وزارة التعليم العالي والبحث العلمي
الجامعة التقنية الشمالية
المعهد التقني الدور

الحقيبة التعليمية

القسم العلمي:	تقنيات الأجهزة الطبية
اسم المقرر:	دوائر التيار الكهربائي المستمر
المرحلة / المستوى:	الاول
الفصل الدراسي:	الاول
السنة الدراسية:	2025-2024

اسم المقرر:	دوائر التيار الكهربائي المستمر				
القسم:	تقنيات الأجهزة الطبية				
الكلية:	المعهد التقني الدور				
المرحلة / المستوى	الاول				
الفصل الدراسي:	الاول				
عدد الساعات الاسبوعية:	نظري	2	عملي	2	
عدد الوحدات الدراسية:	4				
الرمز:	MDDI100				
نوع المادة	نظري		عملي		كلهما *
هل يتوفر نظير للمقرر في الاقسام الاخرى					
اسم المقرر النظير					
القسم					
رمز المقرر النظير					
معلومات تدريسي المادة					
اسم مدرس (مدرسي) المقرر:	فلاح محمد عبد				
اللقب العلمي:	مدرس				
سنة الحصول على اللقب	2022				
الشهادة :	دكتوراه				
سنة الحصول على الشهادة	**2022**				
عدد سنوات الخبرة (تدريس)	**20 سنة**				

نموذج وصف المقرر

دراسة مفهوم الكهرباء والجهد الكهربائي والمواد العازلة والتيار المستمر وكيفية ربط الدائرة الكهربائية

1	المؤسسة التعليمية	الجامعة التقنية الشمالية/المعهد التقني الدور
2	القسم العلمي / المركز	تقنيات الأجهزة الطبية
3	اسم و رمز المقرر	دوائر التيار الكهربائي المستمر/MDDI100
4	اشكال الحضور المتاحة	الزامي
5	الفصل / السنة	**الفصل االول)15 اسبوع(/ المستوى االول**
6	عدد الساعات الدراسية (الكلي)	4 ساعة أسبوعيا -)60(ساعه بالفصل
7	تأريخ اعداد الوصف	2024/2/3
8	اهداف المقرر	قدرة الطالب على ربط الدوائر الكهربائية علمياً في المختبر و تحديد الخطأ .
9	مخرجات البرنامج المطلوبة وطرائق التعليم والتعلم والتقييم	
	أ- الاهداف المعرفية	
أ-1	دراسة مفهوم الكهرباء والجهد الكهربائي والمواد العازلة والتيار المستمر وكيفية ربط الدائرة الكهربائية	
	ب- ا الاهداف لمهاراتية الخاصة بالبرنامج	
ب-1	الطريقة التقليدية في القاء المحاضرة	
ب-2	استخدام التقنيات الحديثة في بعض المواضيع)السبورة الذكية -DATA SHOW واستخدام الأجهزة المختبرية الحديثة	
	طرائق التعليم والتعلم ((المحاضرات النظرية / المحاضرات العملية / الورشة / حل الأمثلة / مشروع التخرج / التدريب الصيفي))	
	طرائق التقييم ((الاختيارات الشفهية/ الاختبارات التحريرية/ التقارير الأسبوعية / الحضور اليومي/ الامتحانات الفصلية والنهائية))	
	ج- الاهداف الوجدانية والقيمية	
ج-1	قدرة الطالب على ربط الدوائر الكهربائية علمياً في المختبر	
ج-2	تنمية قدرة الطالب على تحديد الخطأ في ربط الدوائر الكهربائية	
	طرائق التعليم والتعلم ((المحاضرات النظرية / المحاضرات العملية / الورشة / حل الامثلة / مشروع التخرج / التدريب الصيفي))	
	طرائق التقييم ((الاختبارات الشفهية/ الاختبارات التحريرية/ الملاحظة/ السجل التراكمي للطالب))	
	د- المهارات العامة والتأهيلية المنقولة (المهارات الأخرى المتعلقة بقابلية التوظيف والتطور الشخصي)	
د-1	تحسين مهاراتهم النقاشية	
د-2	رفع مدركاتهم البحثية ونقل الطالب من مرحلة التعليم الى التعلم	
11	البنى التحتية	
*	الكتب المقررة المطلوبة	متوفرة في مجانية القسم ومكتبة المعهد
*	المراجع الرئيسية)الرئيسية(	متوفرة في مجانية القسم ومكتبة المعهد
	المراجع الإلكترونية، مواقع الأنترنيت	شبكة الأنترنيت

12	خطة تطوير المناهج
	- استحداث مناهج دراسية ملائمة مع سوق العمل ت علمية تستهدف تحديث المناهج الدراسية - متابعة التطورات العلمية في مجال التخصص

