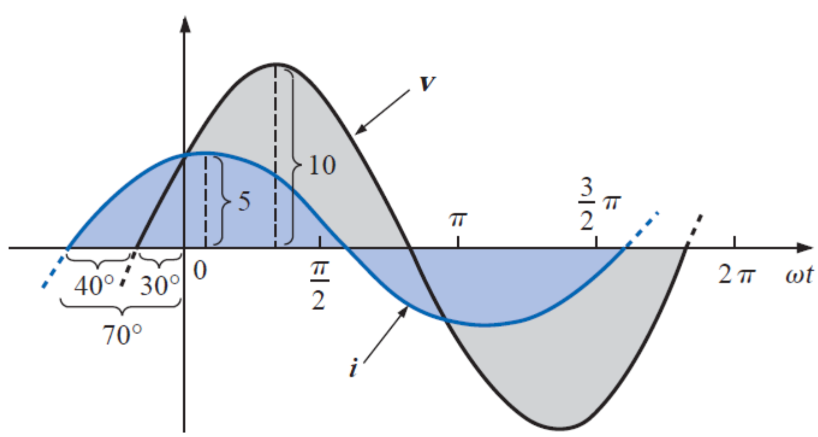
c. $i = 2\cos(\omega t + 10^\circ)$
   $v = 3\sin(\omega t - 10^\circ)$

d. $i = -\sin(\omega t + 30^\circ)$
   $v = 2\sin(\omega t + 10^\circ)$

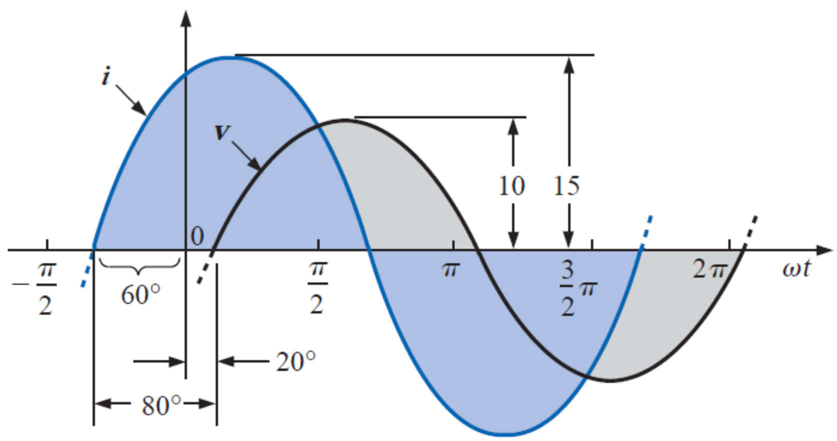
e. $i = -2\cos(\omega t - 60^\circ)$
   $v = 3\sin(\omega t - 150^\circ)$

Solutions:

a) ***i* leads *v* by 40°, or *v* lags *i* by 40°.**



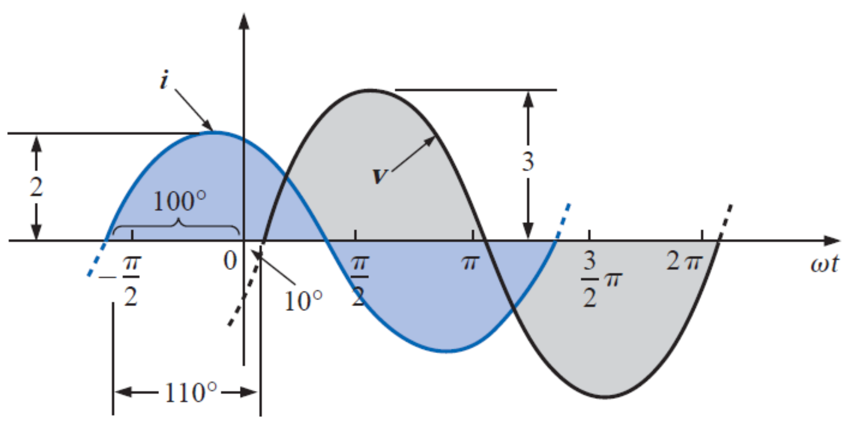
b) ***i* leads *v* by 80°, or *v* lags *i* by 80°.**



C)

$$i = 2\cos(\omega t + 10°) = 2\sin(\omega t + 10° + 90°)$$
$$= 2\sin(\omega t + 100°)$$

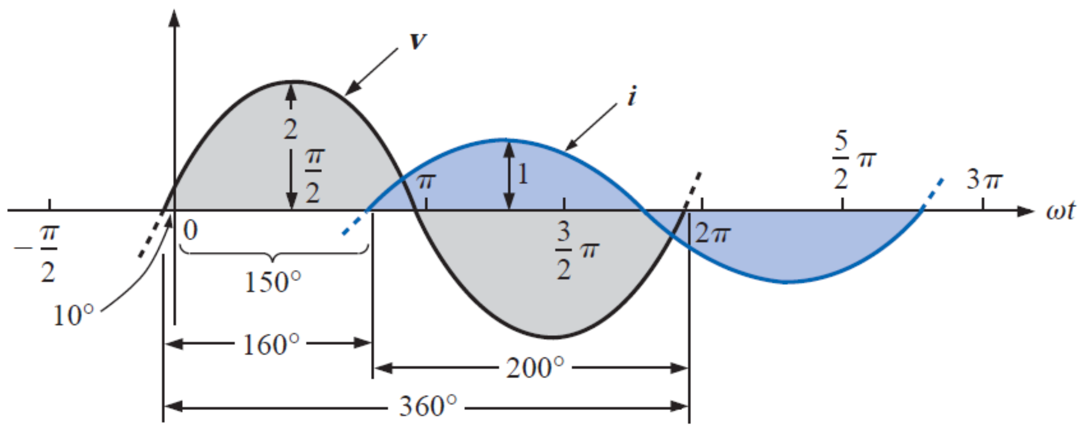
***i* leads *v* by 110°, or *v* lags *i* by 110°.**



d)

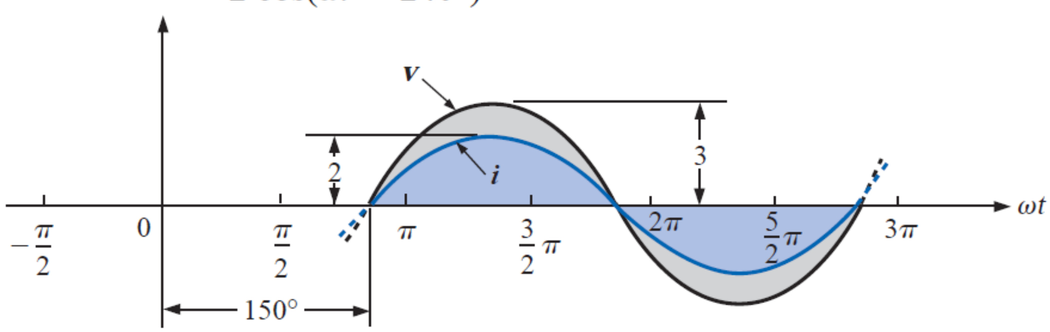
$$-\sin(\omega t + 30°) = \sin(\omega t + 30° - 180°)$$
$$= \sin(\omega t - 150°)$$

***v* leads *i* by 160°, or *i* lags *v* by 160°.**



e)

$$i = -2\cos(\omega t - 60°) = 2\cos(\omega t - 60° - 180°)$$
By choice
$$= 2\cos(\omega t - 240°)$$



However, $\cos\alpha = \sin(\alpha + 90°)$

so that $2\cos(\omega t - 240°) = 2\sin(\omega t - 240° + 90°)$
$= 2\sin(\omega t - 150°)$

***v* and *i* are in phase.**

الوحدة الواحد والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

AVERAGE VALUE (mean)

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الأساليب والأنشطة والوسائل التعليمية

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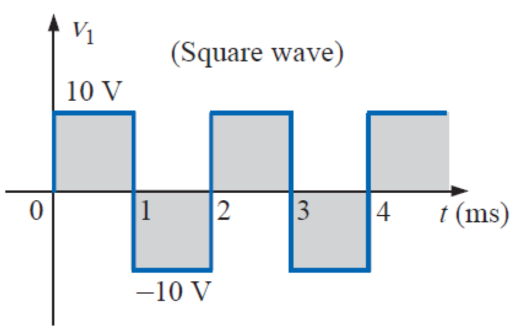
AVERAGE VALUE (mean)

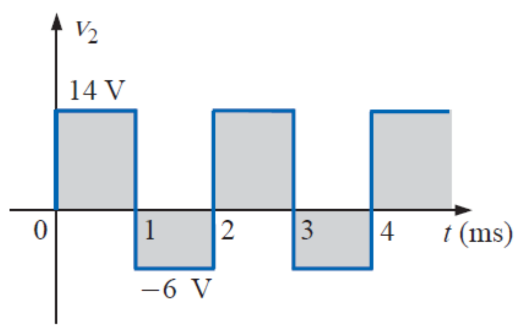
The average value of alternating waveform is the equivalent (DC) value over a complete cycle. In general the average value of a waveform is given as:

$$G \text{ (average value)} = \frac{\text{algebraic sum of areas}}{\text{length of curve}}$$

EXAMPLE: Determine the average value of the waveforms



(a)



(b)

Solutions:

a) By inspection, the area above the axis equals the area below over one cycle, resulting in an average value of zero volts.

$$G = \frac{(10\text{ V})(1\text{ ms}) - (10\text{ V})(1\text{ ms})}{2\text{ ms}}$$

$$= \frac{0}{2\text{ ms}} = \mathbf{0\ V}$$

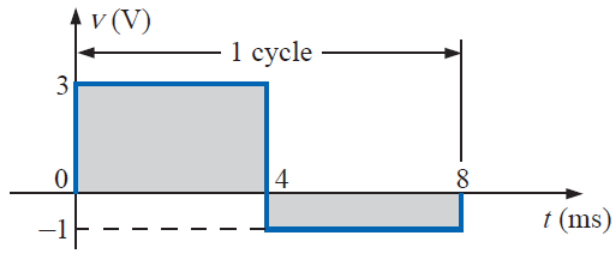
b)

$$G = \frac{(14\text{ V})(1\text{ ms}) - (6\text{ V})(1\text{ ms})}{2\text{ ms}}$$

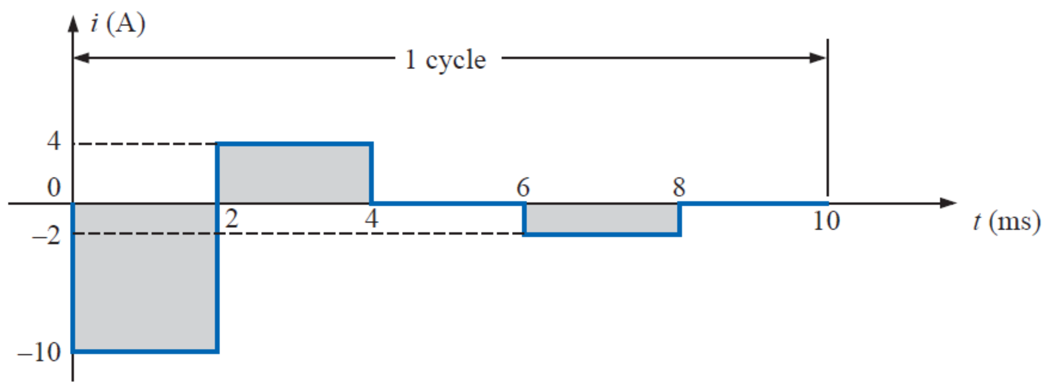
$$= \frac{14\text{ V} - 6\text{ V}}{2} = \frac{8\text{ V}}{2} = \mathbf{4\ V}$$

EXAMPLE: Find the average values of the following waveforms over one full cycle:

a)



b)



Solutions:

a. $G = \dfrac{+(3\text{ V})(4\text{ ms}) - (1\text{ V})(4\text{ ms})}{8\text{ ms}} = \dfrac{12\text{ V} - 4\text{ V}}{8} = \mathbf{1\ V}$

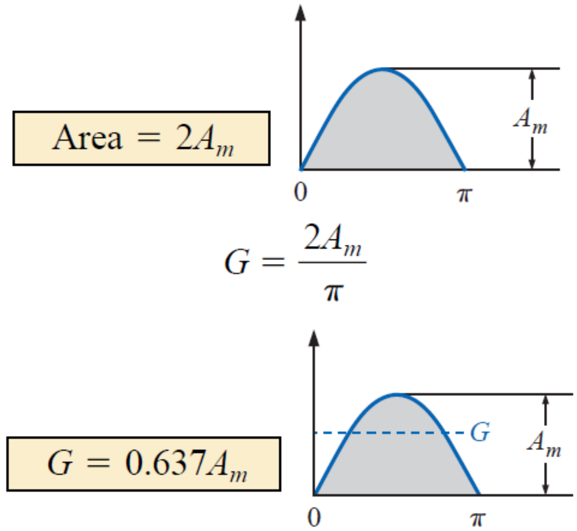
b. $G = \dfrac{-(10\text{ V})(2\text{ ms}) + (4\text{ V})(2\text{ ms}) - (2\text{ V})(2\text{ ms})}{10\text{ ms}}$

$= \dfrac{-20\text{ V} + 8\text{ V} - 4\text{ V}}{10} = -\dfrac{16\text{ V}}{10} = \mathbf{-1.6\ V}$

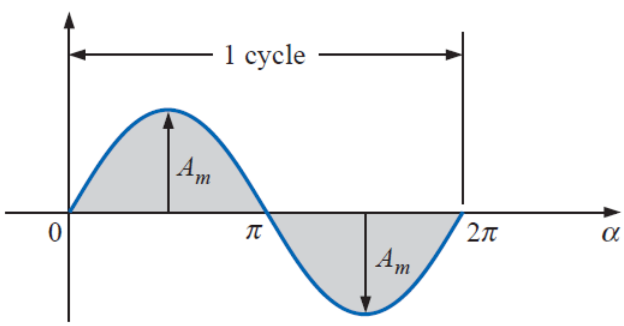
The area of **sine wave** (for one half) can be calculated by the following:

$$\text{Area} = \int_0^{\pi} A_m \sin\alpha \, d\alpha$$

$$\begin{aligned}\text{Area} &= A_m[-\cos\alpha]_0^{\pi} \\ &= -A_m(\cos\pi - \cos 0°) \\ &= -A_m[-1 - (+1)] = -A_m(-2)\end{aligned}$$



EXAMPLE: Determine the average value of the sinusoidal waveform

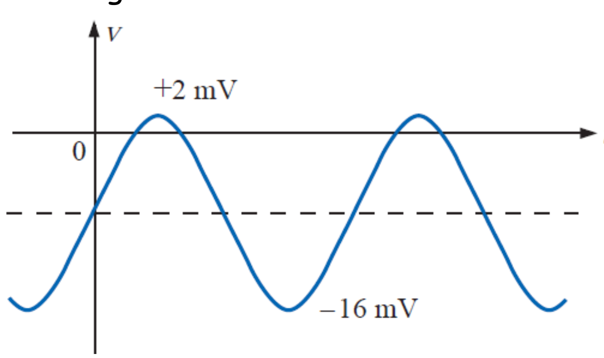


Solutions:

The average value of a pure sinusoidal waveform over one full cycle is zero.

$$G = \frac{+2A_m - 2A_m}{2\pi} = \mathbf{0\ V}$$

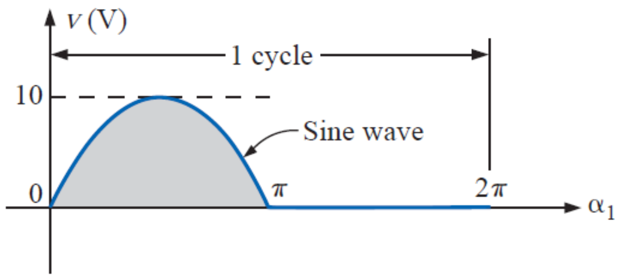
EXAMPLE: Determine the average value of the waveform



Solutions:

The peak-to-peak value of the sinusoidal function is 16 mV + 2 mV = 18 mV. The peak amplitude of the sinusoidal waveform is, therefore, 18 mV/2 = 9 mV. Counting down 9 mV from 2 mV (or 9 mV up from -16 mV) results in an average or dc level of -7 mV.

EXAMPLE: Determine the average value of the waveform



Solutions:

$$G = \frac{2A_m + 0}{2\pi} = \frac{2(10\ \text{V})}{2\pi} \cong \mathbf{3.18\ V}$$

الوحدة الثانية والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

The effective value (or the rms value) of an alternating waveform is given by the steady (dc) current which when flowing through a given circuit, for a given time produces the same heat produced by the alternating current when flowing the same circuit for the same time.

موضوعات المحاضرة

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EFFECTIVE (rms) VALUES

The effective value (or the rms value) of an alternating waveform is given by the steady (dc) current which when flowing through a given circuit, for a given time produces the same heat produced by the alternating current when flowing the same circuit for the same time.

Effective value of the sinusoidal is:

$$I_{\text{eff}} = 0.707 I_m$$

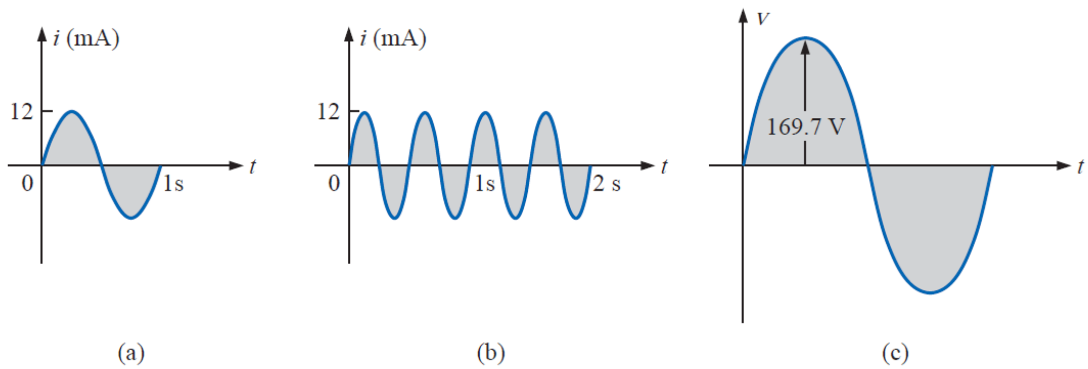
$$E_{\text{eff}} = 0.707 E_m$$

The effective value of any quantity plotted as a function of time can be found by using the following equation:

$$I_{\text{eff}} = \sqrt{\frac{\int_0^T i^2(t)\,dt}{T}}$$

$$I_{\text{eff}} = \sqrt{\frac{\text{area}\,(i^2(t))}{T}}$$

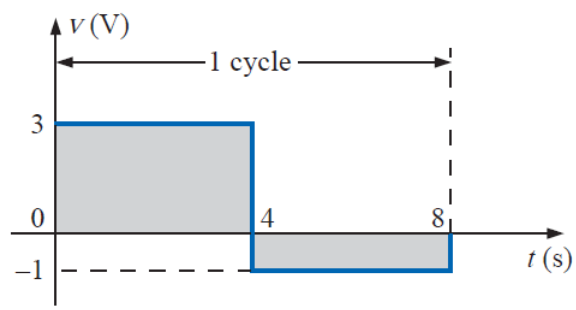
EXAMPLE: Find the rms values of the sinusoidal waveform



Solution:

For part (a), Irms = 0.707(12 * 10^{-3} A) = **8.484 mA.** For part (b), again Irms = **8.484 mA.** Note that frequency did not change the effective value in (b) above compared to (a). For part (c), Vrms = 0.707(169.73 V) ≅ **120 V.**

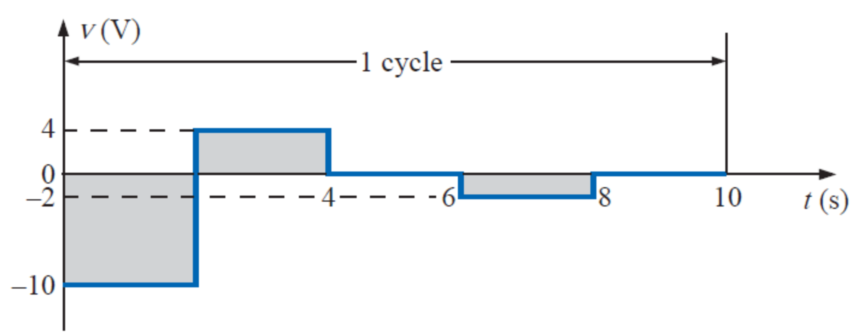
EXAMPLE: Find the effective or rms value of the waveform



Solution:

$$V_{rms} = \sqrt{\frac{(9)(4) + (1)(4)}{8}} = \sqrt{\frac{40}{8}} = \mathbf{2.236\ V}$$

EXAMPLE: Calculate the rms value of the voltage

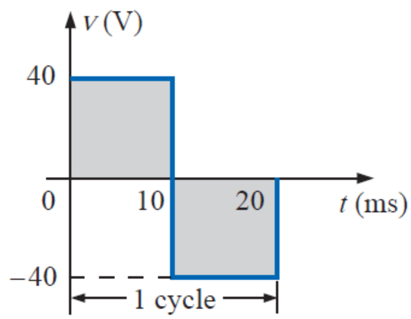


Solution:

$$V_{rms} = \sqrt{\frac{(100)(2) + (16)(2) + (4)(2)}{10}} = \sqrt{\frac{240}{10}}$$

$$= \mathbf{4.899\ V}$$

EXAMPLE: Determine the average and rms values of the square wave.



Solution:

$$V_{rms} = \sqrt{\frac{(1600)(10 \times 10^{-3}) + (1600)(10 \times 10^{-3})}{20 \times 10^{-3}}}$$

$$= \sqrt{\frac{32{,}000 \times 10^{-3}}{20 \times 10^{-3}}} = \sqrt{1600}$$

$$V_{rms} = \mathbf{40\ V}$$

الوحدة الثالثة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

RESPONSE OF BASIC *R, L,* AND *C* ELEMENTS TO A SINUSOIDAL VOLTAGE OR CURREN

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
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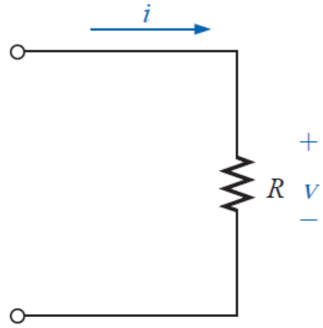
RESPONSE OF BASIC *R, L,* AND *C* ELEMENTS TO A SINUSOIDAL VOLTAGE OR CURREN

1) Resistor

For a purely resistive element, the voltage across and the current through the element are in phase, with their peak values related by Ohm's law.