10. بنية المقرر

المقرر الدراسي :- دوائر التيار الكهربائي المستمر المستوى الاول :- الفصل الاول

الأسبوع	الساعات	مخرجات التعلم المطلوبة	اسم الموضوع	طريقة التعلم	طريقة التقييم
1	4	المعرفة والتطبيق العملي	نظام الوحدات الكهربائية - تطبيقات الرياضيات - تعريف الوحدات الأساسية للجهد والتيار والمقاومة - مكونات الدائرة الكهربائية - قانون أوم - العوامل المؤثرة على المقاومة - مقاومة الموصلات والعوازل - تأثير درجة الحرارة على المقاومة- درجة الحرارة معامل. المقاومة- أمثلة	عملي+ نظري	الاختبارات والتقارير
2	4	المعرفة والتطبيق العملي	تشمل دوائر التيار المستمر: سلسلة اتصال المقاومات والأمثلة- التوصيل الموازي للمقاومات والأمثلة - ربط النجم والدلتا للمقاومات، -جمع ربط المقاومات والأمثلة- التحويل بين النجم والدلتا مع أمثلة	عملي + نظري	الاختبارات والتقارير
3	4	المعرفة والتطبيق العملي	على التوصيلات المتسلسلة والمتوازية والمدمجة والنجومية	عملي + نظري	الاختبارات والتقارير
4	4	المعرفة والتطبيق العملي	قوانين كيرشوف- قوانين كيرشوف للتيار والجهد مع أمثلة	عملي + نظري	الاختبارات والتقارير
5	4	المعرفة والتطبيق العملي	قانون ماكسويل مع األمثلة	عملي + نظري	الاختبارات والتقارير
6	4	المعرفة والتطبيق العملي	كيفية التقديم في تيار مستمر -Thevinin تعريف نظرية	عملي + نظري	الاختبارات والتقارير
7	4	المعرفة والتطبيق العملي	تعريف نظرية نورتون - كيفية التقديم في التيار المستمر	عملي + نظري	الاختبارات والتقارير
8	4	المعرفة والتطبيق العملي	أمثلة على نظريات ثفنن ونورتون	عملي + نظري	الاختبارات والتقارير
9	4	المعرفة والتطبيق العملي	تعريف نظرية موقع الغشاء - تطبيق نظرية الموضع في التيار المستمر- أمثلة- ماكس. نظرية نقل الطاقة مع الأمثلة	عملي + نظري	الاختبارات والتقارير
10	4	المعرفة والتطبيق العملي	كميات التيار المتردد - تعريف خصائص التيار المتردد - توليد تيار - RMS التيار المتردد مع رسم شكل الموجة - عامل شكل قيمة أمثلة	عملي + نظري	الاختبارات والتقارير
11	4	المعرفة والتطبيق العملي	لزاوية Phasor متجه لكميات التيار المتردد - تعريفه - تمثيل ، اضرب ، .Subt، المرحلة AC. - الناتج عن إضافة المتجه قسمة مع أمثلة	عملي + نظري	الاختبارات والتقارير
12	4	المعرفة والتطبيق العملي	يار المتردد على دارة الحث فقط المقاومة - دائرة المكثف فقط - زاوية الطور بين الجهد والتيار مع أمثلة	عملي + نظري	الاختبارات والتقارير
13	4	المعرفة والتطبيق العملي	تأثير تيار التيار المتردد على المقاومة والتحريض في سلسلة مقاومة الدائرة والمكثف في سلسلة المقاومة والتحريض والمكثف في سلسلة - زاوية الطور - المعاوقة الكلية مع أمثلة	عملي + نظري	الاختبارات والتقارير
14	4	المعرفة والتطبيق العملي	تأثير التيار المتردد على المقاومة والتحريض في مقاومة الدائرة المتوازية والمكثف في المقاومة المتسلسلة والحث والمكثف في سلسلة - زاوية الطور - المعاوقة الكلية مع أمثلة	عملي + نظري	الاختبارات والتقارير
15	4	المعرفة والتطبيق العملي	إيجاد الممانعة الكلية - تيار القبول الكلي j استخدام عامل التشغيل، والجهد وزاوية الطور للممانعات المتسلسلة والمتوازية مع الأمثلة	عملي + نظري	الاختبارات والتقارير

curriculum description form

Study the concept of electricity, electrical voltage, insulating materials, direct current, and how to connect an electrical circuit

1	Educational institution	Northern Technical University / Technical Institute Adour
2	Scientific department/center	Medical Instruments technologies
3	Curriculum name and code	**DC Electrical circuits (MDDI100)**
4	Available attendance forms	Mandatory
5	Semester/year	First trimester (15 weeks)\ First Level.
6	Number of study hours (total)	4 hours per week (60 hours).
7	Date the description was prepared	3/2/2024
8	curriculum objectives	The student's ability to scientifically connect electrical circuits in the laboratory and identify errors
9	curriculum outcomes and teaching, learning and evaluation methods	

A - Cognitive objectives	
A-1	Study the concept of electricity, electrical voltage, insulating materials, direct current, and how to connect an electrical circuit
B - The program's Marathi goals	
B-1	The traditional method of giving a lecture .Using modern technologies in some topics (smart board - data show and using devices) Modern laboratory
Teaching and learning methods ((Theoretical lectures/practical lectures))	
Evaluation methods ((Oral exams / written exams / semester and final exams))	
C - emotional and value goals	
C-1	The student's ability to scientifically connect electrical circuits in the laboratory Developing the student's ability to identify errors in connecting electrical circuits
Teaching methods ((Theoretical lectures/practical lectures))	
Evaluation methods .((Oral exams / written exams / semester and final exams))	
D- General and qualifying transferred skills (other skills related to employability and personal development)	
D-1	Improving his physical fitness and increasing his ability to bear the muscular and motor demands of work

10. Curriculum structure					
Week	hours	Learning Outcomes	Unit/module or topic title	Teaching method	Assessment Method
1	4	Acknowledgment and Practical application	Electric units system- Mathmatic applications- definition of basic units of voltage, current and resistance-electric circuit components- ohm's law- factors effecting on resistance- resistivity of conductors and insulators- effect of temp. on resistance- temp. Coeff. of resistance- Examples	Practical+ Theoretical	Quizzes+ Reports
2	4	Acknowledgment and Practical application	DC current circuits includes: -Series connection of resistances and examples -Parallel connection of resistances and examples -Combined connection of resistances and examples -Star and delta connection of resistances, conversion between star and delta with examples	Practical+ Theoretical	Quizzes+ Reports
3	4	Acknowledgment and Practical application	Applications on series, parallel, combined and star- delta connections	Practical+ Theoretical	Quizzes+ Reports
4	4	Acknowledgment and Practical application	Kirchoff Laws- Kirchoff current and voltage laws with examples	Practical+ Theoretical	Quizzes+ Reports
5	4	Acknowledgment and Practical application	Maxwell's law with examples	Practical+ Theoretical	Quizzes+ Reports
6	4	Acknowledgment and Practical application	Definition of Thevenin’s theorem- How to apply in dc current	Practical+ Theoretical	Quizzes+ Reports

7	4	Acknowledgment and Practical application	Definition of Norton's theorem- How to apply in dc current	Practical+ Theoretical	Quizzes+ Reports
8	4	Acknowledgment and Practical application	Examples on Thevinin's and Norton's theorems	Practical+ Theoretical	Quizzes+ Reports
9	4	Acknowledgment and Practical application	Definition of Supper position theorem- application of it in dc current-examples- Max. power transfer theorem with examples	Practical+ Theoretical	Quizzes+ Reports
10	4	Acknowledgment and Practical application	AC quantities- definition of AC current characteristics – generation of AC current with waveform drawing- RMS value- Form factor – examples	Practical+ Theoretical	Quizzes+ Report s
11	4	Acknowledgment and Practical application	Vector of AC quantities- definition of it – Phasor representation of its- phase angle- resultant of vector AC add., Subt., multiply, division with examples	Practical+ Theoretical	Quizzes+ Reports
12	4	Acknowledgment and Practical application	Effect of AC current on only resistance circuit-only inductance circuit- only capacitor circuit- phase angle between voltage and current with examples	Practical+ Theoretical	Quizzes+ Reports
13	4	Acknowledgment and Practical application	Effect of AC current on resistance and inductance in series circuit- resistance and capacitor in series- resistance and inductance and capacitor in series- phase angle- total impedance with examples	Practical+ Theoretical	Quizzes+ Reports
14	4	Acknowledgment and Practical application	Effect of AC current on resistance and inductance in parallel circuit-resistance and capacitor in series- resistance and inductance and	Practical+ Theoretical	Quizzes+ Reports
			capacitor in series- phase angle- total impedance with examples		
15	4	Acknowledgment and Practical application	Using j-operator to find total impedance- total admittance- current, voltage and phase angle for impedances in series and parallel with examples	Practical+ Theoretical	Quizzes+ Reports

المحتوى العلمي

Resistors and Ohm’s Law

1- المقاومة الكهربائية (Electric Resistance)

عندما يمر التيار الكهربائي خلال مسار معين تفقد الالكترونات الطاقة الدافعة (الجهد) التي تتحول معضمها الى حرارة ويمكن تفسير ذلك بما يحدثه الموصل (مسار التيار) من مقاومة في طريق الالكترونات.

وتعرف المقاومة (Resistance) على انها هي خاصية اعاقة مرور التيار الكهربائي في الموصل وتقاس قيمة المقاومة بوحدة الاوم (Ohm) نسبة للعالم الالماني اوم ويرمز لها بالرمز (Ω).

ان مقلوب المقاومة تعرف بالتوصيلية (conductance) (G), وان وحدة قياس التوصيلية هي سمنز (siemens), s.