For $v = V_m \sin \omega t$,

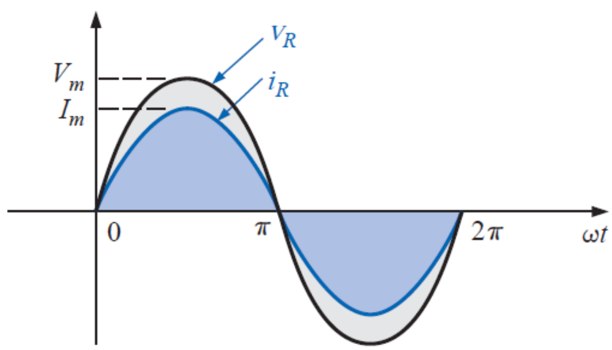
$$i = \frac{v}{R} = \frac{V_m \sin \omega t}{R} = \frac{V_m}{R} \sin \omega t = I_m \sin \omega t$$

$$\boxed{I_m = \frac{V_m}{R}}$$

Or

$$v = iR = (I_m \sin \omega t)R = I_m R \sin \omega t = V_m \sin \omega t$$

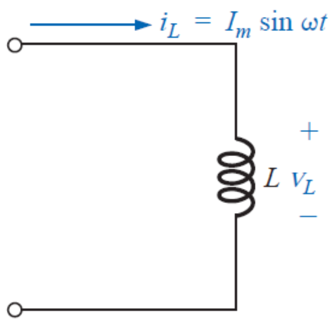
$$\boxed{V_m = I_m R}$$



2) **Inductor**

For an inductor, vL leads iL by 90°, or iL lags vL by 90°.

$$v_L = L\,\frac{di_L}{dt}$$



$$\frac{di_L}{dt} = \frac{d}{dt}(I_m \sin \omega t) = \omega I_m \cos \omega t$$

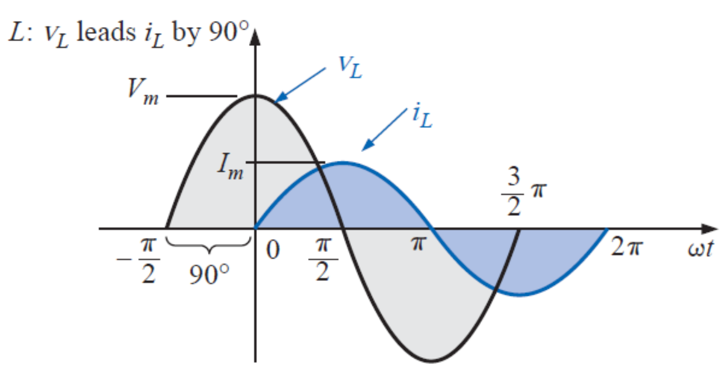
$$v_L = L\,\frac{di_L}{dt} = L(\omega I_m \cos \omega t) = \omega L I_m \cos \omega t$$

$$v_L = V_m \sin(\omega t + 90^\circ)$$

$$V_m = \omega L I_m$$

$$i_L = I_m \sin(\omega t \pm \theta)$$

$$v_L = \omega L I_m \sin(\omega t \pm \theta + 90^\circ)$$



The quantity ωL, called the **reactance** (from the word *reaction*) of an inductor, is symbolically represented by *XL* and is measured in ohms; that is,

$$X_L = \omega L \qquad \text{(ohms, } \Omega)$$

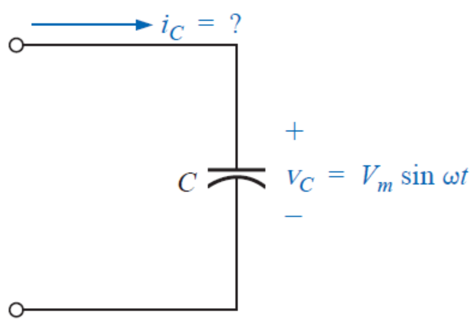
$$X_L = \frac{V_m}{I_m} \qquad \text{(ohms, } \Omega)$$

$$X_L = \omega L = 2\pi f L = 2\pi L f$$

3) **Capacitor**

For a particular capacitance, the greater the rate of change of voltage across the capacitor, the greater the capacitive current.

$$i_C = C\frac{dv_C}{dt}$$



$$\frac{dv_C}{dt} = \frac{d}{dt}(V_m \sin \omega t) = \omega V_m \cos \omega t$$

$$i_C = C\frac{dv_C}{dt} = C(\omega V_m \cos \omega t) = \omega C V_m \cos \omega t$$

$$i_C = I_m \sin(\omega t + 90°)$$

$$I_m = \omega C V_m$$

For a capacitor, iC leads vC by 90°, or vC lags iC by 90°.

$$v_C = V_m \sin(\omega t \pm \theta)$$

$$i_C = \omega C V_m \sin(\omega t \pm \theta + 90°)$$

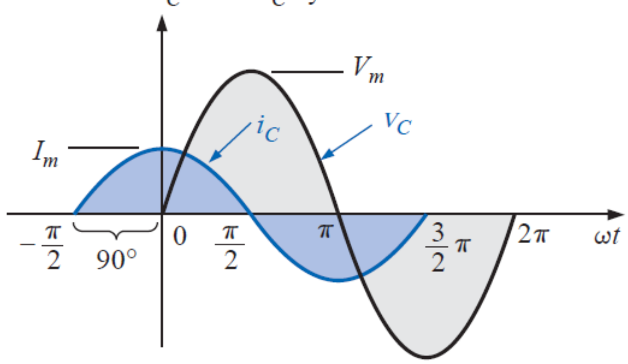
The quantity $1/\omega C$, called the **reactance** of a capacitor, is symbolically represented by XC and is measured in ohms; that is,

$$X_C = \frac{1}{\omega C} \quad \text{(ohms, } \Omega\text{)}$$

$$X_C = \frac{V_m}{I_m} \quad \text{(ohms, } \Omega\text{)}$$

$$X_C = \frac{1}{2\pi f C}$$

C: i_C leads v_C by 90°.

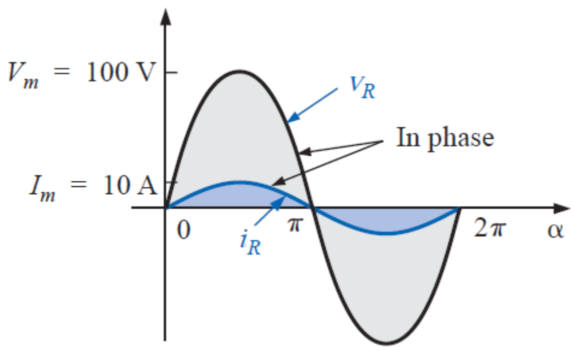


EXAMPLE: The voltage across a resistor is indicated. Find the sinusoidal expression for the current if the resistor is 10Ω. Sketch the curves for v and i.
a) v = 100 sin 377t
b) v = 25 sin(377t + 60°)

Solutions:
a)

$$I_m = \frac{V_m}{R} = \frac{100 \text{ V}}{10 \ \Omega} = 10 \text{ A}$$

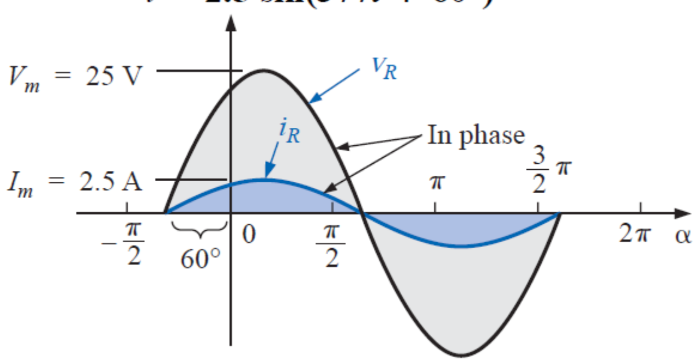
(v and i are in phase) $i = \mathbf{10 \sin 377}t$



b)

$$I_m = \frac{V_m}{R} = \frac{25 \text{ V}}{10\ \Omega} = 2.5 \text{ A}$$

(v and i are in phase) $i = \mathbf{2.5 \sin(377}t \mathbf{+ 60°)}$



EXAMPLE: The current through a 0.1-H coil is provided. Find the sinusoidal expression for the voltage across the coil. Sketch the v and i curves.

a) i = 10 sin 377t

b) i = 7 sin(377t _ 70°)

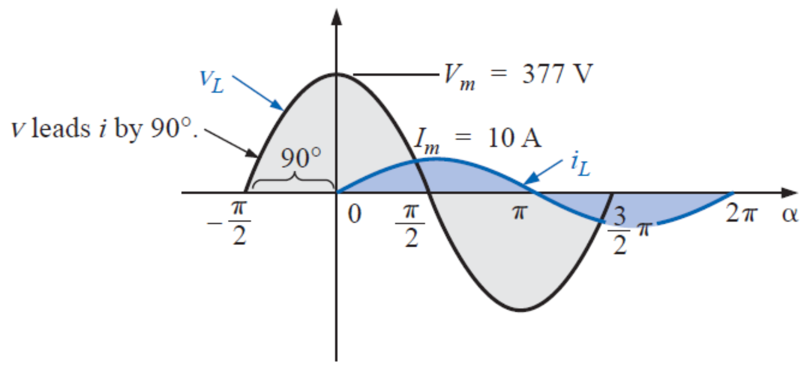
Solutions:

a)

$$X_L = \omega L = (377 \text{ rad/s})(0.1 \text{ H}) = 37.7\ \Omega$$

$$V_m = I_m X_L = (10 \text{ A})(37.7\ \Omega) = 377 \text{ V}$$

v leads i by 90° $v = \mathbf{377 \sin(377}t \mathbf{+ 90°)}$



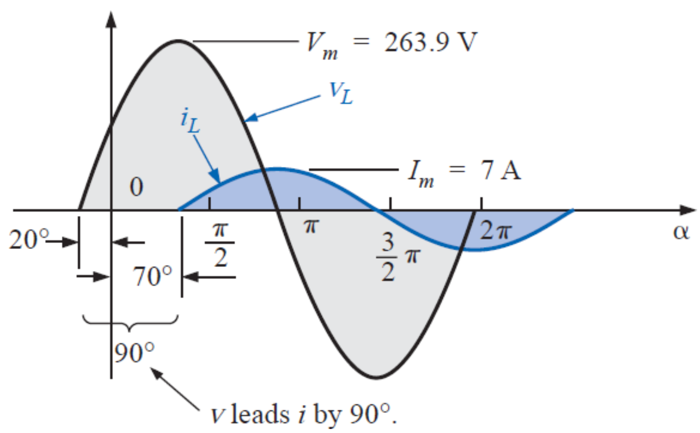
b)

$$V_m = I_m X_L = (7\ \text{A})(37.7\ \Omega) = 263.9\ \text{V}$$

v leads i by 90°

$$v = 263.9 \sin(377t - 70° + 90°)$$

$$v = \mathbf{263.9 \sin(377}t \mathbf{+ 20°)}$$



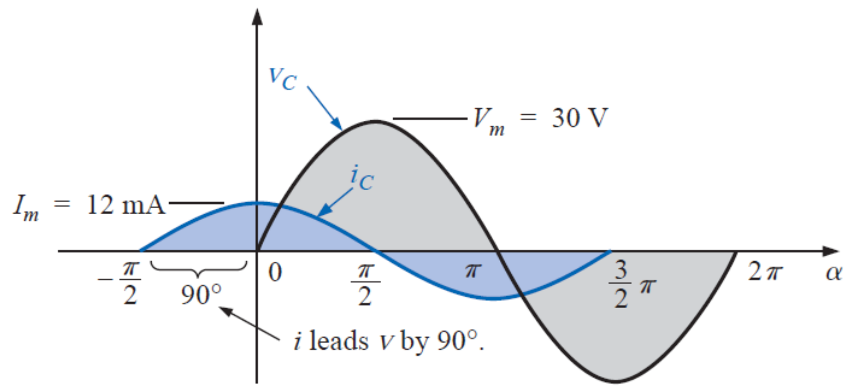
EXAMPLE: The voltage across a 1-μF capacitor is provided below. What is the sinusoidal expression for the current? Sketch the v and i curves.
v =30 sin 400t

Solutions:

$$X_C = \frac{1}{\omega C} = \frac{1}{(400 \text{ rad/s})(1 \times 10^{-6} \text{ F})} = \frac{10^6 \ \Omega}{400} = 2500 \ \Omega$$

$$I_m = \frac{V_m}{X_C} = \frac{30 \text{ V}}{2500 \ \Omega} = 0.0120 \text{ A} = 12 \text{ mA}$$

i leads v by 90° $\quad i = \mathbf{12 \times 10^{-3} \sin(400t + 90°)}$



EXAMPLE: At what frequency will the reactance of a 200-mH inductor match the resistance level of a 5-kΩ resistor?

Solutions:

$$5000 \ \Omega = X_L = 2\pi f L = 2\pi L f$$
$$= 2\pi(200 \times 10^{-3} \text{ H}) f = 1.257 f$$

$$f = \frac{5000 \text{ Hz}}{1.257} \cong \mathbf{3.98 \text{ kHz}}$$

الوحدة الرابعة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

A **complex number** represents a point in a two-dimensional plane located with reference to two distinct axes. This point can also determine a radius vector drawn from the origin to the point.

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
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COMPLEX NUMBERS

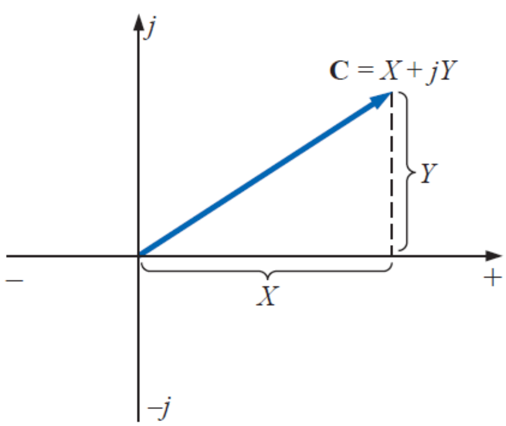
A **complex number** represents a point in a two-dimensional plane located with reference to two distinct axes. This point can also determine a radius vector drawn from the origin to the point. The horizontal axis is called the *real* axis, while the vertical axis is called the *imaginary* axis.

Two forms are used to represent a complex number: **rectangular** and **polar**.

1) RECTANGULAR FORM

The format for the **rectangular form** is

$$\mathbf{C} = X + jY$$



EXAMPLE: Sketch the following complex numbers in the complex plane:

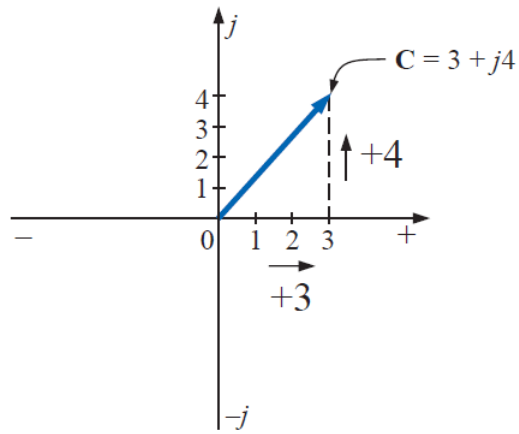
a) $\mathbf{C} = 3 + j\,4$

b) $\mathbf{C} = 0 - j\,6$

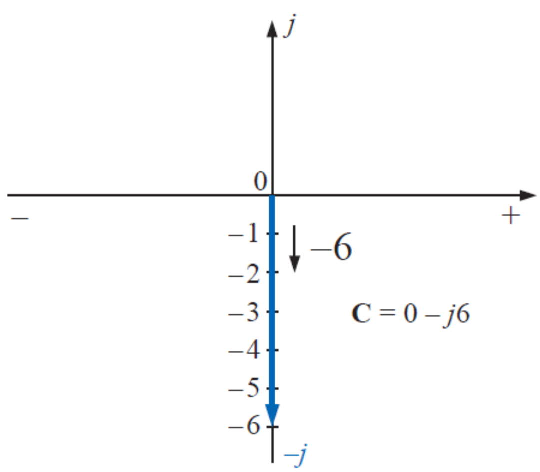
c) $\mathbf{C} = -10 - j20$

Solutions:

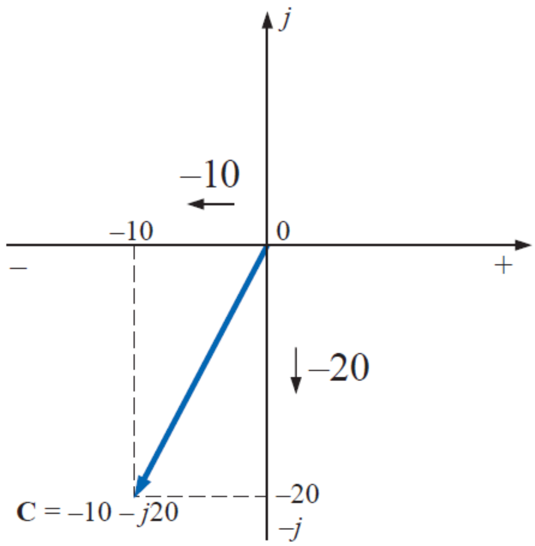
a)



b)



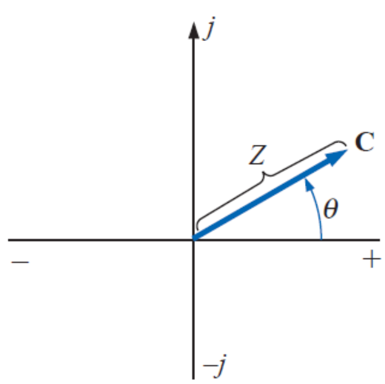
c)



2) POLAR FORM

The format for the **polar form** is

$$\mathbf{C} = Z \angle \theta$$



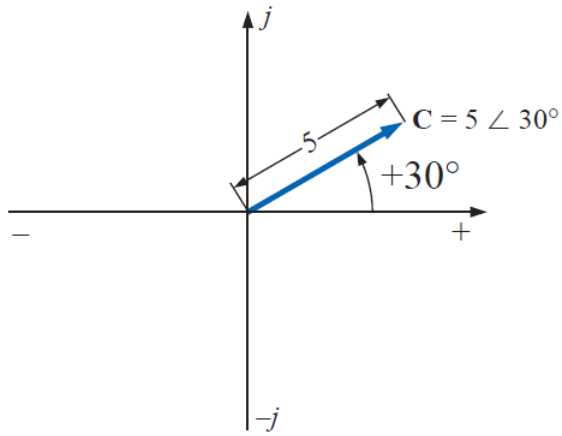
$$-\mathbf{C} = -Z \angle \theta = Z \angle \theta \pm 180°$$

EXAMPLE: Sketch the following complex numbers in the complex plane:

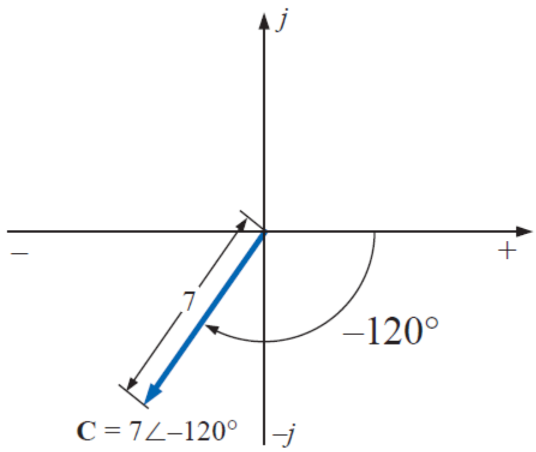
a) $\mathbf{C} = 5 \angle 30°$
b) $\mathbf{C} = 7 \angle -120°$
c) $\mathbf{C} = -4.2 \angle 60°$

Solutions:

a)

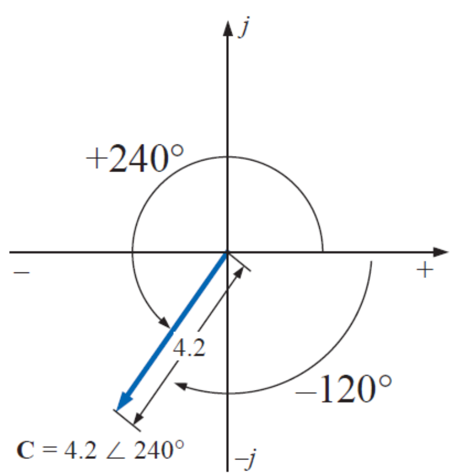


b)

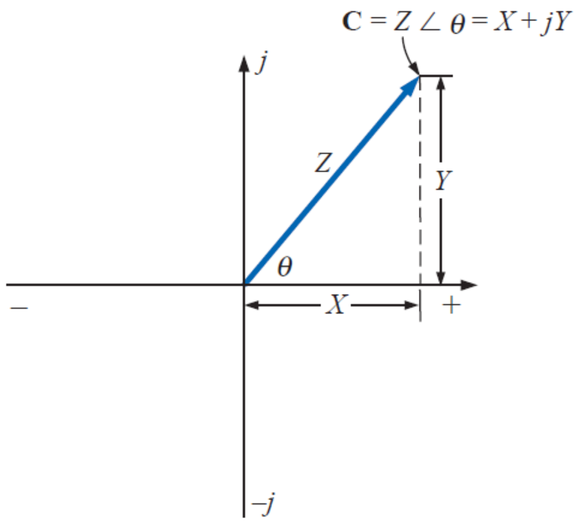


c)

$$C = -4.2 \angle 60^\circ = 4.2 \angle 60^\circ + 180^\circ$$
$$= 4.2 \angle +240^\circ$$



CONVERSION BETWEEN FORMS



1) **Rectangular to Polar**

$$Z = \sqrt{X^2 + Y^2}$$

$$\theta = \tan^{-1}\frac{Y}{X}$$

2) **Polar to Rectangular**

$$X = Z\cos\theta$$

$$Y = Z\sin\theta$$

EXAMPLE: Convert the following from rectangular to polar form:

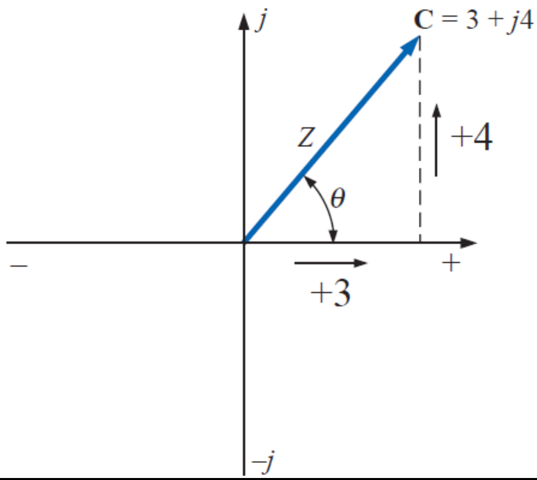
$\mathbf{C} = 3 + j\,4$

Solutions:

$$Z = \sqrt{(3)^2 + (4)^2} = \sqrt{25} = 5$$

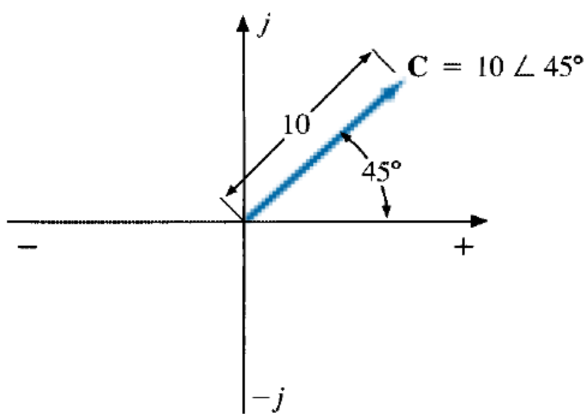
$$\theta = \tan^{-1}\left(\frac{4}{3}\right) = 53.13°$$

$$\mathbf{C = 5 \angle 53.13°}$$



EXAMPLE: Convert the following from polar to rectangular form:

$$\mathbf{C} = 10 \angle 45°$$



Solutions:

$$X = 10 \cos 45° = (10)(0.707) = 7.07$$

$$Y = 10 \sin 45° = (10)(0.707) = 7.07$$

$$\mathbf{C = 7.07 + \mathit{j}7.07}$$

الوحدة الخامسة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Complex numbers lend themselves readily to the basic mathematical operations of addition, subtraction, multiplication, and division.