دائرة المقاوم هي الدائرة التي تبدد الطاقة الكهربائية (عادتاً على شكل حرارة).

ان المقاومة النوعية (المقاومية) Resistivity وهي خاصية للمادة, وتعتمد المقاومة الكهربائية لسلك الموصل على ثلاث عوامل:

1- نوع مادة الموصل ρ (حرف لاتيني رو)

2- طول السلك (l) حيث تتناسب (R) طردياً مع (l).

3- مساحة مقطع السلك (A) حيث تتناسب (R) عكسياً مع (A).

$$\because \qquad R \propto l \qquad , \qquad R \propto \frac{1}{A}$$

ومنها

$$R \propto \frac{l}{A}$$

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

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

وحدة قياس المقاومة النوعية هي (اوم. متر)($\Omega . m$).

Example 1:

Find the resistance of an aluminum wire that has a length of 1000 m and a diameter of 1.626 mm. The wire is at 20 C^0 with resistivity of $2.83*10^{-8}\Omega.m$

Solution:

$$A = \pi r^2$$

$$r = \frac{d}{2} = \frac{1.626*10^{-3}}{2} = 0.813*10^{-3}\,m$$

$$\because \rho = 2.83*10^{-8}\Omega.m$$

$$\therefore R = \rho\frac{l}{A} = 2.83*10^{-8}\frac{1000}{\pi(0.813*10^{-3})^2} = 13.6\Omega$$

Example 2: A coil consists of 2000 turns of copper wire having a cross-sectional area of $0.8mm^2$. The mean length per turn is 80cm and the resistivity of copper is $0.02\mu\Omega - m$. Find the resistance of the coil and power absorbed by the coil when connect across 110V d.c. supply.

Solution:

Length of the coil, $l = 0.8 \times 2000 = 1600\ m;$

$A = 0.8\ mm^2 = 0.8 \times 10^{-6}\ m^2.$

$$R = \rho\ \frac{l}{A} = 0.02 \times 10^{-6} \times \frac{1600}{0.8} \times 10^{-6} = 40\ \Omega$$

$$power\ absorbed = \frac{V^2}{R} = \frac{110^2}{40} = 302.5\ W$$

Example 3:

(a) A rectangular carbon block has dimensions 1.0 cm * 1.0 cm * 50 cm.

i. What is the resistance measured between the two square ends?
ii. Between two opposing rectangular faces / Resistivity of carbon at 20^0 C is $3.5*10^{-5}\ \Omega.\mathrm{m}$.

(b) A current of 5 A exists in a 10 Ω resistance for 4 minutes (i) how many coulombs and (ii) how many electrons pass through any section of the reisitoor in this time? Charge of the electron =$1.6*10^{-19}$ C.

Solution:

(a) (i) $R = \rho \frac{l}{A}$

Here, $A=1*1=1\ cm^2 = 10^{-4}\ m^2$; $l=0.5$ m

$R = 3.5 * 10^{-5}*0.5/10^{-4} = 0.175\ \Omega$

(ii) Here, $l= 1$ cm ; $A=1*50=50\ cm^2 = 5*10^{-3}\ m^2$

$R = 3.5 * 10^{-5} * 10^{-2}/(5 * 10^{-3}) = 7 * 10^{-5}\ \Omega$

(b) (i) $Q = I\,t = 5 * (4* 60) = 1200C$

(ii) $n = \frac{Q}{e} = \frac{1200}{1.6*10^{-19}} = 75 * 10^{20}$

وبما ان مقاومة الموصل تعتمد على درجة الحرارة ارتفاعاً وانخفاضاً فان العلاقة بين شدة التيار الكهربائي (I) وفرق الجهد (V) تكون غير خطية, والحقيقة ان التغيير في درجة الحرارة يسبب تغيراً في المقاومة النوعية وفق المعادلة التالية:

$$R = R_0(1 + \alpha \Delta T)$$

$$\rho = \rho_0(1 + \alpha \Delta T)$$

حيث ان (R) و (ρ) المقاومة النوعية والمقاومة عند درجة الحرارة الجديدة على التوالي.

(R_0) و(ρ_0)المقاومة النوعية والمقاومة عند درجة الحرارة المعلومة.

α : معامل المقاومة النوعية ووحدته [$1/C^0$] او [$1/k^0$].

ΔT: التغير في درجة الحرارة (T_2-T_1) ووحدته [C^0] او [k^0].

Example 4: A coil of copper wire has a resistance of 100Ω when its temperature is 0 C^0. Determine its resistance at 70 C^0 if the temperature coefficient of resistance of copper at 0 C^0 is 0.0043/C^0.

Solution:

$$R_{70} = R_0(1 + \alpha_0 \Delta T)$$

$$R_{70} = 100(1 + 0.0043 * 70)$$

$$= 100(1 + 0.301) = 130.1\Omega$$

Example 5: A platinum coil has a resistance of 3.146 Ω at 40^0 C and 3.767 Ω at 100^0C. Find the resistance at 0^0C .

Solution.

$$R_{100} = R_0(1 + 100\,\alpha_0) \quad ...(i)$$

$$R_{40} = R_0(1 + 40\,\alpha_0) \quad ...(ii)$$

$$\therefore \quad \frac{3.767}{3.146} = \frac{1 + 100\,\alpha_0}{1 + 40\,\alpha_0} \quad \text{or} \quad \alpha_0 = 0.00379 \quad \text{or} \quad 1/264 \text{ per}^\circ\text{C}$$

From (*i*), we have

$$3.767 = R_0(1 + 100 \times 0.00379) \quad \therefore R_0 = \mathbf{2.732\ \Omega}$$

Example 6: A potential difference of 250 V is applied to a field winding at 15^0C and the current is 5 A. what will be the mean temperature of the winding when current has fallen to 3.91 A, applied voltage being constant.

Assume $\alpha_{15} = 1/254.5$

Solution. Let R_1 = winding resistance at 15°C; R_2 = winding resistance at unknown mean temperature t_2°C.

$$\therefore \quad R_1 = 250/5 = 50\ \Omega;\ R_2 = 250/3.91 = 63.94\ \Omega$$

Now

$$R_2 = R_1[1 + \alpha_{15}(t_2 - t_1)] \quad \therefore 63.94 = 50\left[1 + \frac{1}{254.5}(t_2 - 15)\right]$$

$$\therefore \quad t_2 = \mathbf{86^\circ C}$$

Example 7: A coil of copper wire has resistance of 90 Ω at 20^0 C and is connected to a 230V supply. By how much the voltage will be increased in order to maintain the current constant if the temperature of the coil rises to 60^0 C? Take the temperature coefficient of resistance of copper as 0.00428 from 0^0C.

Solution. As seen from Art. 1.10

$$\frac{R_{60}}{R_{20}} = \frac{1+60\times 0.00428}{1+20\times 0.00428} \quad \therefore R_{60} = 90\times\ 1.2568/1.0856 = 104.2\ \Omega$$

Now, current at 20°C = 230/90 = 23/9 A

Since the wire resistance has become 104.2 Ω at 60°C, the new voltage required for keeping the current constant at its previous value = 104.2 × 23/9 = 266.3 V

∴ increase in voltage required = 266.3 − 230 = **36.3 V**

2- قانون اوم

كما ذكر سابقاً ان المقاومة في الدائرة الكهربائية تعيق مرور التيار في الموصل وباستخدام هذه الخاصية قام العالم أوم بإجراء بعض التجارب على الدوائر الكهربائية ووجد بالتجربة ان مرور التيار في دائرة ما يعتمد على قيمة المقاومة في الدائرة وعلى فرق الجهد بين طرفي المقاومة. ولقد بينت هذه التجارب ان هذه العلاقة هي علاقة خطية اي ان بزيادة قيمة المقاومة يكون مقدار النقص في التيار مماثلاً, والعكس صحيح ايضاً.

$$V \propto I$$

اي انه هنالك علاقة طردية بين التيار والجهد

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

والقانون السابق هو قانون أوم وينص على :

ان التيار المار في دائرة يتناسب طردياً مع فرق الجهد عكسياً مع المقاومة. وهو من اهم القوانيين حيث يعتمد عليه في تحليل الدوائر الكهربائية.

$$V = IR$$

و

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

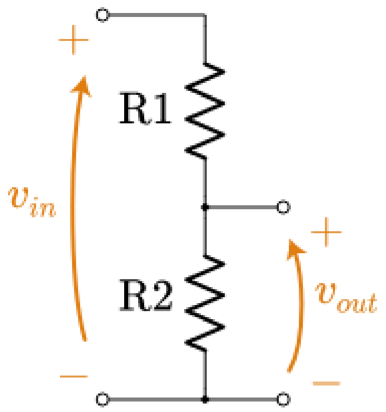
$$P = VI = I^2R = \frac{V^2}{R}$$

وكذلك

$$P = VI = V^2G = \frac{I^2}{G}$$

Voltage divider

A very common and useful resistor circuit goes by the nickname *voltage divider*. We will work out how this circuit works, and we'll see where the nickname comes from.



The voltage divider is really quite simple, and you could analyze it from scratch every time you come across one. But it is *so* common it is a good idea to prepare ahead of time so you can pop out the answer on the spot.

Written by Willy McAllister.