موضوعات المحاضرة الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
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MATHEMATICAL OPERATIONS WITH COMPLEX NUMBERS

Complex numbers lend themselves readily to the basic mathematical operations of addition, subtraction, multiplication, and division. A few basic rules and definitions must be understood before considering these operations.

$$j = \sqrt{-1}$$

$$j^2 = -1$$

$$\frac{1}{j} = -j$$

1) Addition

$$\mathbf{C}_1 = \pm X_1 \pm j\,Y_1 \quad \text{and} \quad \mathbf{C}_2 = \pm X_2 \pm j\,Y_2$$

$$\mathbf{C}_1 + \mathbf{C}_2 = (\pm X_1 \pm X_2) + j\,(\pm Y_1 \pm Y_2)$$

EXAMPLE:

a. Add $\mathbf{C}_1 = 2 + j4$ and $\mathbf{C}_2 = 3 + j1$.
b. Add $\mathbf{C}_1 = 3 + j6$ and $\mathbf{C}_2 = -6 + j3$.

Solutions:

a)
$$\mathbf{C}_1 + \mathbf{C}_2 = (2 + 3) + j(4 + 1) = \mathbf{5 + j5}$$
b)
$$\mathbf{C}_1 + \mathbf{C}_2 = (3 - 6) + j(6 + 3) = \mathbf{-3 + j9}$$

2) Subtraction

$$\mathbf{C}_1 = \pm X_1 \pm j\,Y_1 \quad \text{and} \quad \mathbf{C}_2 = \pm X_2 \pm j\,Y_2$$

$$\mathbf{C}_1 - \mathbf{C}_2 = [\pm X_2 - (\pm X_2)] + j[\pm Y_1 - (\pm Y_2)]$$

EXAMPLE:

a. Subtract $\mathbf{C}_2 = 1 + j4$ from $\mathbf{C}_1 = 4 + j6$.
b. Subtract $\mathbf{C}_2 = -2 + j5$ from $\mathbf{C}_1 = +3 + j3$.

Solutions:

a)
$$\mathbf{C}_1 - \mathbf{C}_2 = (4 - 1) + j(6 - 4) = \mathbf{3 + j2}$$

b)
$$\mathbf{C}_1 - \mathbf{C}_2 = [3 - (-2)] + j(3 - 5) = \mathbf{5 - j2}$$

---

3) Multiplication

$$\mathbf{C}_1 = X_1 + jY_1 \quad \text{and} \quad \mathbf{C}_2 = X_2 + jY_2$$

$$\mathbf{C}_1 \cdot \mathbf{C}_2 = (X_1X_2 - Y_1Y_2) + j(Y_1X_2 + X_1Y_2)$$

$$\mathbf{C}_1 = Z_1 \angle\theta_1 \quad \text{and} \quad \mathbf{C}_2 = Z_2 \angle\theta_2$$

$$\mathbf{C}_1 \cdot \mathbf{C}_2 = Z_1Z_2 \angle\theta_1 + \theta_2$$

EXAMPLE:

a. Find $\mathbf{C}_1 \cdot \mathbf{C}_2$ if

$$\mathbf{C}_1 = 5 \angle 20^\circ \quad \text{and} \quad \mathbf{C}_2 = 10 \angle 30^\circ$$

b. Find $\mathbf{C}_1 \cdot \mathbf{C}_2$ if

$$\mathbf{C}_1 = 2 \angle -40^\circ \quad \text{and} \quad \mathbf{C}_2 = 7 \angle +120^\circ$$

Solutions:

a. $\mathbf{C}_1 \cdot \mathbf{C}_2 = (5 \angle 20^\circ)(10 \angle 30^\circ) = (5)(10) \angle 20^\circ + 30^\circ = \mathbf{50 \angle 50^\circ}$

b. $\mathbf{C}_1 \cdot \mathbf{C}_2 = (2 \angle -40^\circ)(7 \angle +120^\circ) = (2)(7) \angle -40^\circ + 120^\circ$
$= \mathbf{14 \angle +80^\circ}$

---

4) Division

$$\mathbf{C}_1 = Z_1 \angle\theta_1 \quad \text{and} \quad \mathbf{C}_2 = Z_2 \angle\theta_2$$

$$\frac{\mathbf{C}_1}{\mathbf{C}_2} = \frac{Z_1}{Z_2} \angle\theta_1 - \theta_2$$

EXAMPLE:

a. Find $\mathbf{C}_1/\mathbf{C}_2$ if $\mathbf{C}_1 = 15\angle 10°$ and $\mathbf{C}_2 = 2\angle 7°$.
b. Find $\mathbf{C}_1/\mathbf{C}_2$ if $\mathbf{C}_1 = 8\angle 120°$ and $\mathbf{C}_2 = 16\angle -50°$.

Solutions:

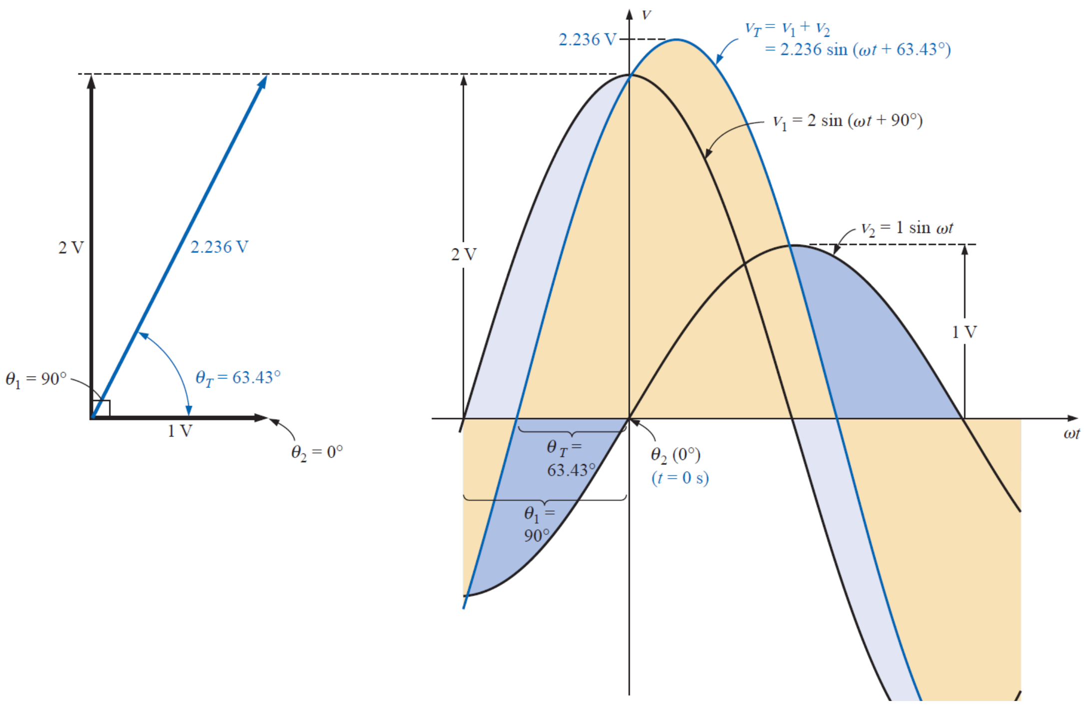
a. $$\frac{\mathbf{C}_1}{\mathbf{C}_2} = \frac{15\angle 10°}{2\angle 7°} = \frac{15}{2}\,\underline{/10° - 7°} = \mathbf{7.5\angle 3°}$$

b. $$\frac{\mathbf{C}_1}{\mathbf{C}_2} = \frac{8\angle 120°}{16\angle -50°} = \frac{8}{16}\,\underline{/120° - (-50°)} = \mathbf{0.5\angle 170°}$$

$$\frac{1}{Z\angle\theta} = \frac{1}{Z}\angle -\theta$$

PHASORS

The *radius vector*, having a *constant magnitude* (length) with *one end fixed at the origin*, is called a **phasor** when applied to electric circuits.



$$e = Vm\sin(\omega t + \theta) \quad \Rightarrow \quad e = \frac{Vm}{\sqrt{2}}\angle\theta = 0.707Vm\angle\theta$$

EXAMPLE: Convert the following from the time to the phasor domain:

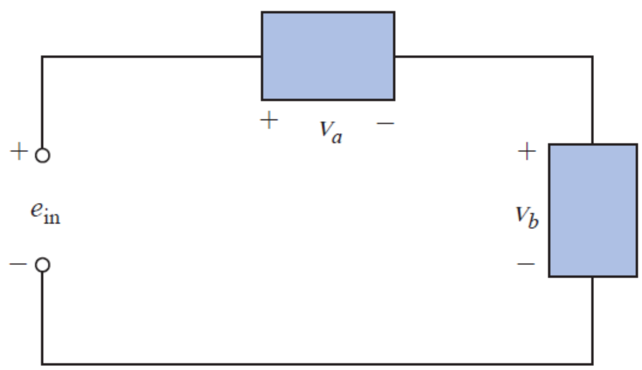
Time Domain	Phasor Domain
a. $\sqrt{2}(50)\sin\omega t$	$\mathbf{50\angle 0°}$
b. $69.6\sin(\omega t + 72°)$	$(0.707)(69.6)\angle 72° = \mathbf{49.21\angle 72°}$
c. $45\cos\omega t$	$(0.707)(45)\angle 90° = \mathbf{31.82\angle 90°}$

EXAMPLE: Write the sinusoidal expression for the following phasors if the frequency is 60 Hz:

Phasor Domain	Time Domain
a. $\mathbf{I} = 10 \angle 30°$	$i = \sqrt{2}(10)\sin(2\pi 60t + 30°)$
	and $i = \mathbf{14.14 \sin(377t + 30°)}$
b. $\mathbf{V} = 115 \angle -70°$	$v = \sqrt{2}(115)\sin(377t - 70°)$
	and $v = \mathbf{162.6 \sin(377t - 70°)}$

EXAMPLE: Find the input voltage of the circuit

$$\left.\begin{aligned} v_a &= 50\sin(377t + 30°) \\ v_b &= 30\sin(377t + 60°) \end{aligned}\right\} f = 60\text{ Hz}$$



Solutions:

$e_{in} = v_a + v_b$

Converting from the time to the phasor domain yields

$$v_a = 50\sin(377t + 30°) \Rightarrow \mathbf{V}_a = 35.35\text{ V} \angle 30°$$
$$v_b = 30\sin(377t + 60°) \Rightarrow \mathbf{V}_b = 21.21\text{ V} \angle 60°$$

Converting from polar to rectangular form for addition yields

$$\mathbf{V}_a = 35.35\text{ V} \angle 30° = 30.61\text{ V} + j\,17.68\text{ V}$$
$$\mathbf{V}_b = 21.21\text{ V} \angle 60° = 10.61\text{ V} + j\,18.37\text{ V}$$

$$\begin{aligned}\mathbf{E}_{in} = \mathbf{V}_a + \mathbf{V}_b &= (30.61\text{ V} + j\,17.68\text{ V}) + (10.61\text{ V} + j\,18.37\text{ V}) \\ &= 41.22\text{ V} + j\,36.05\text{ V}\end{aligned}$$

$$\mathbf{E}_{in} = 41.22\text{ V} + j\,36.05\text{ V} = 54.76\text{ V} \angle 41.17°$$

$$\mathbf{E}_{\text{in}} = 54.76\text{ V}\ \angle 41.17° \Rightarrow e_{\text{in}} = \sqrt{2}(54.76)\sin(377t + 41.17°)$$

$$e_{\text{in}} = \mathbf{77.43\ sin(377}\boldsymbol{t}\mathbf{ + 41.17°)}$$

الوحدة السادس والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

IMPEDANCE AND THE PHASOR DIAGRAM

موضوعات المحاضرة

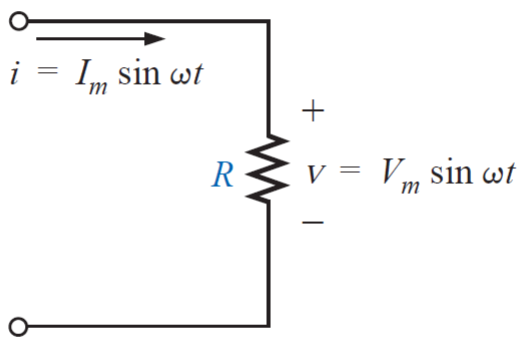
Examples

الأساليب و الأنشطة و الوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
26	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

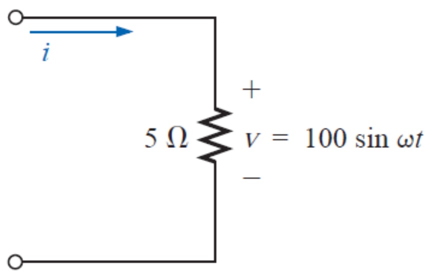
IMPEDANCE AND THE PHASOR DIAGRAM

1) Resistive Elements



$$\mathbf{Z}_R = R \angle 0^\circ$$

EXAMPLE: find the current i for the circuit. Sketch the waveforms of v and i.

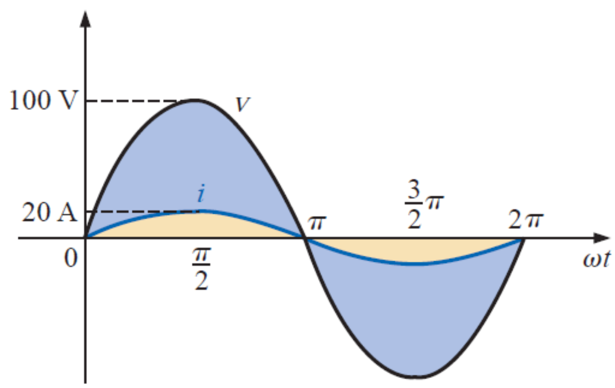


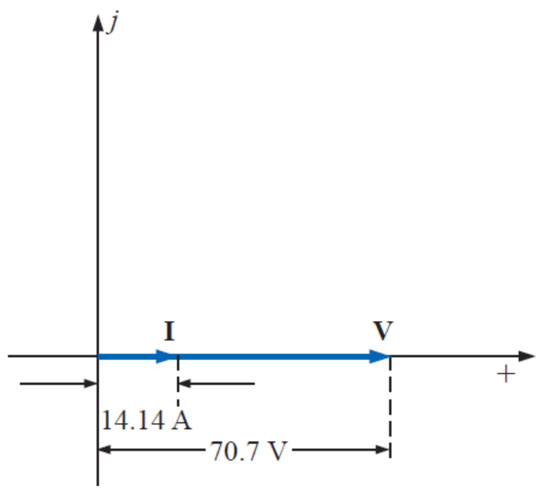
Solutions:

$v = 100 \sin \omega t \Rightarrow$ phasor form $\mathbf{V} = 70.71 \text{ V} \angle 0^\circ$

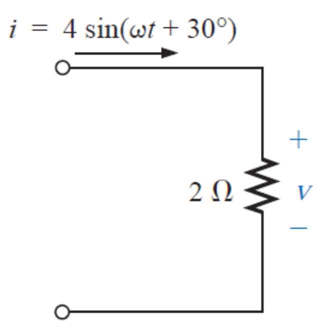
$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}_R} = \frac{V \angle \theta}{R \angle 0^\circ} = \frac{70.71 \text{ V} \angle 0^\circ}{5\ \Omega \angle 0^\circ} = 14.14 \text{ A} \angle 0^\circ$$

$$i = \sqrt{2}(14.14) \sin \omega t = \mathbf{20 \sin \omega t}$$





EXAMPLE: find the voltage v for the circuit. Sketch the waveforms of v and i.

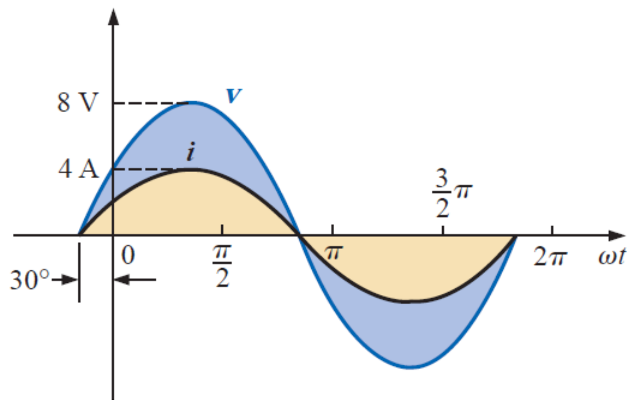


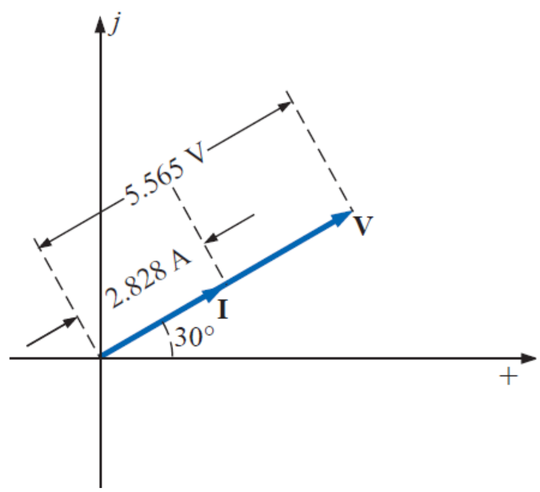
Solutions:

$$i = 4\sin(\omega t + 30°) \Rightarrow \text{phasor form } \mathbf{I} = 2.828\text{ A}\angle 30°$$

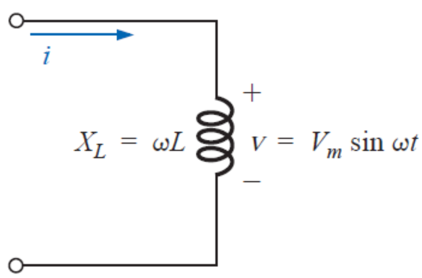
$$\mathbf{V} = \mathbf{I}\mathbf{Z}_R = (I\angle\theta)(R\angle 0°) = (2.828\text{ A}\angle 30°)(2\ \Omega\angle 0°) = 5.656\text{ V}\angle 30°$$

$$v = \sqrt{2}(5.656)\sin(\omega t + 30°) = \mathbf{8.0\sin(\omega t + 30°)}$$



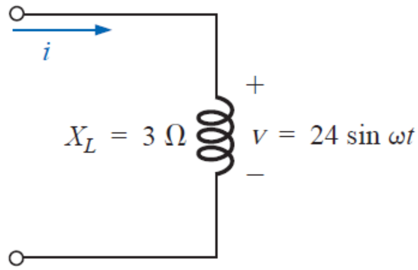


2) Inductive Reactance



$$\mathbf{Z}_L = X_L \angle 90^\circ$$

EXAMPLE: find the current i for the circuit. Sketch the v and i curves.

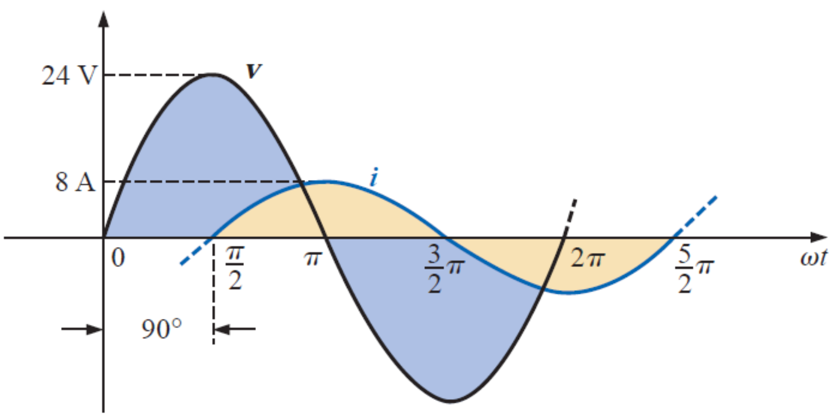


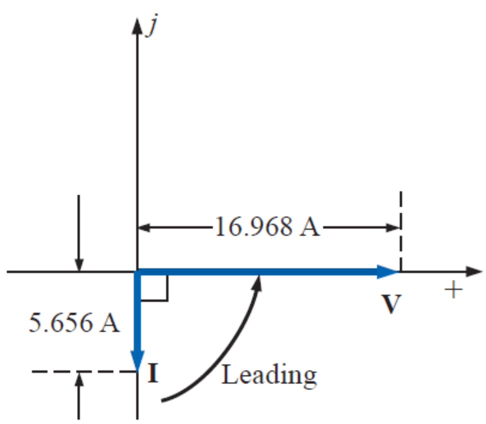
Solutions:

$$v = 24 \sin \omega t \Rightarrow \text{phasor form } \mathbf{V} = 16.968 \text{ V} \angle 0°$$

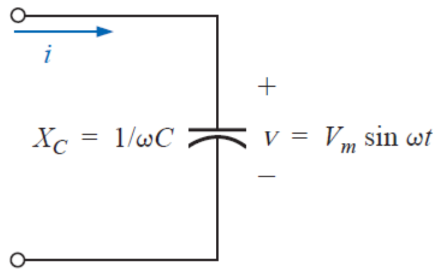
$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}_L} = \frac{V \angle \theta}{X_L \angle 90°} = \frac{16.968 \text{ V} \angle 0°}{3\ \Omega \angle 90°} = 5.656 \text{ A} \angle -90°$$

$$i = \sqrt{2}(5.656) \sin(\omega t - 90°) = \mathbf{8.0 \sin(\omega t - 90°)}$$



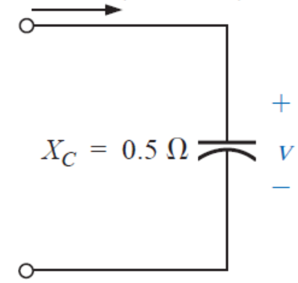


3) Capacitive Reactance



$$\mathbf{Z}_C = X_C \angle -90°$$

EXAMPLE: find the voltage v for the circuit. Sketch the v and i curves.