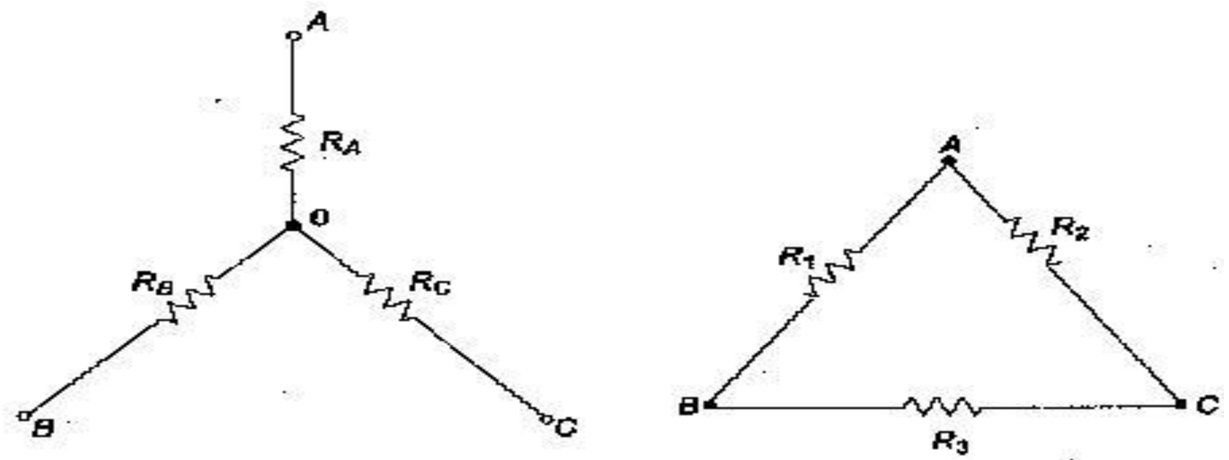
Contents

- [What's in a nickname?]

- # Where we're headed
- A "voltage divider" is the pattern of two resistor in series, with an input voltage applied to both ends and an output voltage measured across one of the resistors.
- The output voltage is a function of the input voltage and the ratio of resistor values,

Star Delta Control Circuit:

The star delta transformation is another technique useful in solving complex networks. Basically, any three circuit elements, i.e. resistive, inductive or capacitive, may be connected in two different ways. One way of connecting these elements is called the star connection, or the Y connection. The other way of connecting these elements is called the delta (Δ) connection. The circuit is said to be in Star Delta Control Circuit, if three elements are connected as shown in Fig. 3.1(a), when it appears like a star (Y). Similarly, the circuit is said to be in delta connection, if three elements are connected as shown in Fig. 3.1(b), when it appears like a delta (Δ).



(a) (b)

Fig. 3.1

The above two circuits are equal if their respective resistances from the terminals AB, BC and CA are equal. Consider the Star Delta Control Circuit in Fig. 3.1(a); the resistance from the terminals AB, BC and CA respectively are

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

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

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

From the above results, we can say that a star connected circuit can be transformed into a delta connected circuit and vice-versa.

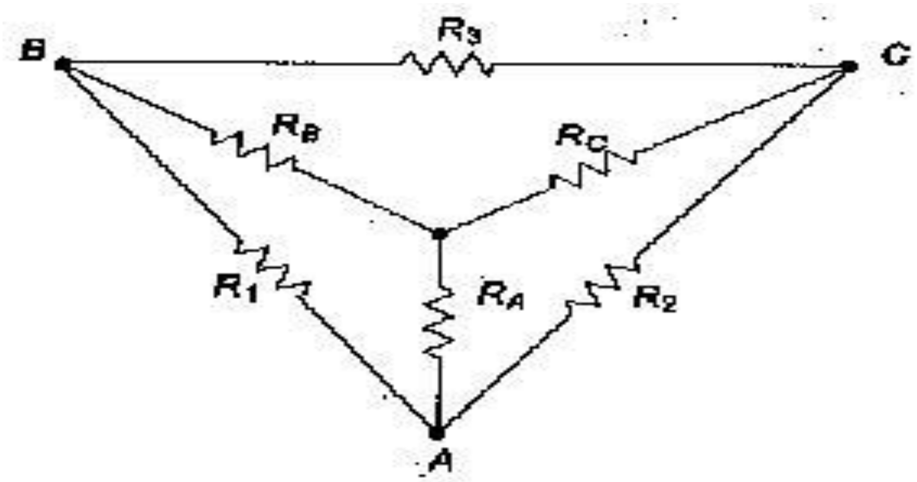
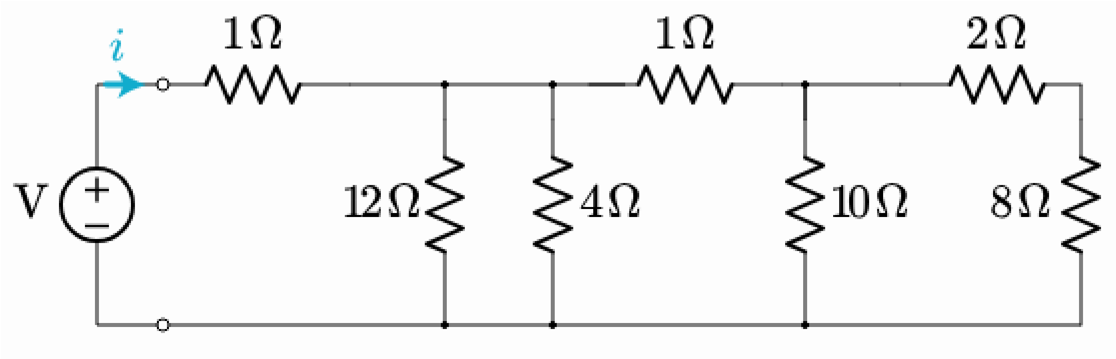


Fig. 3.2

From Fig. 3.2 and the above results, we can conclude that any resistance of the delta circuit is equal to the sum of the products of all possible pairs of star resistances divided by the opposite resistance of the star circuit. Similarly, any resistance of the star circuit is equal to the product of two adjacent resistances in the delta connected circuit divided by the sum of all resistances in delta connected circuit.

Simplify resistor networks



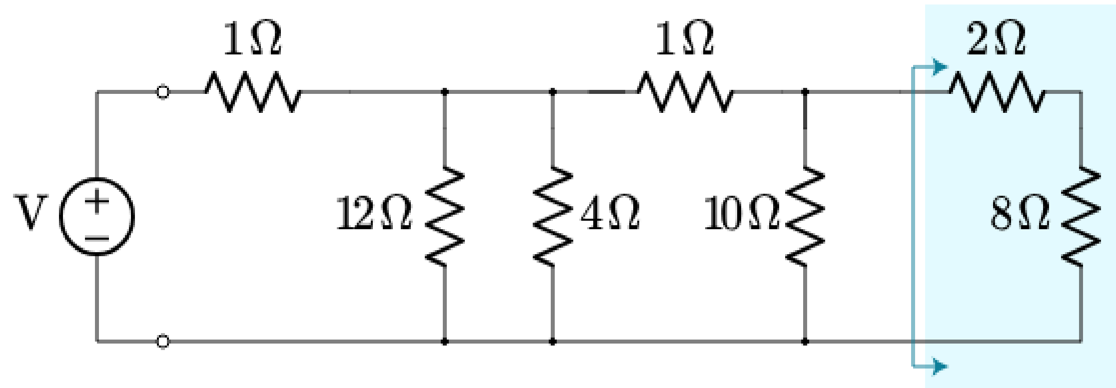
Here is the example circuit we will work through together

Step-by-step solution to the example

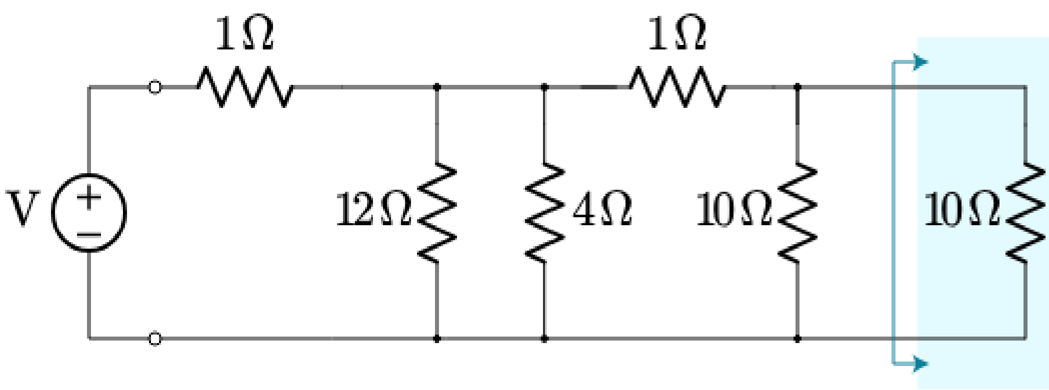
The original question asked about the current from the voltage source. So the “location in question” is near the voltage source on the far left end of the circuit. Therefore, we start the simplification process way over on the far right, and work our way back toward the source.

Simplifying a circuit is a process of many small steps. Consider a small chunk of circuit, simplify, and then move to the next chunk. Tip: Redraw the schematic after every step so you don’t miss an opportunity to simplify.