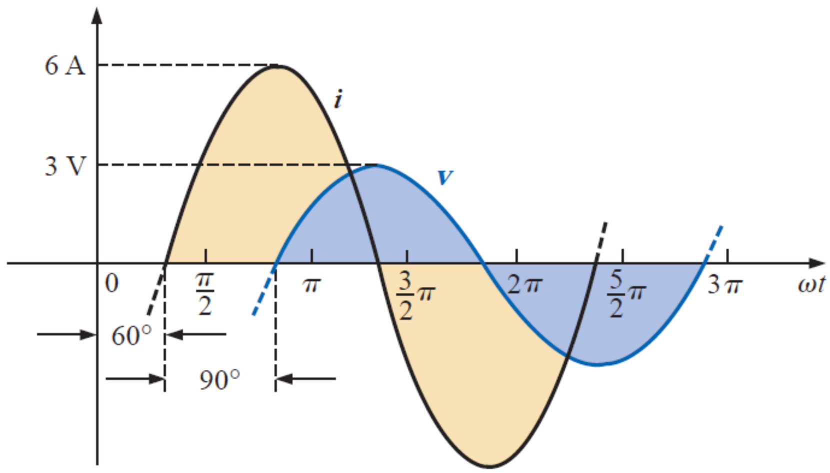


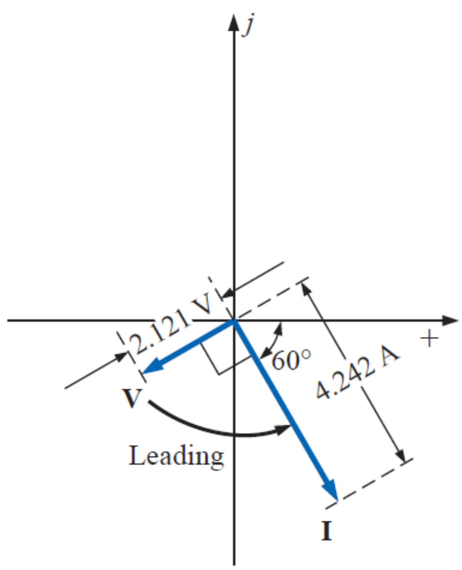
Solutions:

$i = 6 \sin(\omega t - 60°) \Rightarrow$ phasor notation $\mathbf{I} = 4.242 \text{ A} \angle -60°$

$$\mathbf{V} = \mathbf{I}\mathbf{Z}_C = (I \angle \theta)(X_C \angle -90°) = (4.242 \text{ A} \angle -60°)(0.5\ \Omega \angle -90°)$$
$$= 2.121 \text{ V} \angle -150°$$

and $\quad v = \sqrt{2}(2.121) \sin(\omega t - 150°) = \mathbf{3.0 \sin(\omega t - 150°)}$


6 A
3 V
i
v
0
$\frac{\pi}{2}$
π
$\frac{3}{2}\pi$
2π
$\frac{5}{2}\pi$
3π
ωt
60°
90°


j
2.121 V
60°
4.242 A
+
V
Leading
I

الوحدة السابعة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

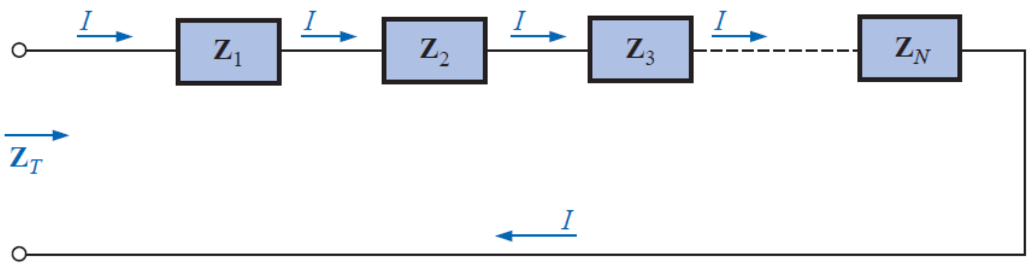
SERIES CONFIGURATION

موضوعات المحاضرة

الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
27	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

SERIES CONFIGURATION

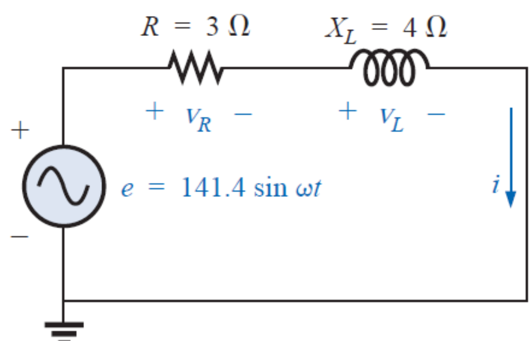


$$Z_T = Z_1 + Z_2 + Z_3 + \cdots + Z_N$$

---

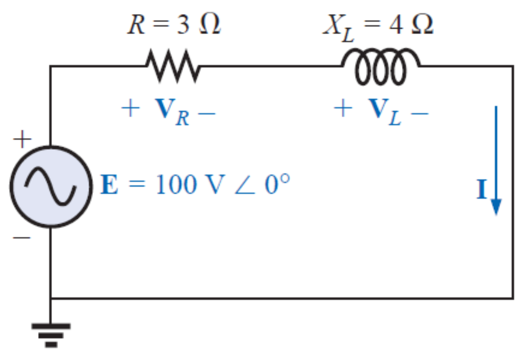
1) R-L

EXAMPLE: Determine the input impedance to the series network and find i , Vr,VL. Draw the impedance diagram.



Solutions:

$$e = 141.4 \sin \omega t \Rightarrow \mathbf{E} = 100 \text{ V} \angle 0^\circ$$



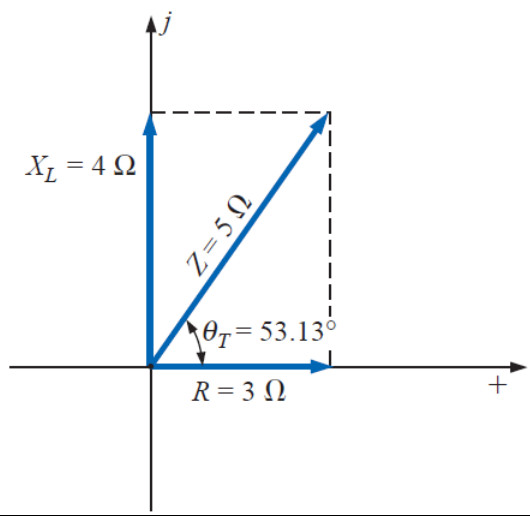
$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 = 3\ \Omega\ \angle 0° + 4\ \Omega\ \angle 90° = 3\ \Omega + j4\ \Omega$$

$$\mathbf{Z}_T = \mathbf{5\ \Omega\ \angle 53.13°}$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{100\text{ V}\ \angle 0°}{5\ \Omega\ \angle 53.13°} = \mathbf{20\ A\ \angle -53.13°}$$

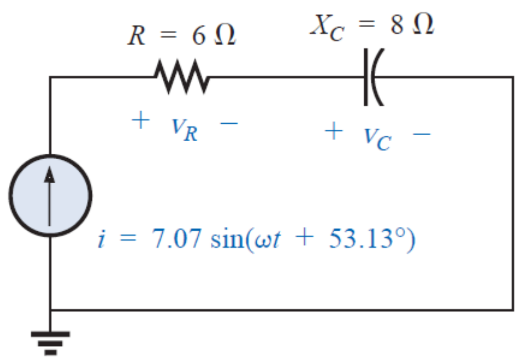
$$\mathbf{V}_R = \mathbf{IZ}_R = (20\text{ A}\ \angle -53.13°)(3\ \Omega\ \angle 0°) = \mathbf{60\ V \angle -53.13°}$$

$$\mathbf{V}_L = \mathbf{IZ}_L = (20\text{ A}\ \angle -53.13°)(4\ \Omega\ \angle 90°) = \mathbf{80\ V\ \angle 36.87°}$$



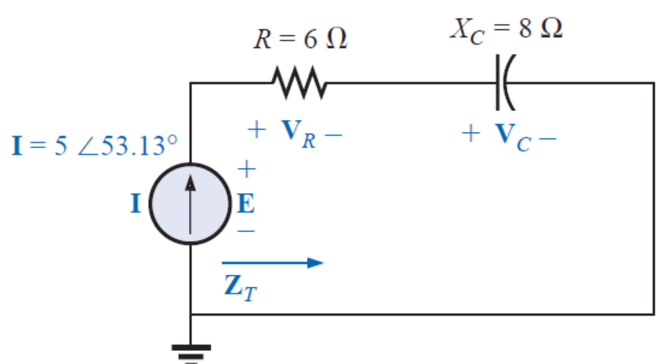
2) R-C

EXAMPLE: Determine the input impedance to the series network and find E , Vr,Vc. Draw the impedance diagram.



Solutions:

$i = 7.07\sin(\omega t + 53.13°) \Rightarrow \mathbf{I} = 5\text{ A}\angle 53.13°$



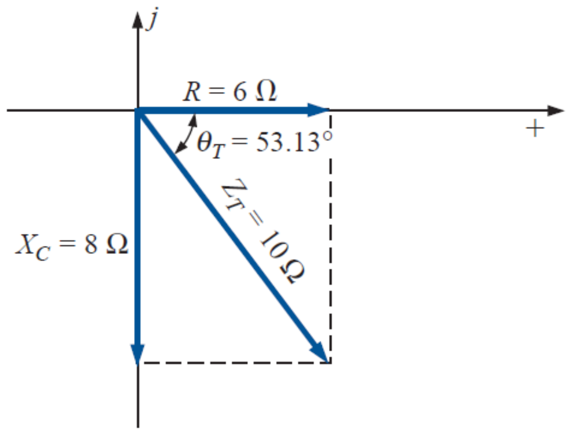
$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 = 6\ \Omega\angle 0° + 8\ \Omega\angle -90° = 6\ \Omega - j8\ \Omega$$

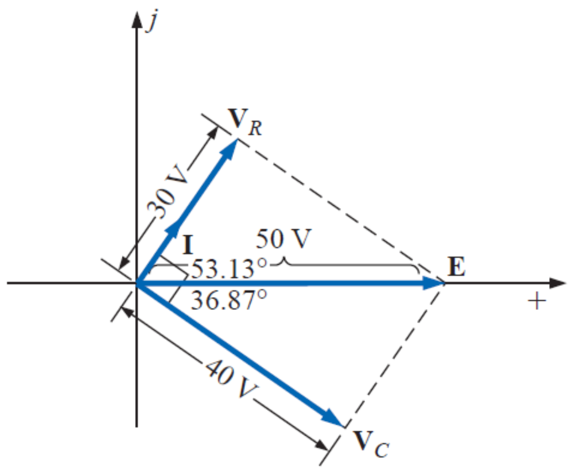
$$\mathbf{Z}_T = \mathbf{10\ \Omega\angle -53.13°}$$

$$\mathbf{E} = \mathbf{I}\mathbf{Z}_T = (5\text{ A}\angle 53.13°)(10\ \Omega\angle -53.13°) = \mathbf{50\ V\angle 0°}$$

$$\mathbf{V}_R = \mathbf{I}\mathbf{Z}_R = (I\angle\theta)(R\angle 0°) = (5\text{ A}\angle 53.13°)(6\ \Omega\angle 0°) = \mathbf{30\ V\angle 53.13°}$$

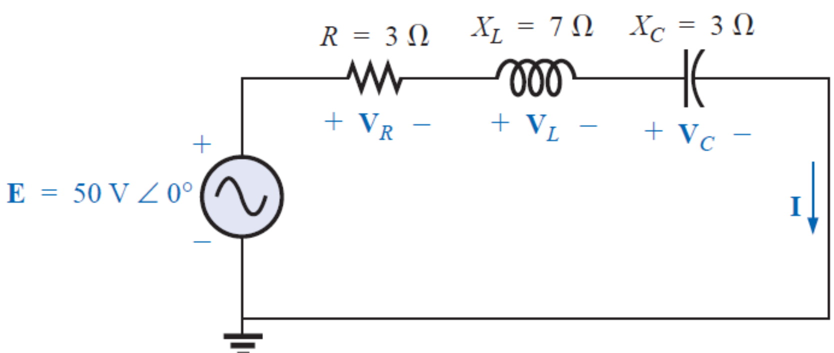
$$\mathbf{V}_C = \mathbf{I}\mathbf{Z}_C = (I\angle\theta)(X_C\angle -90°) = (5\text{ A}\angle 53.13°)(8\ \Omega\angle -90°) = \mathbf{40\ V\angle -36.87°}$$


j
R = 6 Ω
θT = 53.13°
ZT = 10 Ω
XC = 8 Ω
+


j
VR
30 V
I
50 V
53.13°
36.87°
E
+
40 V
VC

3) R-L-C

EXAMPLE: Determine the input impedance to the series network and find i , Vr, Vc ,VL. Draw the impedance diagram.



Solutions:

$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3 = R\angle 0^\circ + X_L\angle 90^\circ + X_C\angle -90^\circ$$
$$= 3\ \Omega + j\,7\ \Omega - j\,3\ \Omega = 3\ \Omega + j\,4\ \Omega$$

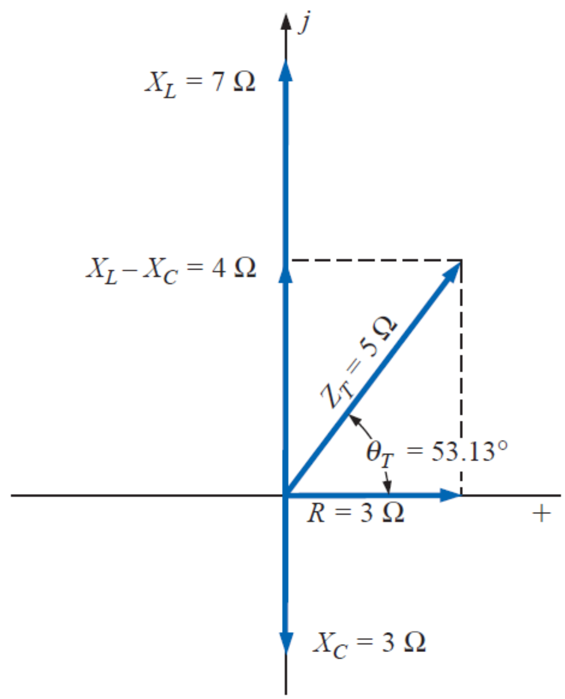
$$\mathbf{Z}_T = \mathbf{5\ \Omega\ \angle 53.13^\circ}$$

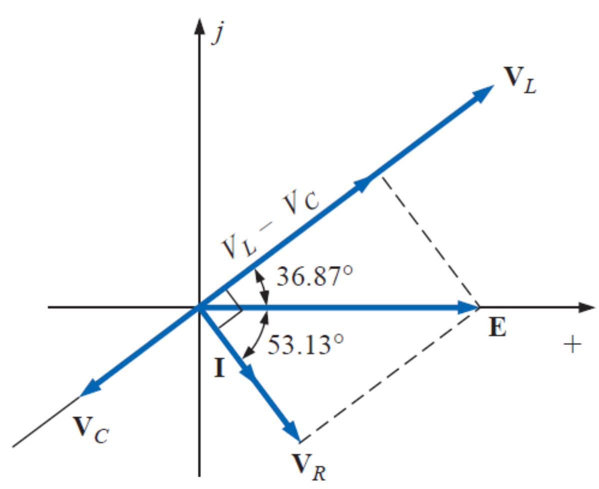
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\text{ V}\angle 0^\circ}{5\ \Omega\angle 53.13^\circ} = \mathbf{10\ A\ \angle -53.13^\circ}$$

$$\mathbf{V}_R = \mathbf{I}\mathbf{Z}_R = (I \angle \theta)(R \angle 0°) = (10 \text{ A} \angle -53.13°)(3\ \Omega \angle 0°) = \mathbf{30\ V \angle -53.13°}$$

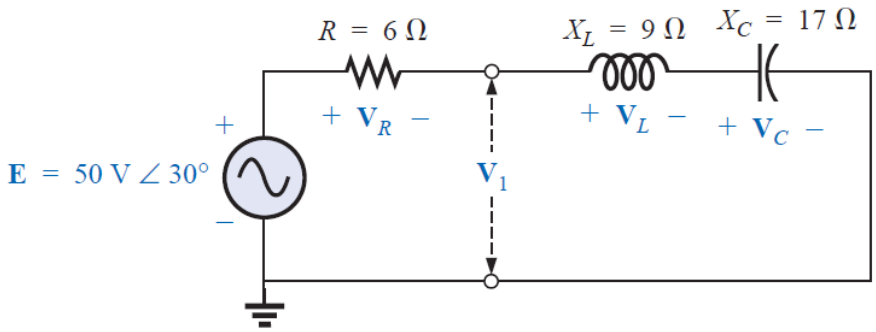
$$\mathbf{V}_L = \mathbf{I}\mathbf{Z}_L = (I \angle \theta)(X_L \angle 90°) = (10 \text{ A} \angle -53.13°)(7\ \Omega \angle 90°) = \mathbf{70\ V \angle 36.87°}$$

$$\mathbf{V}_C = \mathbf{I}\mathbf{Z}_C = (I \angle \theta)(X_C \angle -90°) = (10 \text{ A} \angle -53.13°)(3\ \Omega \angle -90°) = \mathbf{30\ V \angle -143.13°}$$





EXAMPLE: Using the voltage divider rule, find the unknown voltages **VR**, **VL**, **VC**, and **V1** for the circuit.



Solutions:

$$\mathbf{V}_R = \frac{\mathbf{Z}_R\mathbf{E}}{\mathbf{Z}_R + \mathbf{Z}_L + \mathbf{Z}_C} = \frac{(6\ \Omega\ \angle 0°)(50\ \text{V}\ \angle 30°)}{6\ \Omega\ \angle 0° + 9\ \Omega\ \angle 90° + 17\ \Omega\ \angle -90°}$$

$$= \frac{300\ \angle 30°}{6 + j\,9 - j\,17} = \frac{300\ \angle 30°}{6 - j\,8}$$

$$= \frac{300\ \angle 30°}{10\ \angle -53.13°} = \mathbf{30\ V\ \angle 83.13°}$$

$$\mathbf{V}_L = \frac{\mathbf{Z}_L\mathbf{E}}{\mathbf{Z}_T} = \frac{(9\ \Omega\ \angle 90°)(50\ \text{V}\ \angle 30°)}{10\ \Omega\ \angle -53.13°} = \frac{450\ \text{V}\angle 120°}{10\ \angle -53.13°}$$

$$= \mathbf{45\ V\ \angle 173.13°}$$

$$\mathbf{V}_C = \frac{\mathbf{Z}_C\mathbf{E}}{\mathbf{Z}_T} = \frac{(17\ \Omega\ \angle -90°)(50\ \text{V}\ \angle 30°)}{10\ \Omega\ \angle -53.13°} = \frac{850\ \text{V}\angle -60°}{10\ \angle -53°}$$

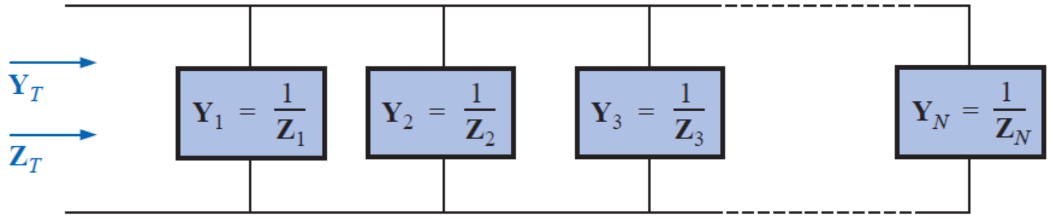
$$= \mathbf{85\ V\ \angle -6.87°}$$

$$\mathbf{V}_1 = \frac{(\mathbf{Z}_L + \mathbf{Z}_C)\mathbf{E}}{\mathbf{Z}_T} = \frac{(9\ \Omega\ \angle 90° + 17\ \Omega\ \angle -90°)(50\ \text{V}\ \angle 30°)}{10\ \Omega\ \angle -53.13°}$$

$$= \frac{(8\ \angle -90°)(50\ \angle 30°)}{10\ \angle -53.13°}$$

$$= \frac{400\ \angle -60°}{10\ \angle -53.13°} = \mathbf{40\ V\ \angle -6.87°}$$

PARALLEL ac CIRCUITS



$$\mathbf{Y}_T = \mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3 + \cdots + \mathbf{Y}_N$$

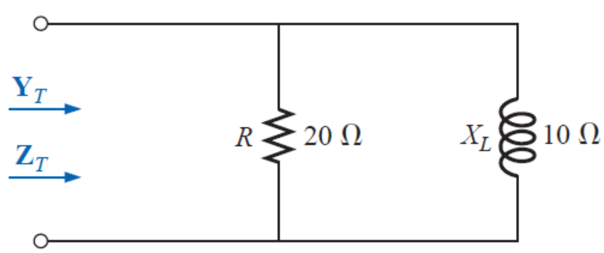
$$\frac{1}{\mathbf{Z}_T} = \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3} + \cdots + \frac{1}{\mathbf{Z}_N}$$

For two impedances in parallel

$$\mathbf{Z}_T = \frac{\mathbf{Z}_1\mathbf{Z}_2}{\mathbf{Z}_1 + \mathbf{Z}_2}$$

EXAMPLE: For the network

a. Find the admittance of each parallel branch.
b. Determine the input admittance.
c. Calculate the input impedance.
d. Draw the admittance diagram.



Solutions:

a. $\mathbf{Y}_R = G \angle 0° = \frac{1}{R} \angle 0° = \frac{1}{20\ \Omega} \angle 0°$

$= \mathbf{0.05\ S \angle 0° = 0.05\ S} + j\,\mathbf{0}$

$\mathbf{Y}_L = B_L \angle -90° = \frac{1}{X_L} \angle -90° = \frac{1}{10\ \Omega} \angle -90°$

$= \mathbf{0.1\ S \angle -90° = 0 -} j\,\mathbf{0.1\ S}$

b. $\mathbf{Y}_T = \mathbf{Y}_R + \mathbf{Y}_L = (0.05\text{ S} + j\,0) + (0 - j\,0.1\text{ S})$

$$= \mathbf{0.05\ S - \mathit{j}\ 0.1\ S} = G - jB_L$$

c. $$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.05\text{ S} - j\,0.1\text{ S}} = \frac{1}{0.112\text{ S}\angle -63.43^\circ}$$

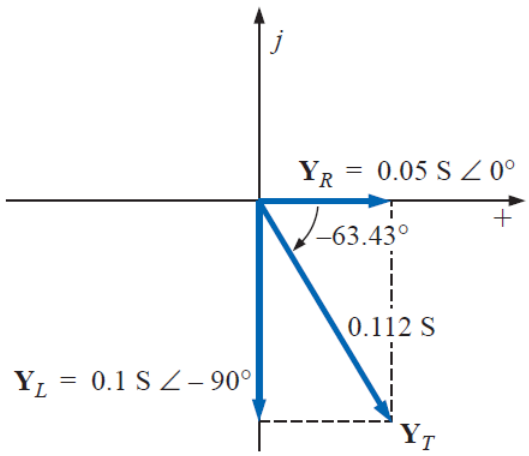
$$= \mathbf{8.93\ \Omega\ \angle 63.43^\circ}$$

Or

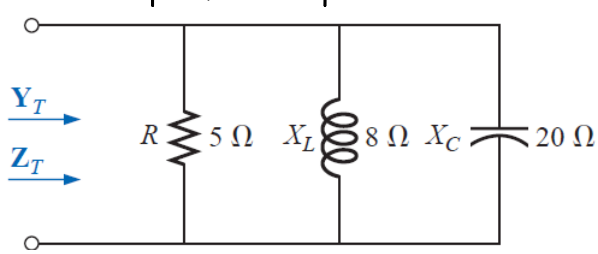
$$\mathbf{Z}_T = \frac{\mathbf{Z}_R\mathbf{Z}_L}{\mathbf{Z}_R + \mathbf{Z}_L} = \frac{(20\ \Omega\angle 0^\circ)(10\ \Omega\angle 90^\circ)}{20\ \Omega + j\,10\ \Omega}$$

$$= \frac{200\ \Omega\angle 90^\circ}{22.36\angle 26.57^\circ} = \mathbf{8.93\ \Omega\ \angle 63.43^\circ}$$

d.



EXAMPLE: Repeat the above Example for the parallel network.



Solutions:

a. $$\mathbf{Y}_R = G\angle 0^\circ = \frac{1}{R}\angle 0^\circ = \frac{1}{5\ \Omega}\angle 0^\circ$$

$$= \mathbf{0.2\ S\ \angle 0^\circ = 0.2\ S + \mathit{j}\ 0}$$

$$\mathbf{Y}_L = B_L \angle -90^\circ = \frac{1}{X_L} \angle -90^\circ = \frac{1}{8\ \Omega} \angle -90^\circ$$
$$= \mathbf{0.125\ S \angle -90^\circ = 0 - j\ 0.125\ S}$$

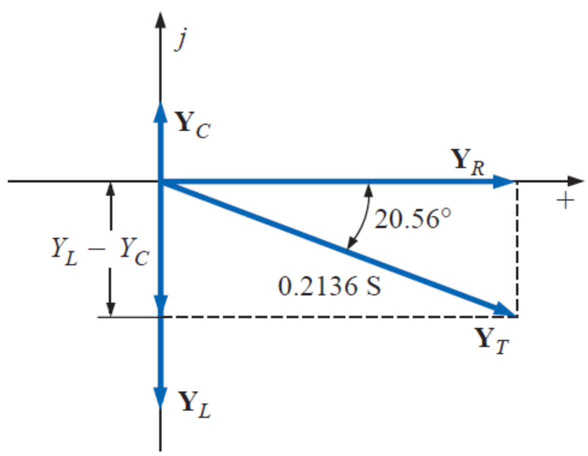
$$\mathbf{Y}_C = B_C \angle 90^\circ = \frac{1}{X_C} \angle 90^\circ = \frac{1}{20\ \Omega} \angle 90^\circ$$
$$= \mathbf{0.050\ S \angle +90^\circ = 0 + j\ 0.050\ S}$$

b. $\mathbf{Y}_T = \mathbf{Y}_R + \mathbf{Y}_L + \mathbf{Y}_C$

$$= (0.2\ S + j\ 0) + (0 - j\ 0.125\ S) + (0 + j\ 0.050\ S)$$
$$= 0.2\ S - j\ 0.075\ S = \mathbf{0.2136\ S \angle -20.56^\circ}$$

c. $\mathbf{Z}_T = \dfrac{1}{0.2136\ S \angle -20.56^\circ} = \mathbf{4.68\ \Omega \angle 20.56^\circ}$

d.



الوحدة الثامنة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

PARALLEL ac NETWORKS

موضوعات المحاضرة

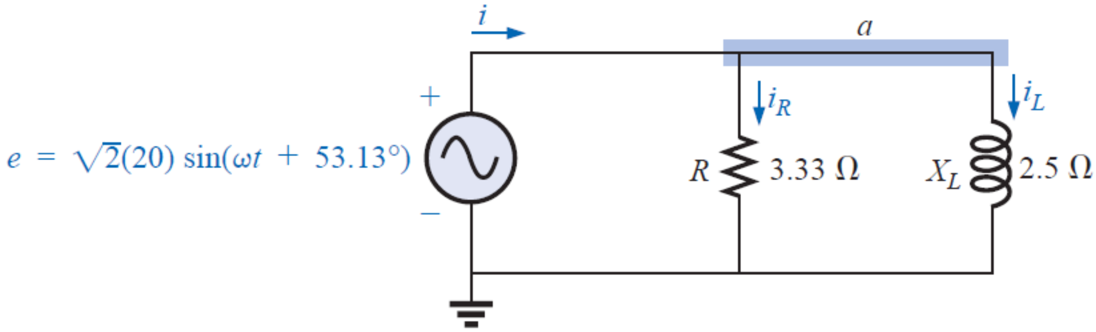
الأساليب والأنشطة والوسائل التعليمية

م	الأساليب والأنشطة التعليمية	الوسائل التعليمية
28	• نشاط التعارف • محاضرة • مناقشة • سؤال وجواب	• جهاز حاسوب • جهاز عرض • سبورة • اوراق واقلام

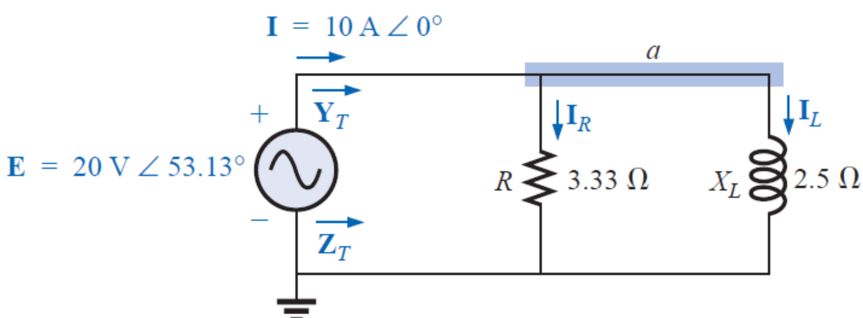
PARALLEL ac NETWORKS

1) R-L

EXAMPLE: find the total impedance and the current in each branch for the network.



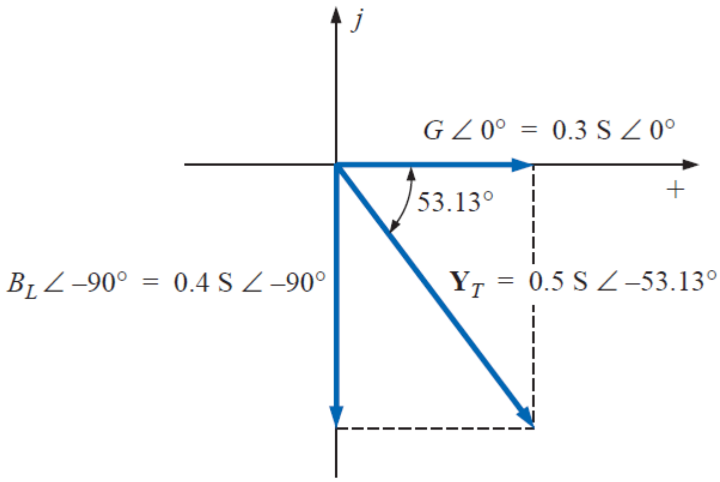
Solutions:



$$\mathbf{Y}_T = \mathbf{Y}_R + \mathbf{Y}_L$$
$$= G\angle 0° + B_L\angle -90° = \frac{1}{3.33\ \Omega}\angle 0° + \frac{1}{2.5\ \Omega}\angle -90°$$
$$= 0.3\ \text{S}\angle 0° + 0.4\ \text{S}\angle -90° = 0.3\ \text{S} - j\,0.4\ \text{S}$$
$$= \mathbf{0.5\ S\angle -53.13°}$$
$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.5\ \text{S}\angle -53.13°} = \mathbf{2\ \Omega\angle 53.13°}$$

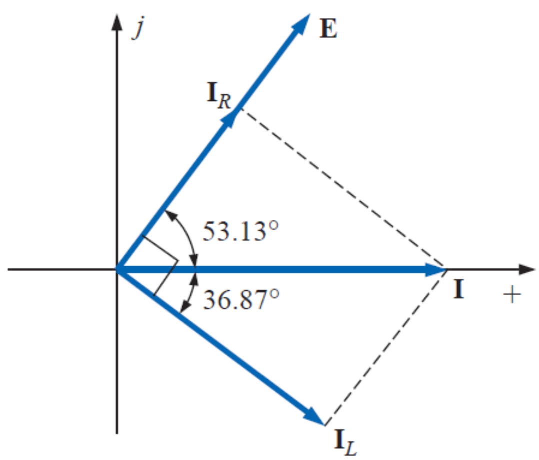
Or

$$\mathbf{Z}_T = \frac{\mathbf{Z}_R\mathbf{Z}_L}{\mathbf{Z}_R + \mathbf{Z}_L} = \frac{(3.33\ \Omega\angle 0°)(2.5\ \Omega\angle 90°)}{3.33\ \Omega\angle 0° + 2.5\ \Omega\angle 90°}$$
$$= \frac{8.325\angle 90°}{4.164\angle 36.87°} = \mathbf{2\ \Omega\angle 53.13°}$$



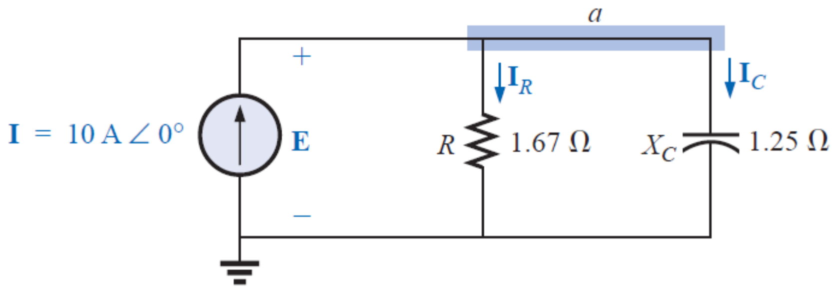
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \mathbf{E}\mathbf{Y}_T = (20\text{ V}\angle 53.13^\circ)(0.5\text{ S}\angle -53.13^\circ) = \mathbf{10\text{ A}\angle 0^\circ}$$

$$\mathbf{I}_R = \frac{E\angle\theta}{R\angle 0^\circ} = (E\angle\theta)(G\angle 0^\circ)$$
$$= (20\text{ V}\angle 53.13^\circ)(0.3\text{ S}\angle 0^\circ) = \mathbf{6\text{ A}\angle 53.13^\circ}$$
$$\mathbf{I}_L = \frac{E\angle\theta}{X_L\angle 90^\circ} = (E\angle\theta)(B_L\angle -90^\circ)$$
$$= (20\text{ V}\angle 53.13^\circ)(0.4\text{ S}\angle -90^\circ)$$
$$= \mathbf{8\text{ A}\angle -36.87^\circ}$$



2) R-C

EXAMPLE: find the total impedance and the current in each branch for the network.



Solutions:

$$\mathbf{Y}_T = \mathbf{Y}_R + \mathbf{Y}_C = G\angle 0^\circ + B_C\angle 90^\circ = \frac{1}{1.67\ \Omega}\angle 0^\circ + \frac{1}{1.25\ \Omega}\angle 90^\circ$$

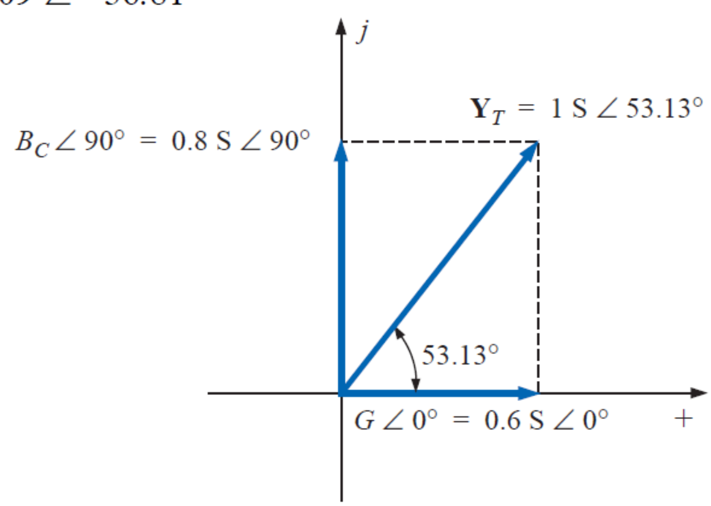
$$= 0.6\text{ S}\angle 0^\circ + 0.8\text{ S}\angle 90^\circ = 0.6\text{ S} + j\,0.8\text{ S} = \mathbf{1.0\ S\angle 53.13^\circ}$$

$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{1.0\text{ S}\angle 53.13^\circ} = \mathbf{1\ \Omega\angle -53.13^\circ}$$

Or

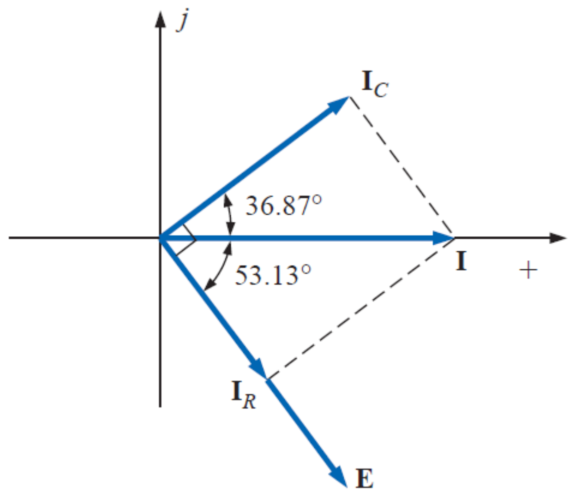
$$\mathbf{Z}_T = \frac{\mathbf{Z}_R\mathbf{Z}_C}{\mathbf{Z}_R + \mathbf{Z}_C} = \frac{(1.67\ \Omega\angle 0^\circ)(1.25\ \Omega\angle -90^\circ)}{1.67\ \Omega\angle 0^\circ + 1.25\ \Omega\angle -90^\circ}$$

$$= \frac{2.09\angle -90^\circ}{2.09\angle -36.81^\circ} = \mathbf{1\ \Omega\angle -53.19^\circ}$$



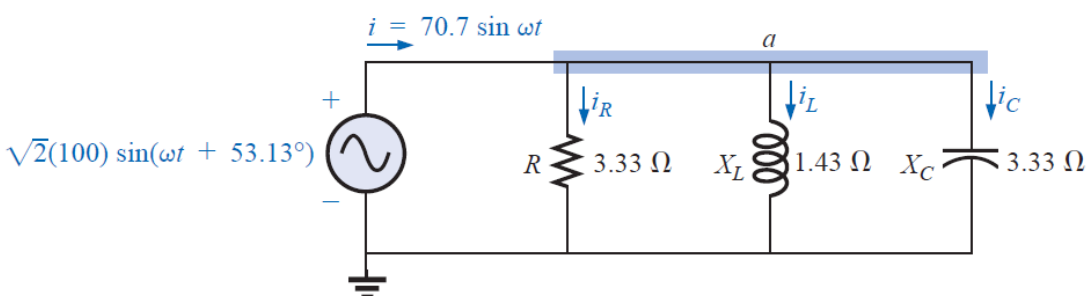
$$\mathbf{E} = \mathbf{I}\mathbf{Z}_T = \frac{\mathbf{I}}{\mathbf{Y}_T} = \frac{10\text{ A}\angle 0^\circ}{1\text{ S}\angle 53.13^\circ} = \mathbf{10\ V\angle -53.13^\circ}$$

$$\mathbf{I}_R = (E \angle \theta)(G \angle 0°)$$
$$= (10 \text{ V} \angle -53.13°)(0.6 \text{ S} \angle 0°) = \mathbf{6 \text{ A} \angle -53.13°}$$
$$\mathbf{I}_C = (E \angle \theta)(B_C \angle 90°)$$
$$= (10 \text{ V} \angle -53.13°)(0.8 \text{ S} \angle 90°) = \mathbf{8 \text{ A} \angle 36.87°}$$

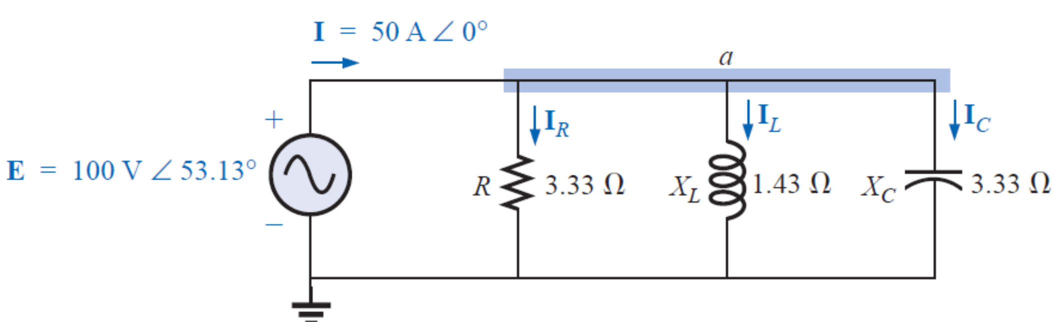


3) R-L-C

EXAMPLE: find the total impedance and the current in each branch for the network.

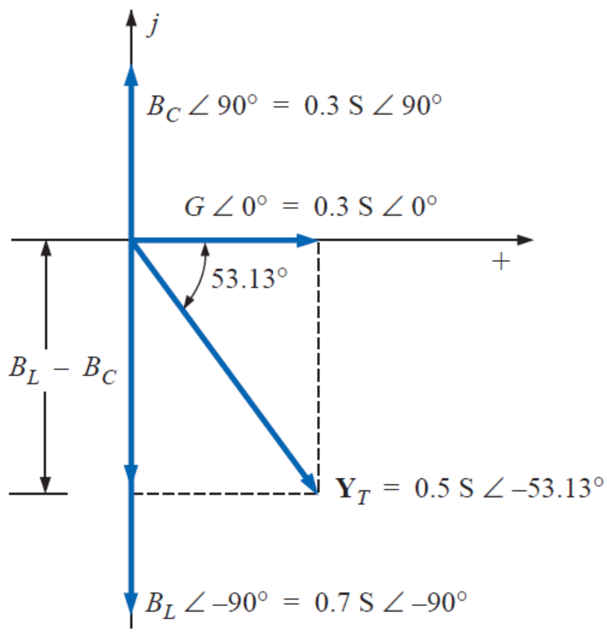


Solutions:



$$\begin{aligned}\mathbf{Y}_T &= \mathbf{Y}_R + \mathbf{Y}_L + \mathbf{Y}_C = G\angle 0^\circ + B_L\angle -90^\circ + B_C\angle 90^\circ\\ &= \frac{1}{3.33\ \Omega}\angle 0^\circ + \frac{1}{1.43\ \Omega}\angle -90^\circ + \frac{1}{3.33\ \Omega}\angle 90^\circ\\ &= 0.3\ \text{S}\angle 0^\circ + 0.7\ \text{S}\angle -90^\circ + 0.3\ \text{S}\angle 90^\circ\\ &= 0.3\ \text{S} - j\,0.7\ \text{S} + j\,0.3\ \text{S}\\ &= 0.3\ \text{S} - j\,0.4\ \text{S} = \mathbf{0.5\ S\angle -53.13^\circ}\end{aligned}$$

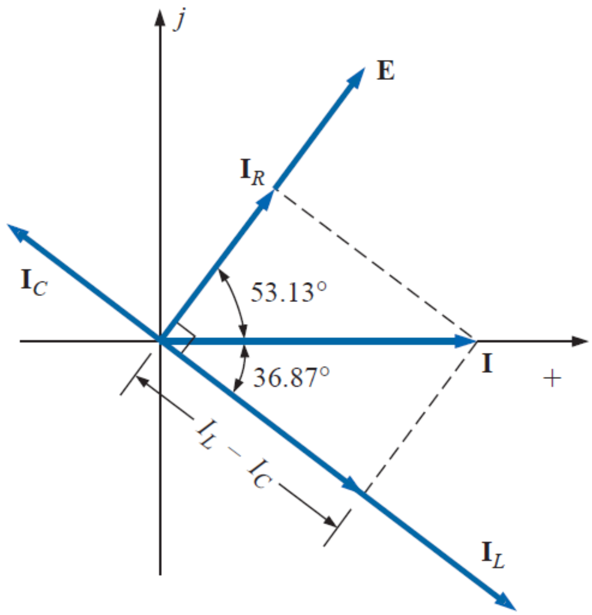
$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.5\ \text{S}\angle -53.13^\circ} = \mathbf{2\ \Omega\angle 53.13^\circ}$$



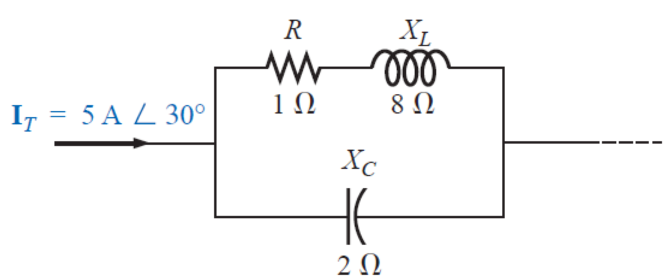
$$\begin{aligned}\mathbf{I}_R &= (E\angle\theta)(G\angle 0^\circ)\\ &= (100\ \text{V}\angle 53.13^\circ)(0.3\ \text{S}\angle 0^\circ) = \mathbf{30\ A\angle 53.13^\circ}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_L &= (E\angle\theta)(B_L\angle -90^\circ)\\ &= (100\ \text{V}\angle 53.13^\circ)(0.7\ \text{S}\angle -90^\circ) = \mathbf{70\ A\angle -36.87^\circ}\end{aligned}$$

$$\begin{aligned}\mathbf{I}_C &= (E\angle\theta)(B_C\angle 90^\circ)\\ &= (100\ \text{V}\angle 53.13^\circ)(0.3\ \text{S}\angle +90^\circ) = \mathbf{30\ A\angle 143.13^\circ}\end{aligned}$$



EXAMPLE: Using the current divider rule, find the current through each parallel branch.



Solutions:

$$\mathbf{I}_{R\text{-}L} = \frac{\mathbf{Z}_C \mathbf{I}_T}{\mathbf{Z}_C + \mathbf{Z}_{R\text{-}L}} = \frac{(2\ \Omega \angle -90^\circ)(5\ \text{A} \angle 30^\circ)}{-j\,2\ \Omega + 1\ \Omega + j\,8\ \Omega} = \frac{10\ \text{A} \angle -60^\circ}{1 + j\,6}$$

$$= \frac{10\ \text{A} \angle -60^\circ}{6.083 \angle 80.54^\circ} \cong \mathbf{1.644\ A \angle -140.54^\circ}$$

$$\mathbf{I}_C = \frac{\mathbf{Z}_{R\text{-}L}\mathbf{I}_T}{\mathbf{Z}_{R\text{-}L} + \mathbf{Z}_C} = \frac{(1\ \Omega + j\ 8\ \Omega)(5\ \text{A} \angle 30^\circ)}{6.08\ \Omega \angle 80.54^\circ}$$

$$= \frac{(8.06 \angle 82.87^\circ)(5\ \text{A} \angle 30^\circ)}{6.08 \angle 80.54^\circ} = \frac{40.30\ \text{A} \angle 112.87^\circ}{6.083 \angle 80.54^\circ}$$

$$= \mathbf{6.625\ A \angle 32.33^\circ}$$

الوحدة التاسعة والعشرون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Series-Parallel ac Networks

موضوعات المحاضرة

Examples

الأساليب والأنشطة والوسائل التعليمية

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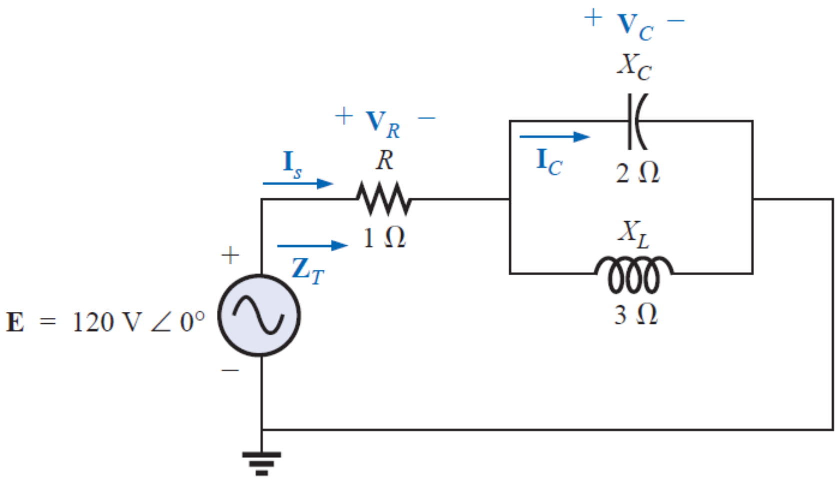
Series-Parallel ac Networks

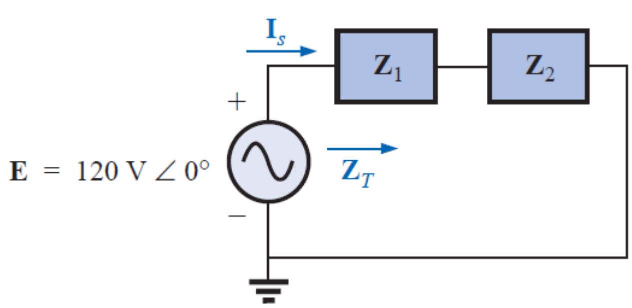
EXAMPLE: For the network

a. Calculate $\mathbf{Z}_T$.
b. Determine $\mathbf{I}_s$.
c. Calculate $\mathbf{V}_R$ and $\mathbf{V}_C$.
d. Find $\mathbf{I}_C$.



Solutions:

a)



$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2$$

$$\mathbf{Z}_1 = R \angle 0° = 1\ \Omega \angle 0°$$

$$\mathbf{Z}_2 = \mathbf{Z}_C \parallel \mathbf{Z}_L = \frac{(X_C \angle -90°)(X_L \angle 90°)}{-j X_C + j X_L} = \frac{(2\ \Omega \angle -90°)(3\ \Omega \angle 90°)}{-j\,2\ \Omega + j\,3\ \Omega}$$

$$= \frac{6\ \Omega \angle 0°}{j\,1} = \frac{6\ \Omega \angle 0°}{1 \angle 90°} = 6\ \Omega \angle -90°$$

$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 = 1\ \Omega - j\,6\ \Omega = \mathbf{6.08\ \Omega \angle -80.54°}$$

b)

$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{120\ \text{V}\ \angle 0^\circ}{6.08\ \Omega\ \angle -80.54^\circ} = \mathbf{19.74\ A\ \angle 80.54^\circ}$$

c)

$$\mathbf{V}_R = \mathbf{I}_s\mathbf{Z}_1 = (19.74\ \text{A}\ \angle 80.54^\circ)(1\ \Omega\ \angle 0^\circ) = \mathbf{19.74\ V\ \angle 80.54^\circ}$$

$$\mathbf{V}_C = \mathbf{I}_s\mathbf{Z}_2 = (19.74\ \text{A}\ \angle 80.54^\circ)(6\ \Omega\ \angle -90^\circ)$$

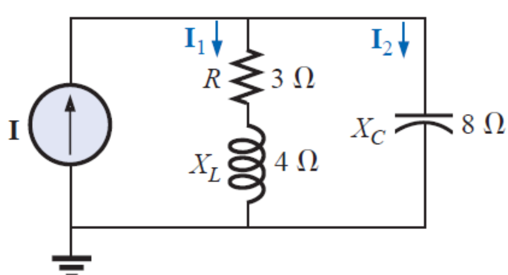
$$= \mathbf{118.44\ V\ \angle -9.46^\circ}$$

d)

$$\mathbf{I}_C = \frac{\mathbf{V}_C}{\mathbf{Z}_C} = \frac{118.44\ \text{V}\ \angle -9.46^\circ}{2\ \Omega\ \angle -90^\circ} = \mathbf{59.22\ A\ \angle 80.54^\circ}$$

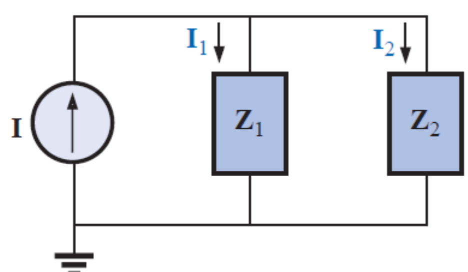
EXAMPLE: For the network

a. If $\mathbf{I}$ is 50 A $\angle 30^\circ$, calculate $\mathbf{I}_1$ using the current divider rule.
b. Repeat part (a) for $\mathbf{I}_2$.
c. Verify Kirchhoff's current law at one node.



Solutions:

a)



$$\mathbf{Z}_1 = R + jX_L = 3\ \Omega + j\,4\ \Omega = 5\ \Omega\ \angle 53.13^\circ$$

$$\mathbf{Z}_2 = -jX_C = -j\,8\ \Omega = 8\ \Omega\ \angle -90^\circ$$

$$\mathbf{I}_1 = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(8\ \Omega\ \angle -90^\circ)(50\ \text{A}\ \angle 30^\circ)}{(-j\,8\ \Omega) + (3\ \Omega + j\,4\ \Omega)} = \frac{400\ \angle -60^\circ}{3 - j\,4}$$

$$= \frac{400\ \angle -60^\circ}{5\ \angle -53.13^\circ} = \mathbf{80\ A\ \angle -6.87^\circ}$$

b)

$$\mathbf{I}_2 = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(5\ \Omega\ \angle 53.13^\circ)(50\ \text{A}\ \angle 30^\circ)}{5\ \Omega\ \angle -53.13^\circ} = \frac{250\ \angle 83.13^\circ}{5\ \angle -53.13^\circ}$$

$$= \mathbf{50\ A\ \angle 136.26^\circ}$$

c)

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2$$

$$50\ \text{A}\ \angle 30^\circ = 80\ \text{A}\ \angle -6.87^\circ + 50\ \text{A}\ \angle 136.26^\circ$$

$$= (79.43 - j\,9.57) + (-36.12 + j\,34.57)$$

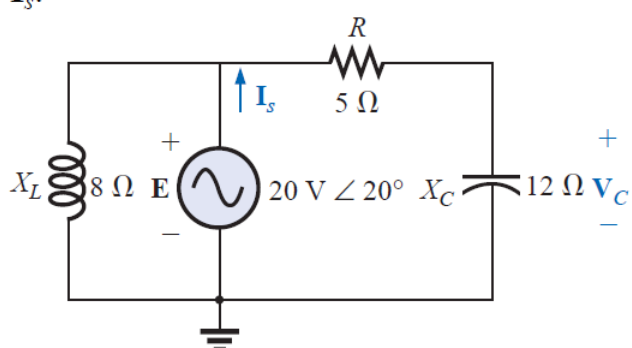
$$= 43.31 + j\,25.0$$

$$50\ \text{A}\ \angle 30^\circ = 50\ \text{A}\ \angle 30^\circ \quad \text{(checks)}$$

EXAMPLE: For the network

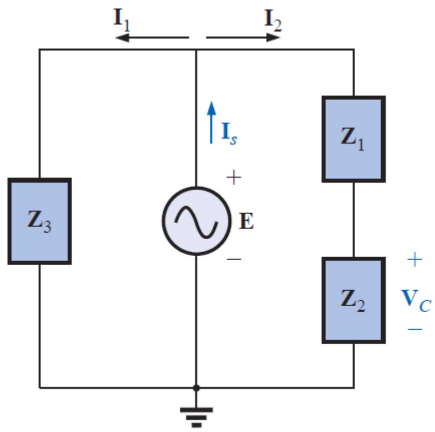
a. Calculate the voltage $\mathbf{V}_C$ using the voltage divider rule.

b. Calculate the current $\mathbf{I}_s$.



Solutions:

a)



$$V_C = \frac{Z_2 E}{Z_1 + Z_2} = \frac{(12\ \Omega \angle -90^\circ)(20\ V \angle 20^\circ)}{5\ \Omega - j\ 12\ \Omega} = \frac{240\ V \angle -70^\circ}{13 \angle -67.38^\circ}$$
$$= \mathbf{18.46\ V \angle -2.62^\circ}$$

b)

$$I_1 = \frac{E}{Z_3} = \frac{20\ V \angle 20^\circ}{8\ \Omega \angle 90^\circ} = 2.5\ A \angle -70^\circ$$

$$I_2 = \frac{E}{Z_1 + Z_2} = \frac{20\ V \angle 20^\circ}{13\ \Omega \angle -67.38^\circ} = 1.54\ A \angle 87.38^\circ$$

$$I_s = I_1 + I_2$$
$$= 2.5\ A \angle -70^\circ + 1.54\ A \angle 87.38^\circ$$
$$= (0.86 - j\ 2.35) + (0.07 + j\ 1.54)$$
$$I_s = 0.93 - j\ 0.81 = \mathbf{1.23\ A \angle -41.05^\circ}$$

الوحدة الثلاثون- الزمن: 90 دقيقة

أهداف المحاضرة

يتوقع في نهاية الجلسة أن يكون الطالب قادراً على:

Methods of Analysis (ac)

Power (ac)

APPARENT POWER

موضوعات المحاضرة

Examples

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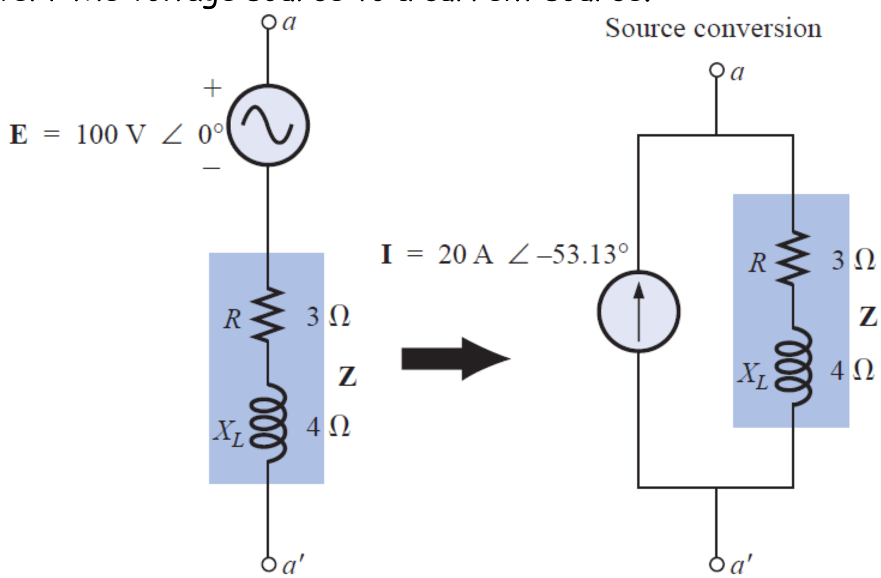
Methods of Analysis (ac)

EXAMPLE: Convert the voltage source to a current source.

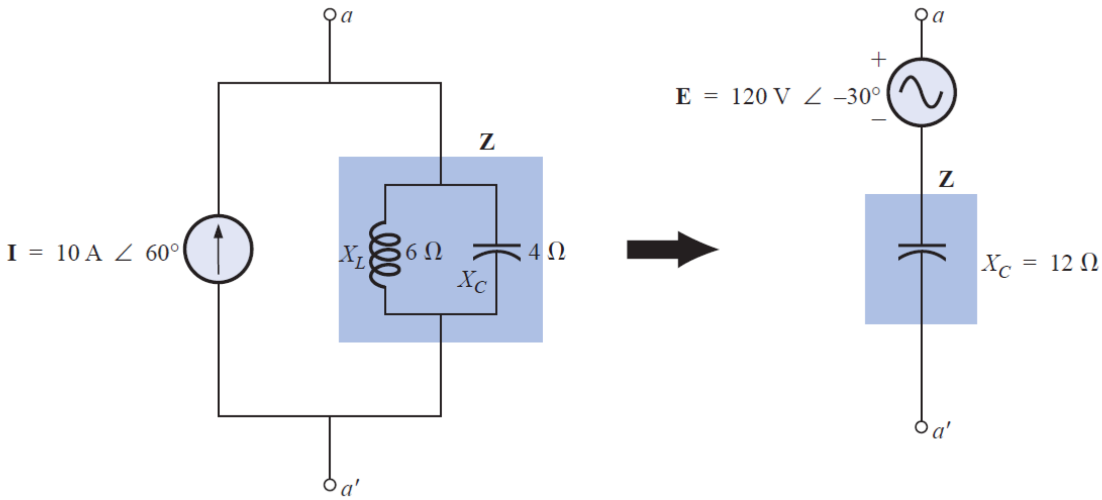


Solutions:

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{100\ \text{V}\ \angle 0^\circ}{5\ \Omega\ \angle 53.13^\circ}$$

$$= \mathbf{20\ A\ \angle -53.13^\circ}$$

EXAMPLE: Convert the current source to a voltage source.



Solutions:

$$\mathbf{Z} = \frac{\mathbf{Z}_C\mathbf{Z}_L}{\mathbf{Z}_C + \mathbf{Z}_L} = \frac{(X_C \angle -90^\circ)(X_L \angle 90^\circ)}{-j\,X_C + j\,X_L}$$

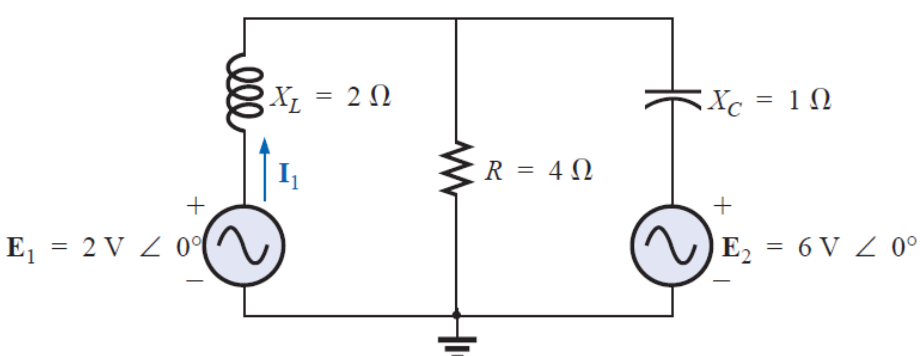
$$= \frac{(4\ \Omega \angle -90^\circ)(6\ \Omega \angle 90^\circ)}{-j\,4\ \Omega + j\,6\ \Omega} = \frac{24\ \Omega \angle 0^\circ}{2 \angle 90^\circ}$$

$$= \mathbf{12\ \Omega \angle -90^\circ} \qquad \text{[Fig. 17.7(b)]}$$

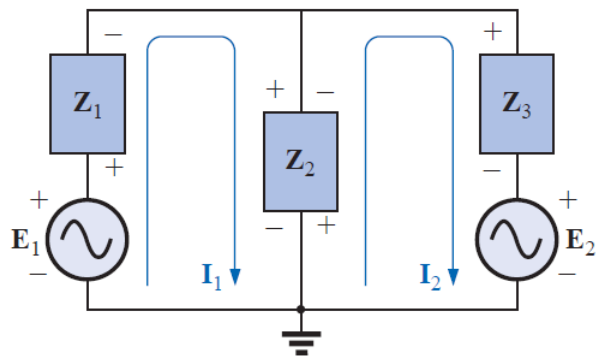
$$\mathbf{E} = \mathbf{IZ} = (10\ \text{A} \angle 60^\circ)(12\ \Omega \angle -90^\circ)$$

$$= \mathbf{120\ V \angle -30^\circ} \qquad \text{[Fig. 17.7(b)]}$$

EXAMPLE: Using the general approach to mesh analysis, find the current **I1**.



Solutions:



$\mathbf{Z}_1 = +j X_L = +j\,2\,\Omega \qquad \mathbf{E}_1 = 2\text{ V}\angle 0°$

$\mathbf{Z}_2 = R = 4\,\Omega \qquad \mathbf{E}_2 = 6\text{ V}\angle 0°$

$\mathbf{Z}_3 = -j X_C = -j\,1\,\Omega$

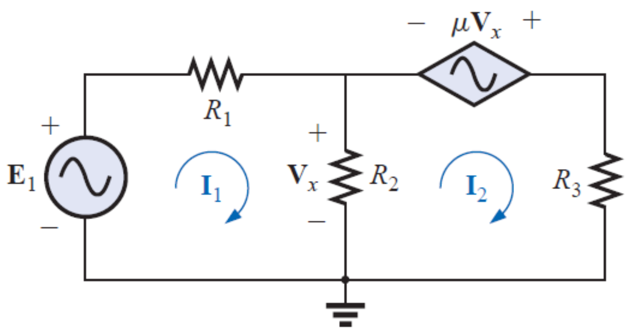
$$\mathbf{I}_1(\mathbf{Z}_1 + \mathbf{Z}_2) - \mathbf{I}_2\mathbf{Z}_2 = \mathbf{E}_1$$
$$\mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_3) - \mathbf{I}_1\mathbf{Z}_2 = -\mathbf{E}_2$$

$$\begin{aligned} \mathbf{I}_1(\mathbf{Z}_1 + \mathbf{Z}_2) - \mathbf{I}_2\mathbf{Z}_2 \qquad\qquad &= \mathbf{E}_1 \\ -\mathbf{I}_1\mathbf{Z}_2 \qquad + \mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_3) &= -\mathbf{E}_2 \end{aligned}$$

$$\mathbf{I}_1 = \frac{\begin{vmatrix} \mathbf{E}_1 & -\mathbf{Z}_2 \\ -\mathbf{E}_2 & \mathbf{Z}_2 + \mathbf{Z}_3 \end{vmatrix}}{\begin{vmatrix} \mathbf{Z}_1 + \mathbf{Z}_2 & -\mathbf{Z}_2 \\ -\mathbf{Z}_2 & \mathbf{Z}_2 + \mathbf{Z}_3 \end{vmatrix}} = \frac{\mathbf{E}_1(\mathbf{Z}_2 + \mathbf{Z}_3) - \mathbf{E}_2(\mathbf{Z}_2)}{(\mathbf{Z}_1 + \mathbf{Z}_2)(\mathbf{Z}_2 + \mathbf{Z}_3) - (\mathbf{Z}_2)^2} = \frac{(\mathbf{E}_1 - \mathbf{E}_2)\mathbf{Z}_2 + \mathbf{E}_1\mathbf{Z}_3}{\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3}$$

$$\mathbf{I}_1 = \frac{(2\text{ V} - 6\text{ V})(4\,\Omega) + (2\text{ V})(-j\,1\,\Omega)}{(+j\,2\,\Omega)(4\,\Omega) + (+j\,2\,\Omega)(-j\,2\,\Omega) + (4\,\Omega)(-j\,2\,\Omega)}$$
$$= \frac{-16 - j\,2}{j\,8 - j^2 2 - j\,4} = \frac{-16 - j\,2}{2 + j\,4} = \frac{16.12\text{ A}\angle -172.87°}{4.47\angle 63.43°}$$
$$= \mathbf{3.61\ A\angle -236.30°} \quad \text{or} \quad \mathbf{3.61\ A\angle 123.70°}$$

EXAMPLE: Write the mesh currents for the network having a dependent voltage source.



Solutions:

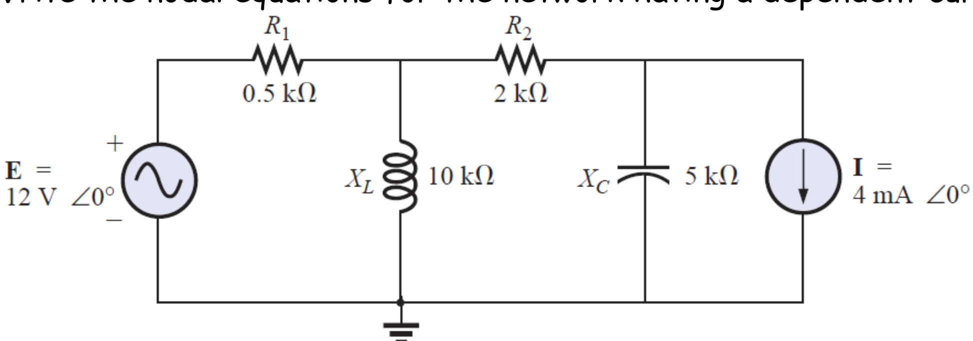
$$E_1 - I_1R_1 - R_2(I_1 - I_2) = 0$$

$$R_2(I_2 - I_1) + \mu V_x - I_2R_3 = 0 \qquad V_x = (I_1 - I_2)R_2$$

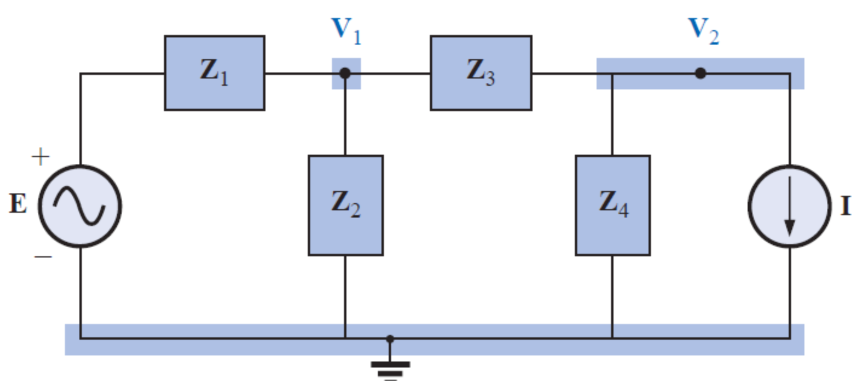
$$E_1 - I_1R_1 - R_2(I - I_2) = 0$$

$$R_2(I_2 - I_1) + \mu R_2(I_1 - I_2) - I_2R_3 = 0$$

EXAMPLE: Write the nodal equations for the network having a dependent current source.



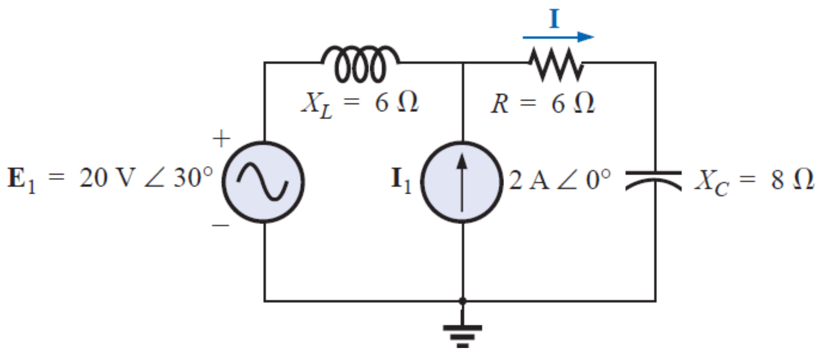
Solutions:



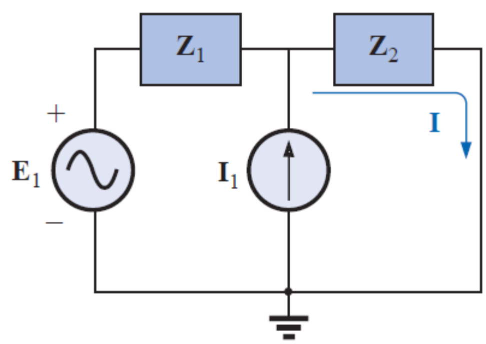
$$V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right] - V_2\left[\frac{1}{Z_3}\right] = \frac{E_1}{Z_1}$$

$$\mathbf{V}_2\left[\frac{1}{\mathbf{Z}_3}+\frac{1}{\mathbf{Z}_4}\right]-\mathbf{V}_1\left[\frac{1}{\mathbf{Z}_3}\right]=-\mathbf{I}$$

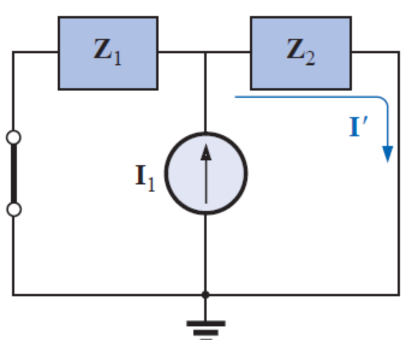
EXAMPLE: Using superposition, find the current **I** through the 6-Ω resistor.



Solutions:



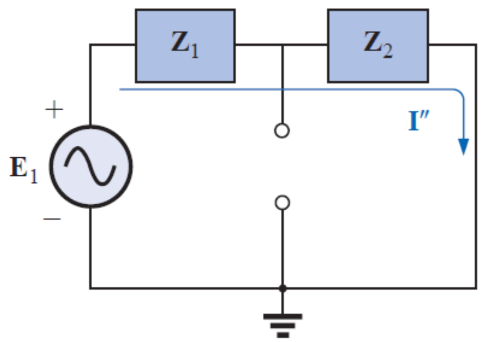
$$\mathbf{Z}_1 = j\,6\ \Omega \qquad \mathbf{Z}_2 = 6 - j\,8\ \Omega$$



$$\mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}_1}{\mathbf{Z}_1+\mathbf{Z}_2} = \frac{(j\,6\ \Omega)(2\ \text{A})}{j\,6\ \Omega + 6\ \Omega - j\,8\ \Omega} = \frac{j\,12\ \text{A}}{6 - j\,2}$$

$$= \frac{12\ \text{A} \angle 90°}{6.32 \angle -18.43°}$$

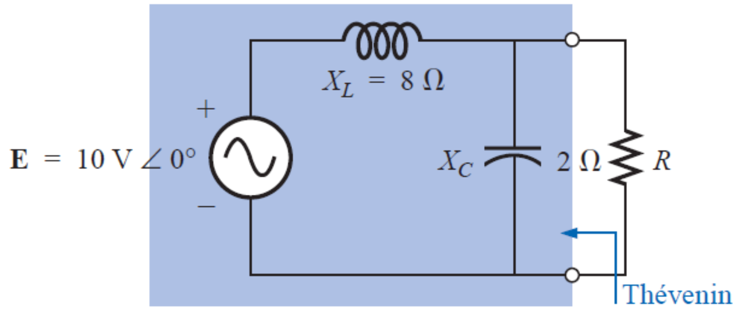
$$\mathbf{I}' = 1.9\ \text{A} \angle 108.43°$$



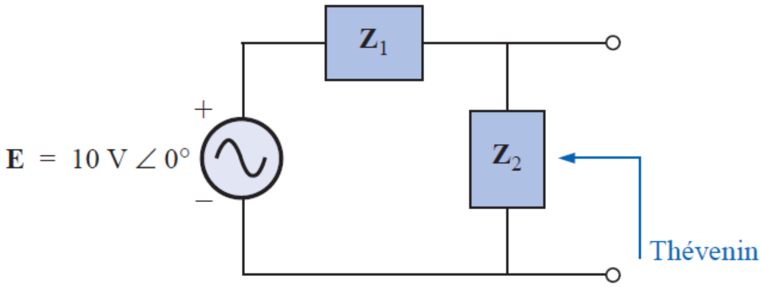
$$\mathbf{I}'' = \frac{\mathbf{E}_1}{\mathbf{Z}_T} = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{20\text{ V}\angle 30^\circ}{6.32\ \Omega\angle -18.43^\circ}$$
$$= 3.16\text{ A}\angle 48.43^\circ$$

$$\mathbf{I} = \mathbf{I}' + \mathbf{I}''$$
$$= 1.9\text{ A}\angle 108.43^\circ + 3.16\text{ A}\angle 48.43^\circ$$
$$= (-0.60\text{ A} + j\,1.80\text{ A}) + (2.10\text{ A} + j\,2.36\text{ A})$$
$$= 1.50\text{ A} + j\,4.16\text{ A}$$
$$\mathbf{I} = \mathbf{4.42\text{ A}\angle 70.2^\circ}$$

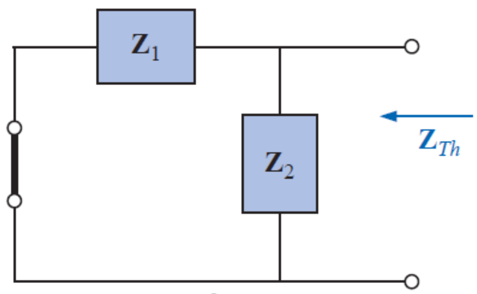
EXAMPLE: Find the Thévenin equivalent circuit for the network external to resistor *R*.



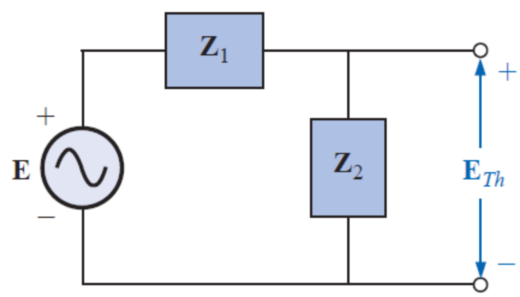
Solutions:



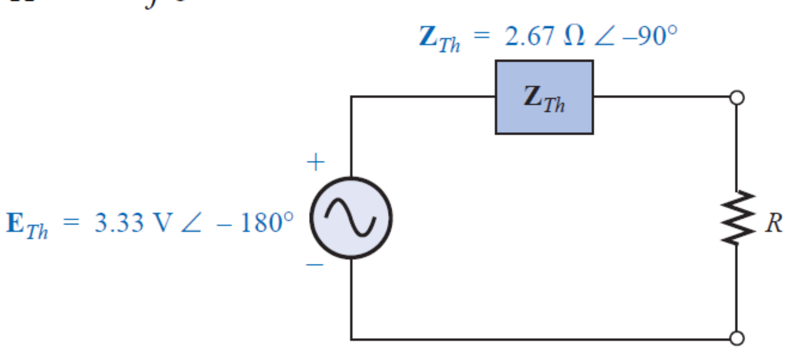
$\mathbf{Z}_1 = j\,X_L = j\,8\,\Omega \qquad \mathbf{Z}_2 = -j\,X_C = -j\,2\,\Omega$

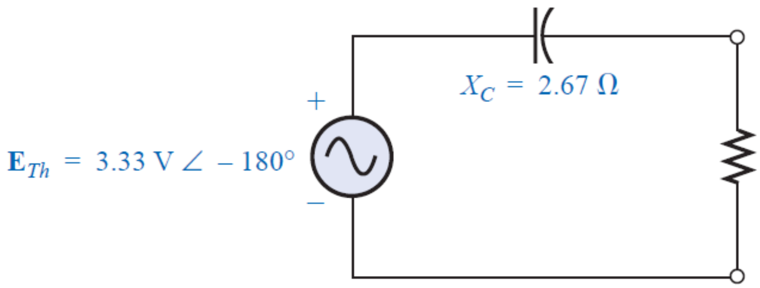


$$\mathbf{Z}_{Th} = \frac{\mathbf{Z}_1\mathbf{Z}_2}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(j\,8\,\Omega)(-j\,2\,\Omega)}{j\,8\,\Omega - j\,2\,\Omega} = \frac{-j^2 16\,\Omega}{j\,6} = \frac{16\,\Omega}{6\,\angle 90^\circ}$$
$$= \mathbf{2.67\,\Omega\,\angle -90^\circ}$$

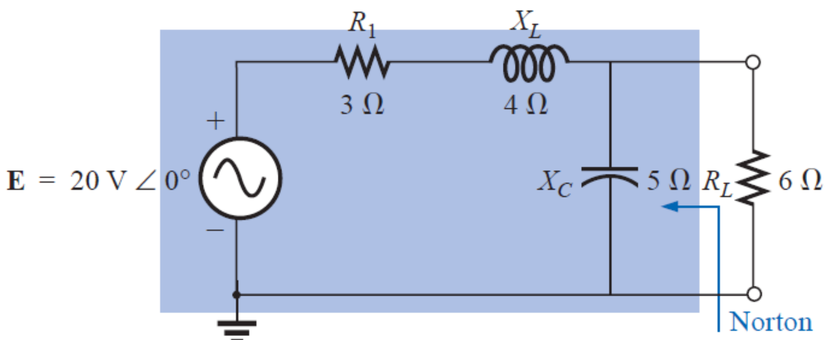


$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_1 + \mathbf{Z}_2} \qquad \text{(voltage divider rule)}$$
$$= \frac{(-j\,2\,\Omega)(10\,\text{V})}{j\,8\,\Omega - j\,2\,\Omega} = \frac{-j\,20\,\text{V}}{j\,6} = \mathbf{3.33\,V\,\angle -180^\circ}$$

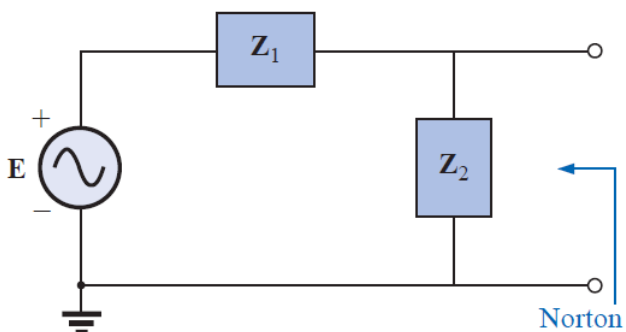




EXAMPLE: Determine the Norton equivalent circuit for the network external to the 6-Ω resistor.

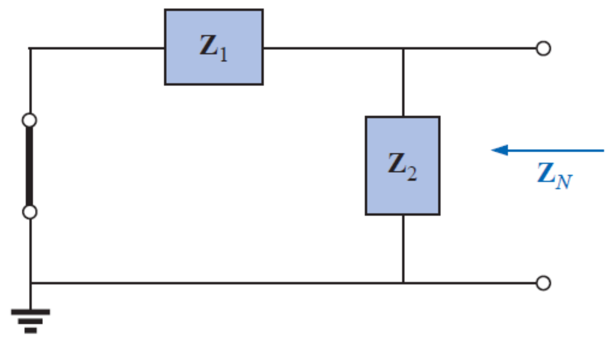


Solutions:



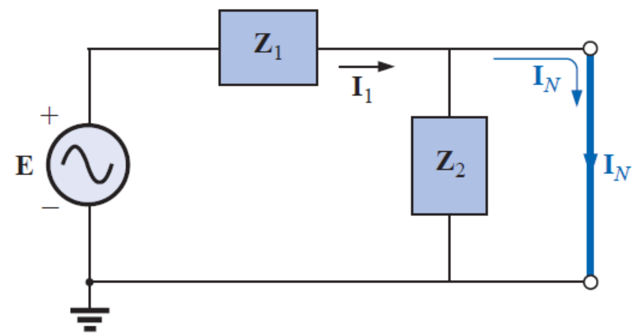
$$Z_1 = R_1 + jX_L = 3\ \Omega + j\,4\ \Omega = 5\ \Omega\ \angle 53.13°$$

$$Z_2 = -jX_C = -j\,5\ \Omega$$

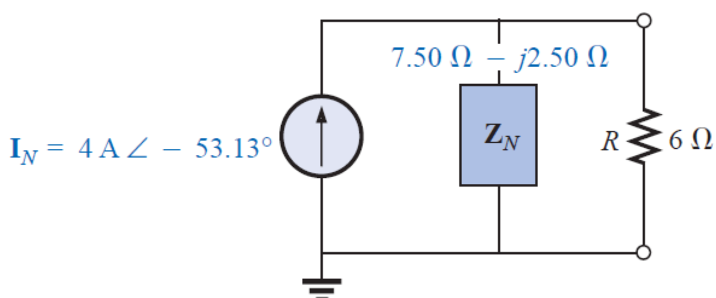


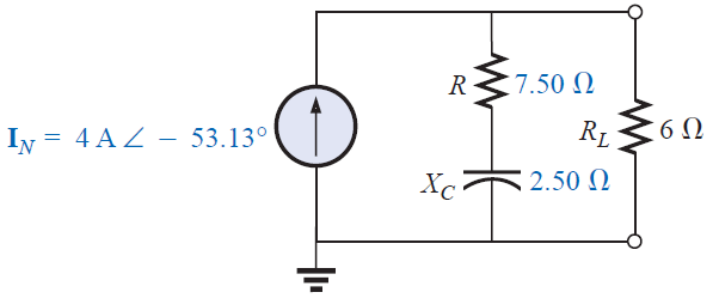
$$\mathbf{Z}_N = \frac{\mathbf{Z}_1\mathbf{Z}_2}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(5\ \Omega \angle 53.13^\circ)(5\ \Omega \angle -90^\circ)}{3\ \Omega + j\,4\ \Omega - j\,5\ \Omega} = \frac{25\ \Omega \angle -36.87^\circ}{3 - j\,1}$$

$$= \frac{25\ \Omega \angle -36.87^\circ}{3.16 \angle -18.43^\circ} = 7.91\ \Omega \angle -18.44^\circ = \mathbf{7.50\ \Omega - j\,2.50\ \Omega}$$



$$\mathbf{I}_N = \mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{20\ \text{V} \angle 0^\circ}{5\ \Omega \angle 53.13^\circ} = \mathbf{4\ A \angle -53.13^\circ}$$

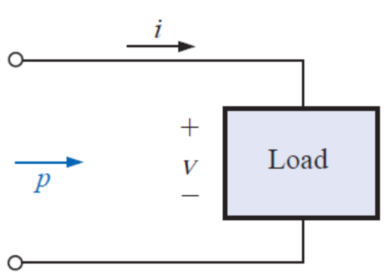




Power (ac)

AVERAGE POWER AND POWER FACTOR

The average power, or **real power** as it is sometimes called, is the power delivered to and dissipated by the load. It corresponds to the power calculations performed for dc networks.



$$p = vi$$

Since *v* and *i* are sinusoidal quantities, let us establish a general case where:

$$v = V_m \sin(\omega t + \theta)$$

$$i = I_m \sin \omega t$$

* The angle (θ) is the phase angle between *v* and *i*.

Substituting the above equations for *v* and *i* into the power equation will result in

$$p = V_m I_m \sin \omega t \sin(\omega t + \theta)$$

If we now apply a number of trigonometric identities, the following form for the power equation will result:

$$p = VI \cos \theta (1 - \cos 2\omega t) + VI \sin \theta (\sin 2\omega t)$$

* where *V* and *I* are the **rms** values.

$$V = \frac{Vm}{\sqrt{2}} \quad \text{and} \quad I = \frac{\text{Im}}{\sqrt{2}}$$

So that the power is

$$p = \underbrace{VI \cos \theta}_{\text{Average}} - \underbrace{VI \cos \theta}_{\text{Peak}} \underbrace{\cos 2\omega t}_{2x} + \underbrace{VI \sin \theta}_{\text{Peak}} \underbrace{\sin 2\omega t}_{2x}$$

The average power equal

$$P = VI \cos \theta$$

* The magnitude of average power delivered is independent of whether v leads i or i leads v.

- for resistor $\theta = 0$ then $P = VI\cos 0 = VI$
- for Inductor v leads i by 90°, then $P = VI\cos 90 = 0$
- for Capacitor i leads v by 90°, then $P = VI\cos 90 = 0$

Power factor

The power factor is the factor that has significant control over the delivered power level.

$$\text{Power factor} = F_p = \cos\theta$$

- Capacitive networks have leading power factors,
- Inductive networks have lagging power factors.

APPARENT POWER

It is a power rating of significant usefulness in the description and analysis of sinusoidal ac networks and in the maximum rating of a number of electrical components and systems.

$$S = VI \qquad \text{(volt-amperes, VA)}$$

$$S = I^2 Z \qquad \text{(VA)}$$

$$S = \frac{V^2}{Z} \qquad \text{(VA)}$$

Therefore

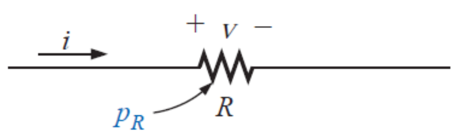
$$P = S\cos\theta \qquad \text{(W)}$$

$$F_p = \cos\theta = \frac{P}{S}$$

---

1) RESISTIVE CIRCUIT

For a purely resistive circuit, v and i are in phase, and $\theta = 0°$,



$$p_R = VI\cos(0°)(1 - \cos 2\omega t) + VI\sin(0°)\sin 2\omega t$$
$$= VI(1 - \cos 2\omega t) + 0$$

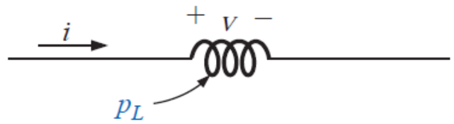
$$p_R = VI - VI\cos 2\omega t$$

The **average (real) power** is

$$P = VI = \frac{V_m I_m}{2} = I^2 R = \frac{V^2}{R} \qquad \text{(watts, W)}$$

2) INDUCTIVE CIRCUIT

For a purely inductive circuit, v leads i by 90°, $\theta = 90°$.



$$p_L = VI\cos(90°)(1 - \cos 2\omega t) + VI\sin(90°)(\sin 2\omega t)$$
$$= 0 + VI\sin 2\omega t$$

$$p_L = VI\sin 2\omega t$$

The **reactive power** is

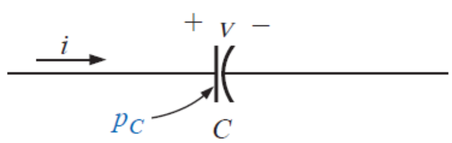
$$Q = VI\sin\theta \qquad \text{(volt-ampere reactive, VAR)}$$

$$Q_L = I^2 X_L \qquad \text{(VAR)}$$

$$Q_L = \frac{V^2}{X_L} \qquad \text{(VAR)}$$

3) CAPACITIVE CIRCUIT

For a purely capacitive circuit, *i* leads *v* by 90°, θ =-90°.



$$p_C = VI\cos(-90°)(1 - \cos 2\omega t) + VI\sin(-90°)(\sin 2\omega t)$$
$$= 0 - VI\sin 2\omega t$$

$$p_C = -VI\sin 2\omega t$$

The **reactive power** is

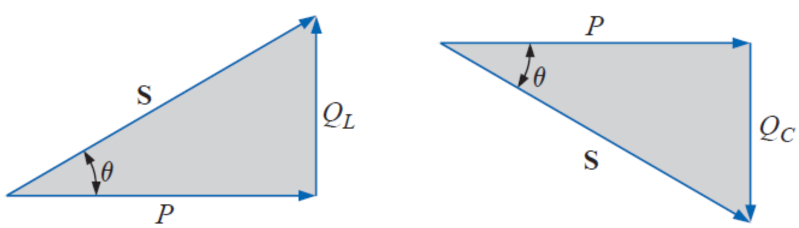
$$Q = VI \sin\theta \quad \text{(volt-ampere reactive, VAR)}$$

$$Q_C = I^2 X_C$$

$$Q_C = \frac{V^2}{X_C}$$

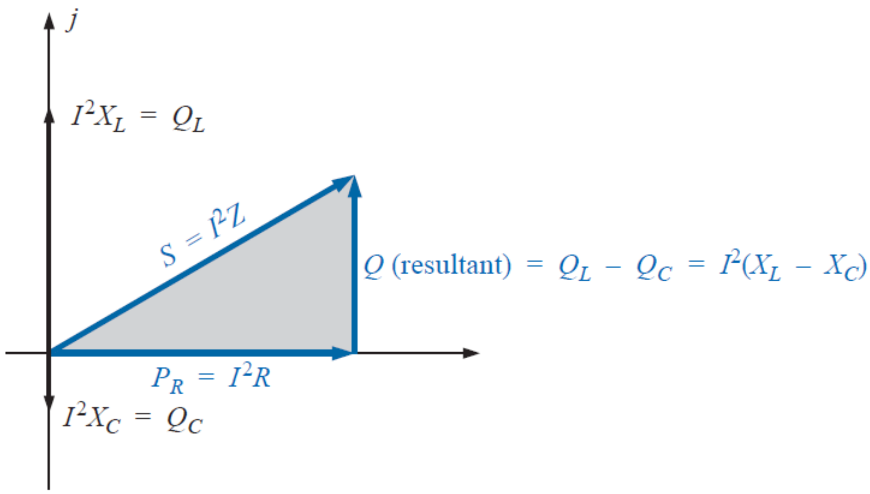
THE POWER TRIANGLE

The three quantities **average power (P)**, **apparent power (S)**, and **reactive power (Q)** can be related in the vector domain by



$$S = P + jQ$$
$$Q = Q_L - Q_C$$

$$S^2 = P^2 + Q^2$$

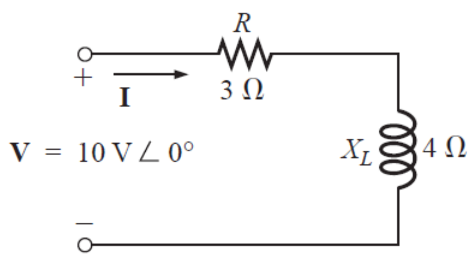


$$S = \sqrt{P^2 + Q^2}$$

$$F_p = \cos\theta = \frac{P}{S}$$

1. Find the real power and reactive power for each branch of the circuit.
2. The total real power of the system (PT) is then the sum of the average power delivered to each branch.
3. The total reactive power (QT) is the difference between the reactive power of the inductive loads and that of the capacitive loads.
4. The total apparent power is $S_T = \sqrt{P_T + Q_T}$.
5. The total power factor is P_T / S_T.

EXAMPLE: Find the total number of watts, volt-amperes reactive, and volt-amperes for the network.



Solutions:

$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}_T} = \frac{10\text{ V} \angle 0^\circ}{3\ \Omega + j\,4\ \Omega} = \frac{10\text{ V} \angle 0^\circ}{5\ \Omega \angle 53.13^\circ} = 2\text{ A} \angle -53.13^\circ$$

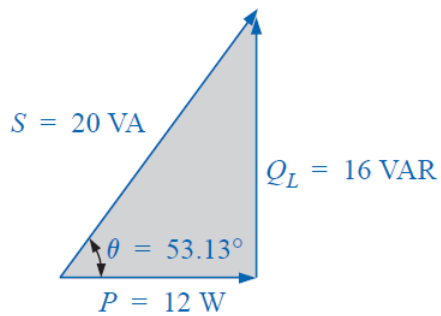
$$P = I^2R = (2\text{ A})^2(3\ \Omega) = 12\text{ W}$$

$$Q_L = I^2X_L = (2\text{ A})^2(4\ \Omega) = 16\text{ VAR }(L)$$

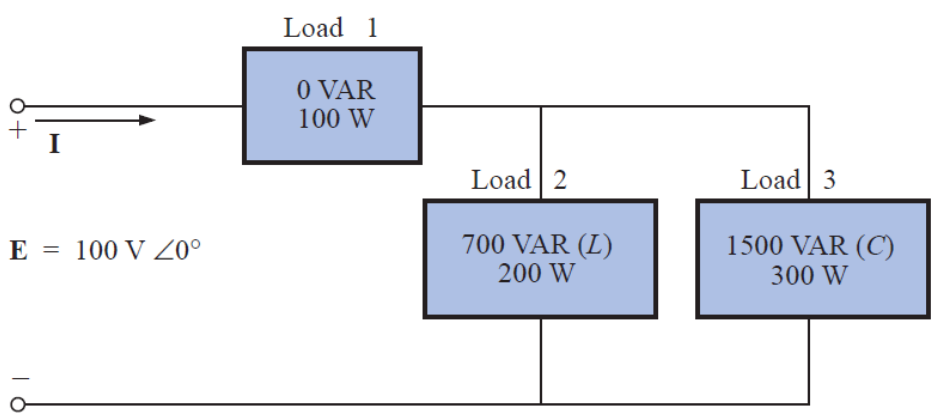
$$\mathbf{S} = P + j\,Q_L = 12\text{ W} + j\,16\text{ VAR }(L) = 20\text{ VA} \angle 53.13^\circ$$

Or

$$\mathbf{S} = \mathbf{VI}^* = (10\text{ V} \angle 0^\circ)(2\text{ A} \angle +53.13^\circ) = 20\text{ VA} \angle 53.13^\circ$$



EXAMPLE: Find the total number of watts, volt-amperes reactive, and volt-amperes, and the power factor *Fp* of the network. Draw the power triangle and find the current in phasor form.



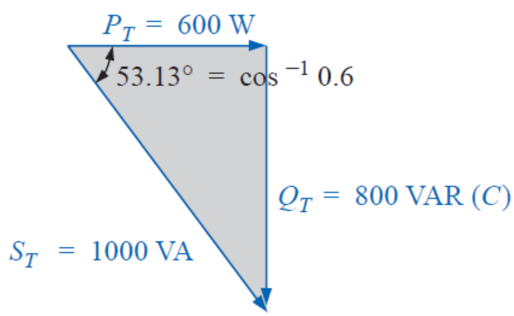
Solutions:

Load	W	VAR	VA
1	100	0	100
2	200	700 (*L*)	$\sqrt{(200)^2 + (700)^2} = 728.0$
3	300	1500 (*C*)	$\sqrt{(300)^2 + (1500)^2} = 1529.71$
	$P_T = $ **600** Total power dissipated	$Q_T = $ **800 (*C*)** Resultant reactive power of network	$S_T = \sqrt{(600)^2 + (800)^2} = $ **1000** (Note that $S_T \neq$ sum of each branch: $1000 \neq 100 + 728 + 1529.71$)

$$F_p = \frac{P_T}{S_T} = \frac{600\text{ W}}{1000\text{ VA}} = \mathbf{0.6\ leading\ (}\boldsymbol{C}\mathbf{)}$$

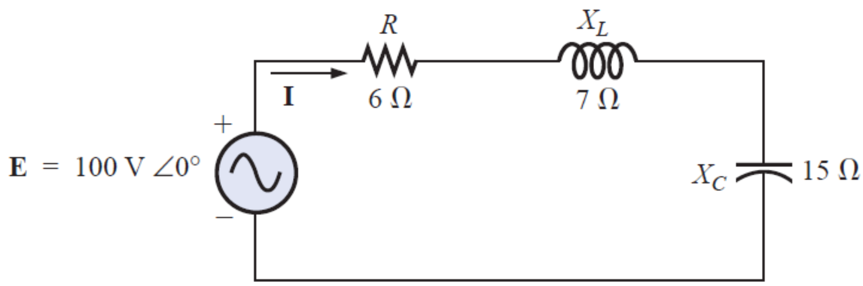
$$I = 1000\text{ VA}/100\text{ V} = 10\text{ A}$$

$$\mathbf{I = 10\ A \angle +53.13^\circ}$$



EXAMPLE:

a) Find the total number of watts, volt-amperes reactive, and volt-amperes, and the power factor *Fp* for the network.
b) Sketch the power triangle.



Solutions:

a)

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{100\text{ V}\angle 0^\circ}{6\ \Omega + j\,7\ \Omega - j\,15\ \Omega} = \frac{100\text{ V}\angle 0^\circ}{10\ \Omega\angle -53.13^\circ}$$
$$= 10\text{ A}\angle 53.13^\circ$$

$$\mathbf{V}_R = (10\text{ A}\angle 53.13^\circ)(6\ \Omega\angle 0^\circ) = 60\text{ V}\angle 53.13^\circ$$
$$\mathbf{V}_L = (10\text{ A}\angle 53.13^\circ)(7\ \Omega\angle 90^\circ) = 70\text{ V}\angle 143.13^\circ$$
$$\mathbf{V}_C = (10\text{ A}\angle 53.13^\circ)(15\ \Omega\angle -90^\circ) = 150\text{ V}\angle -36.87^\circ$$

$$P_T = EI\cos\theta = (100\text{ V})(10\text{ A})\cos 53.13^\circ = \mathbf{600\ W}$$
$$= I^2R = (10\text{ A})^2(6\ \Omega) = \mathbf{600\ W}$$
$$= \frac{V_R^2}{R} = \frac{(60\text{ V})^2}{6} = \mathbf{600\ W}$$

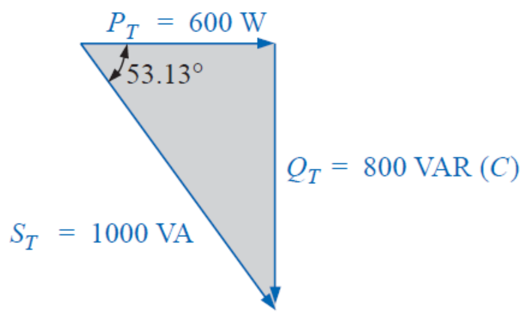
$$S_T = EI = (100\text{ V})(10\text{ A}) = \mathbf{1000\ VA}$$
$$= I^2Z_T = (10\text{ A})^2(10\ \Omega) = \mathbf{1000\ VA}$$
$$= \frac{E^2}{Z_T} = \frac{(100\text{ V})^2}{10\ \Omega} = \mathbf{1000\ VA}$$

$$Q_T = EI\sin\theta = (100\text{ V})(10\text{ A})\sin 53.13^\circ = \mathbf{800\ VAR}$$
$$= Q_C - Q_L$$
$$= I^2(X_C - X_L) = (10\text{ A})^2(15\ \Omega - 7\ \Omega) = \mathbf{800\ VAR}$$

$$Q_T = \frac{V_C^2}{X_C} - \frac{V_L^2}{X_L} = \frac{(150\text{ V})^2}{15\ \Omega} - \frac{(70\text{ V})^2}{7\ \Omega}$$
$$= 1500\text{ VAR} - 700\text{ VAR} = \mathbf{800\ VAR}$$

$$F_p = \frac{P_T}{S_T} = \frac{600\text{ W}}{1000\text{ VA}} = \mathbf{0.6\ leading\ (C)}$$

b)



EXAMPLE: An electrical device is rated 5 kVA, 100 V at a 0.6 power-factor lag. What is the impedance of the device in rectangular coordinates?

Solutions:

$S = EI = 5000\text{ VA}$

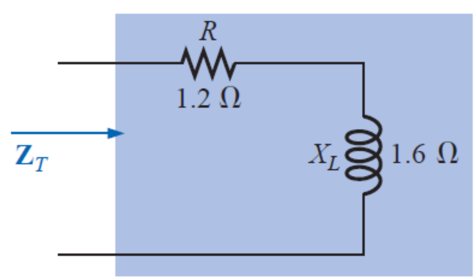
$$I = \frac{5000\text{ VA}}{100\text{ V}} = 50\text{ A}$$

$\theta = \cos^{-1} 0.6 = 53.13°$

for $\mathbf{E} = 100\text{ V} \angle 0°$,

$$\mathbf{I} = 50\text{ A} \angle -53.13°$$

$$\mathbf{Z}_T = \frac{\mathbf{E}}{\mathbf{I}} = \frac{100\text{ V} \angle 0°}{50\text{ A} \angle -53.13°} = 2\ \Omega \angle 53.13° = \mathbf{1.2\ \Omega\ + j\,1.6\ \Omega}$$

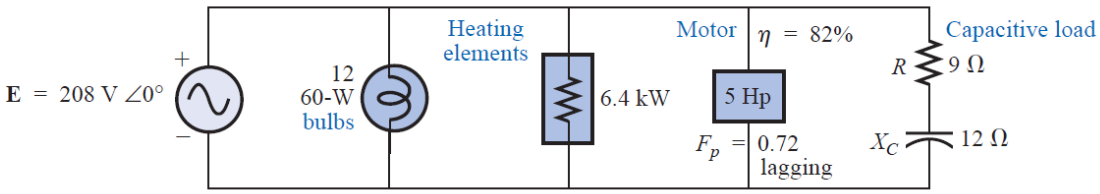


EXAMPLE: For the system

a. Find the average power, apparent power, reactive power, and *Fp* for each branch.

b. Find the total number of watts, volt-amperes reactive, and volt-amperes, and the power factor of the system. Sketch the power triangle.

c. Find the source current *I*.



Solutions:

a)

Bulbs:

Total dissipation of applied power

$$P_1 = 12(60\text{ W}) = \mathbf{720\ W}$$
$$Q_1 = \mathbf{0\ VAR}$$
$$S_1 = P_1 = \mathbf{720\ VA}$$
$$F_{p_1} = \mathbf{1}$$

Heating elements:

Total dissipation of applied power

$$P_2 = \mathbf{6.4\ kW}$$
$$Q_2 = \mathbf{0\ VAR}$$
$$S_2 = P_2 = \mathbf{6.4\ kVA}$$
$$F_{p_2} = \mathbf{1}$$

Motor:

$$\eta = \frac{P_o}{P_i} \longrightarrow P_i = \frac{P_o}{\eta} = \frac{5(746\text{ W})}{0.82} = \mathbf{4548.78\ W} = P_3$$

$$F_p = \mathbf{0.72\ lagging}$$

$$P_3 = S_3 \cos\theta \longrightarrow S_3 = \frac{P_3}{\cos\theta} = \frac{4548.78\text{ W}}{0.72} = \mathbf{6317.75\ VA}$$

Also, $\theta = \cos^{-1} 0.72 = 43.95°$, so that

$$Q_3 = S_3 \sin\theta = (6317.75\text{ VA})(\sin 43.95°)$$
$$= (6317.75\text{ VA})(0.694) = \mathbf{4384.71\ VAR\ (\mathit{L})}$$

Capacitive load:

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{208\ \text{V} \angle 0°}{9\ \Omega - j\ 12\ \Omega} = \frac{208\ \text{V} \angle 0°}{15\ \Omega \angle -53.13°} = 13.87\ \text{A} \angle 53.13°$$

$$P_4 = I^2R = (13.87\ \text{A})^2 \cdot 9\ \Omega = \mathbf{1731.39\ W}$$

$$Q_4 = I^2X_C = (13.87\ \text{A})^2 \cdot 12\ \Omega = \mathbf{2308.52\ VAR\ (\mathit{C})}$$

$$S_4 = \sqrt{P_4^2 + Q_4^2} = \sqrt{(1731.39\ \text{W})^2 + (2308.52\ \text{VAR})^2}$$

$$= \mathbf{2885.65\ VA}$$

$$F_p = \frac{P_4}{S_4} = \frac{1731.39\ \text{W}}{2885.65\ \text{VA}} = \mathbf{0.6\ leading}$$

b)

$$P_T = P_1 + P_2 + P_3 + P_4$$

$$= 720\ \text{W} + 6400\ \text{W} + 4548.78\ \text{W} + 1731.39\ \text{W}$$

$$= \mathbf{13{,}400.17\ W}$$

$$Q_T = \pm Q_1 \pm Q_2 \pm Q_3 \pm Q_4$$

$$= 0 + 0 + 4384.71\ \text{VAR}\ (L) - 2308.52\ \text{VAR}\ (C)$$

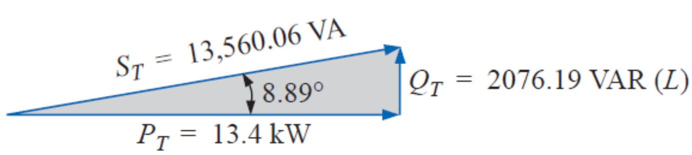
$$= \mathbf{2076.19\ VAR\ (\mathit{L})}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \sqrt{(13{,}400.17\ \text{W})^2 + (2076.19\ \text{VAR})^2}$$

$$= 13{,}560.06\ \text{VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{13.4\ \text{kW}}{13{,}560.06\ \text{VA}} = \mathbf{0.988\ lagging}$$

$$\theta = \cos^{-1} 0.988 = 8.89°$$



c)

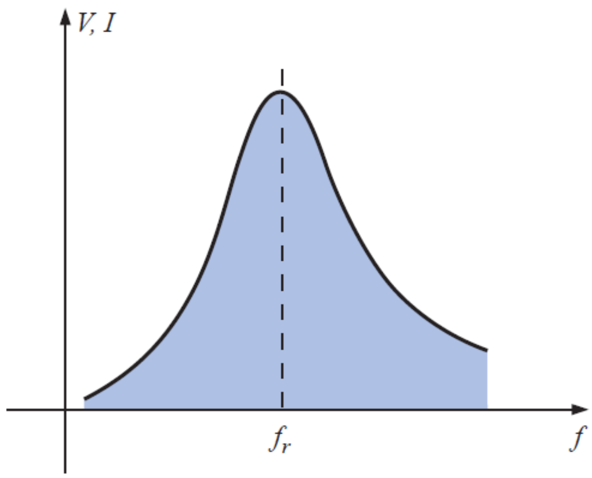
$$S_T = EI \longrightarrow I = \frac{S_T}{E} = \frac{13{,}559.89\ \text{VA}}{208\ \text{V}} = 65.19\ \text{A}$$

Lagging power factor: **E** leads **I** by 8.89°, and

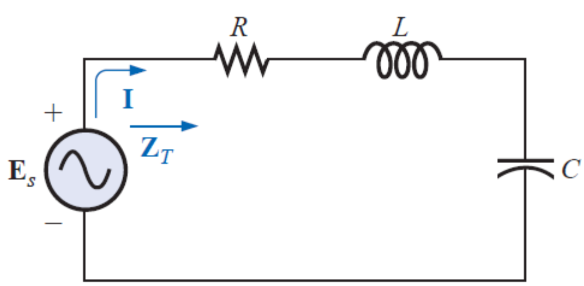
$$\mathbf{I = 65.19\ A \angle -8.89°}$$

Resonance

The resonant circuit is a combination of R, L, and C elements having a frequency response characteristic similar to the one appearing in Figure below. Note in the figure that the response is a maximum for the frequency fr, decreasing to the right and left of this frequency.



1-SERIES RESONANT CIRCUIT



$$\mathbf{Z}_T = R + j\,X_L - j\,X_C = R + j\,(X_L - X_C)$$

$$X_L = X_C$$

$$\mathbf{Z}_{T_s} = R$$

$$\omega L = \frac{1}{\omega C} \quad \text{and} \quad \omega^2 = \frac{1}{LC}$$

$$\omega_s = \frac{1}{\sqrt{LC}}$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

f = hertz (Hz)
L = henries (H)
C = farads (F)

$$V_{L_s} = V_{C_s}$$

$$F_p = \cos\theta = \frac{P}{S}$$

$$F_{p_s} = 1$$

THE QUALITY FACTOR (*Q*)

The quality factor Q of a series resonant circuit is defined as the ratio of the reactive power of either the inductor or the capacitor to the average power of the resistor at resonance; that is,

$$Q_s = \frac{\text{reactive power}}{\text{average power}}$$

$$Q_s = \frac{I^2 X_L}{I^2 R}$$

$$Q_s = \frac{X_L}{R} = \frac{\omega_s L}{R}$$

$$Q_s = \frac{\omega_s L}{R} = \frac{2\pi f_s L}{R} = \frac{2\pi}{R}\left(\frac{1}{2\pi\sqrt{LC}}\right) L$$
$$= \frac{L}{R}\left(\frac{1}{\sqrt{LC}}\right) = \left(\frac{\sqrt{L}}{\sqrt{L}}\right)\frac{L}{R\sqrt{LC}}$$

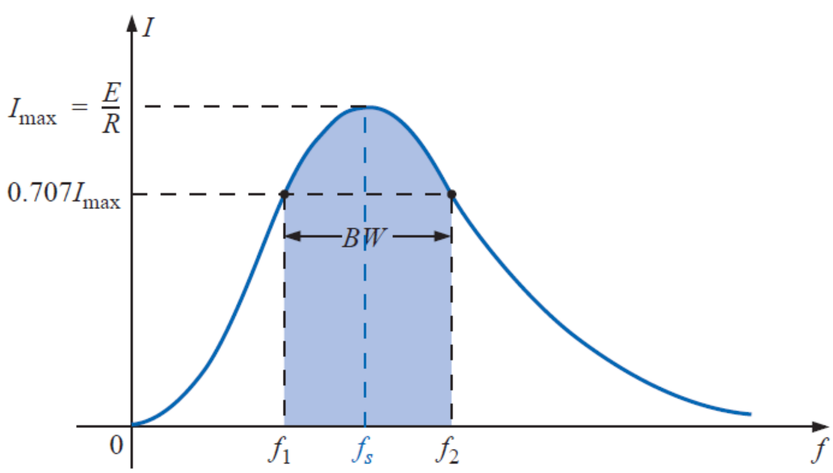
$$Q_s = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$V_{L_s} = Q_s E$$

$$V_{C_s} = Q_s E$$

SELECTIVITY

There is a definite range of frequencies at which the current is near its maximum value and the impedance is at a minimum. Those frequencies corresponding to 0.707 of the maximum current are called the **band frequencies**, **cutoff frequencies**, or **half-power frequencies**. They are indicated by f1 and f2 in Figure below. The range of frequencies between the two is referred to as the bandwidth (abbreviated BW) of the resonant circuit.



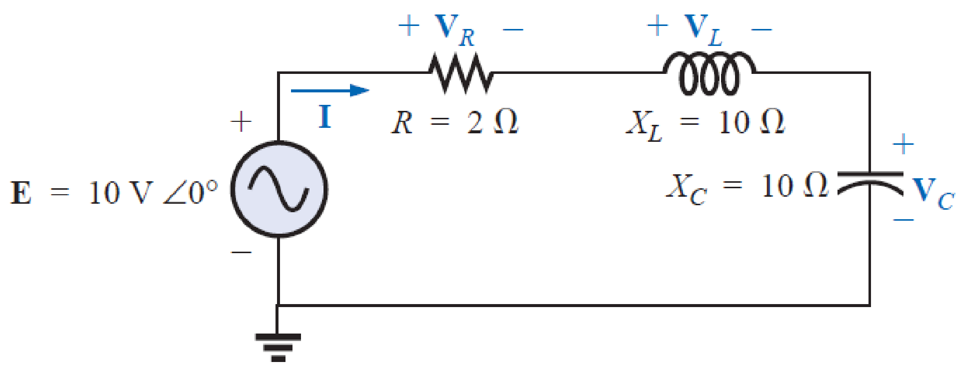
$$P_{HPF} = \frac{1}{2} P_{max}$$

$$BW = f_2 - f_1 = \frac{R}{2\pi L}$$

$$BW = \frac{f_s}{Q_s}$$

EXAMPLE:

a. For the series resonant circuit, find **I**, **V**R, **V**L, and **V**C at resonance.
b. What is the Qs of the circuit?
c. If the resonant frequency is 5000 Hz, find the bandwidth.
d. What is the power dissipated in the circuit at the half-power frequencies?



Solutions:

a. $\mathbf{Z}_{T_s} = R = 2\ \Omega$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_{T_s}} = \frac{10\ \text{V}\ \angle 0^\circ}{2\ \Omega\ \angle 0^\circ} = \mathbf{5\ A\ \angle 0^\circ}$$

$$\mathbf{V}_R = \mathbf{E} = 10\ \text{V}\ \angle 0^\circ$$

$$\mathbf{V}_L = (I\ \angle 0^\circ)(X_L\ \angle 90^\circ) = (5\ \text{A}\ \angle 0^\circ)(10\ \Omega\ \angle 90^\circ) = \mathbf{50\ V\ \angle 90^\circ}$$

$$\mathbf{V}_C = (I\ \angle 0^\circ)(X_C\ \angle -90^\circ) = (5\ \text{A}\ \angle 0^\circ)(10\ \Omega\ \angle -90^\circ) = \mathbf{50\ V\ \angle -90^\circ}$$

b. $Q_s = \dfrac{X_L}{R} = \dfrac{10\ \Omega}{2\ \Omega} = \mathbf{5}$

c. $BW = f_2 - f_1 = \dfrac{f_s}{Q_s} = \dfrac{5000\ \text{Hz}}{5} = \mathbf{1000\ Hz}$

d. $P_{\text{HPF}} = \dfrac{1}{2}P_{\text{max}} = \dfrac{1}{2}I^2_{\text{max}}R = \left(\dfrac{1}{2}\right)(5\ \text{A})^2(2\ \Omega) = \mathbf{25\ W}$

EXAMPLE: The bandwidth of a series resonant circuit is 400 Hz.
a. If the resonant frequency is 4000 Hz, what is the value of *Qs*?
b. If *R* = 10 Ω, what is the value of *XL* at resonance?
c. Find the inductance *L* and capacitance *C* of the circuit.

Solutions:

a. $BW = \dfrac{f_s}{Q_s}$ or $Q_s = \dfrac{f_s}{BW} = \dfrac{4000\ \text{Hz}}{400\ \text{Hz}} = \mathbf{10}$

b. $Q_s = \dfrac{X_L}{R}$ or $X_L = Q_sR = (10)(10\ \Omega) = \mathbf{100\ \Omega}$

c. $X_L = 2\pi f_s L$ or $L = \dfrac{X_L}{2\pi f_s} = \dfrac{100\ \Omega}{2\pi(4000\ \text{Hz})} = \mathbf{3.98\ mH}$

$$X_C = \frac{1}{2\pi f_s C} \quad \text{or} \quad C = \frac{1}{2\pi f_s X_C} = \frac{1}{2\pi(4000\ \text{Hz})(100\ \Omega)} = \mathbf{0.398\ \mu F}$$

EXAMPLE: A series *R*-*L*-*C* circuit has a series resonant frequency of 12,000 Hz.
a. If *R* = 5 Ω, and if *XL* at resonance is 300 Ω, find the bandwidth.
b. Find the cutoff frequencies.

Solutions:

a. $Q_s = \dfrac{X_L}{R} = \dfrac{300\ \Omega}{5\ \Omega} = 60$

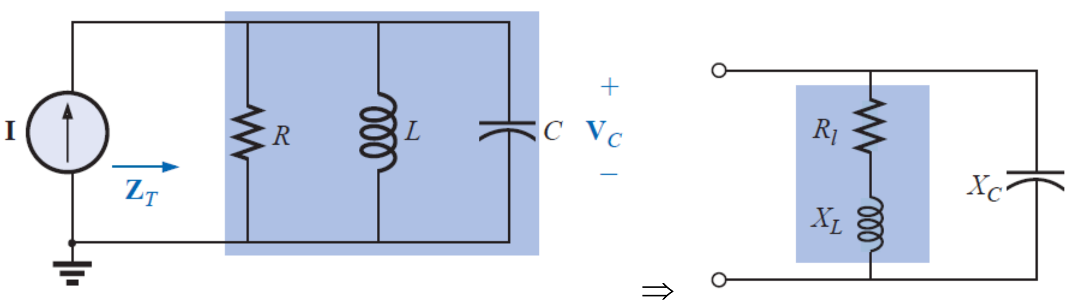
$$BW = \frac{f_s}{Q_s} = \frac{12{,}000\ \text{Hz}}{60} = \mathbf{200\ Hz}$$

b. Since $Q_s \geq 10$, the bandwidth is bisected by f_s. Therefore,

$$f_2 = f_s + \frac{BW}{2} = 12{,}000\ \text{Hz} + 100\ \text{Hz} = \mathbf{12{,}100\ Hz}$$

and $f_1 = 12{,}000\ \text{Hz} - 100\ \text{Hz} = \mathbf{11{,}900\ Hz}$

2-PARALLEL RESONANT CIRCUIT



$$R_p = \frac{R_l^2 + X_L^2}{R_l}$$

$$X_{L_p} = \frac{R_l^2 + X_L^2}{X_L}$$

$$X_{L_p} = X_C$$

$$f_p = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R_l^2 C}{L}}$$

$$f_p = f_s\sqrt{1 - \frac{R_l^2 C}{L}}$$

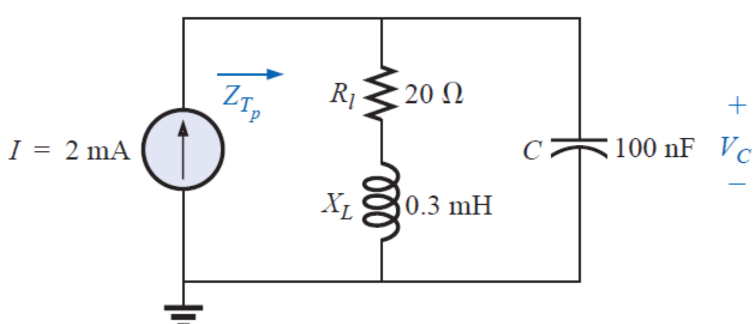
SELECTIVITY CURVE FOR PARALLEL RESONANT CIRCUITS

$$Q_p = \frac{X_L}{R_l} = Q_l$$

$$BW = f_2 - f_1 = \frac{f_r}{Q_p}$$

EXAMPLE: For the parallel resonant circuit

a. Determine *fs*, and *fp*, and compare their levels.
b. Determine the quality factor *Qp*.
c. Calculate the bandwidth.



Solutions:

a. $f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.3\text{ mH})(100\text{ nF})}} = \mathbf{29.06\ kHz}$

$$f_p = f_s\sqrt{1 - \frac{R_l^2 C}{L}} = (29.06\ \text{kHz})\sqrt{1 - \left[\frac{(20\ \Omega)^2(100\ \text{nF})}{0.3\ \text{mH}}\right]}$$
$$= \mathbf{27.06\ kHz}$$

b.

$$Q_p = \frac{R_s \parallel R_p}{X_{L_p}} = \frac{R_p}{X_{L_p}} = Q_l = \frac{X_L}{R_l}$$
$$= \frac{2\pi(27.06\ \text{kHz})(0.3\ \text{mH})}{20\ \Omega} = \frac{51\ \Omega}{20\ \Omega} = \mathbf{2.55}$$

c.

$$BW = \frac{f_p}{Q_p} = \frac{27.06\ \text{kHz}}{2.55} = \mathbf{10.61\ kHz}$$