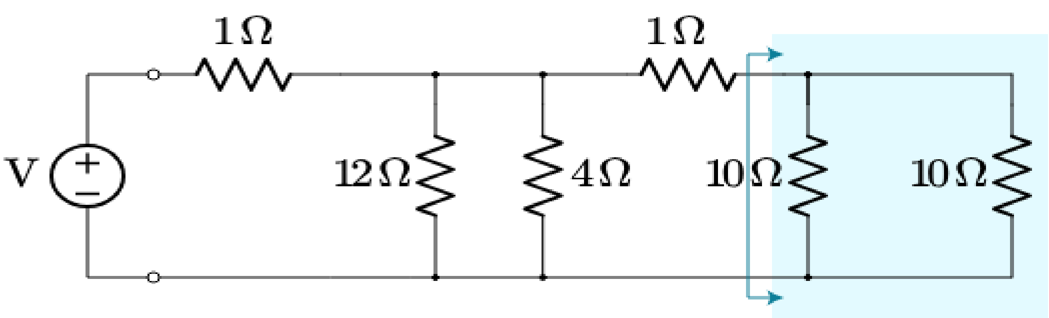
Step 1. The shaded resistors, 2 Ω2\,\Omega2Ω and 8 Ω8\,\Omega8Ω, are in series



The two resistors can be replaced by their equivalent resistance



Step 2. We now find two $10\,\Omega$ resistors in parallel at the new far right of the circuit.



These two resistors can be replaced by their parallel combination.

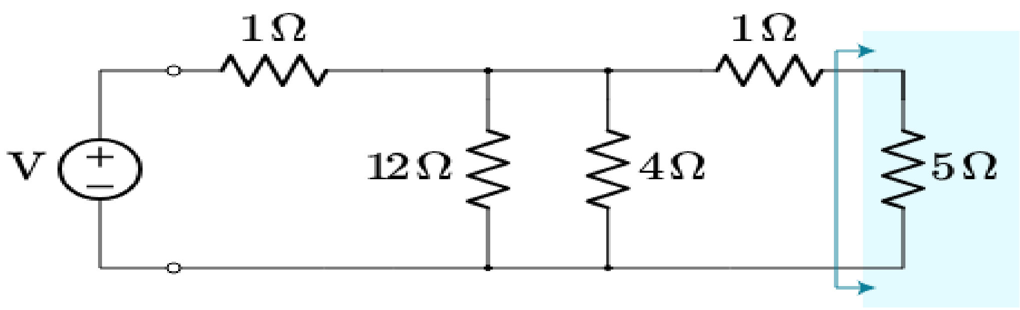
The resulting equivalent resistor is: ______ Ω.

show answer

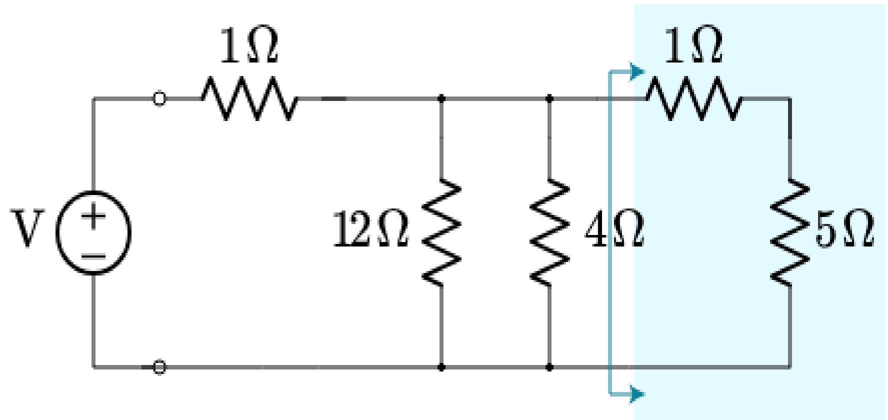
$10\,\Omega \parallel 10\,\Omega = \dfrac{10\cdot 10}{10 + 10}=5\,\Omega$

The $\parallel$ notation means "in parallel with".

Again, looking into the shaded box from the left, the current and voltage with the equivalent $5\,\Omega$ resistor is still indistinguishable from the entire original.

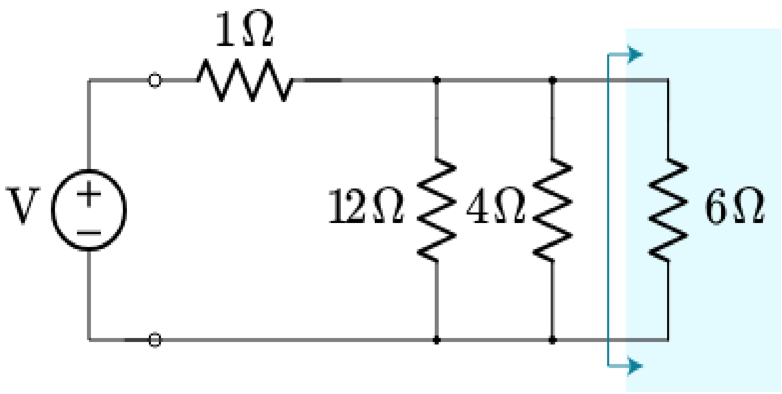


Step 3. Can you see a pattern emerging? We are working through the schematic from right to left, simplifying and redrawing as we go. Next up we find two series resistors, 1 Ω1\,\Omega1Ω and 5 Ω5\,\Omega5Ω.

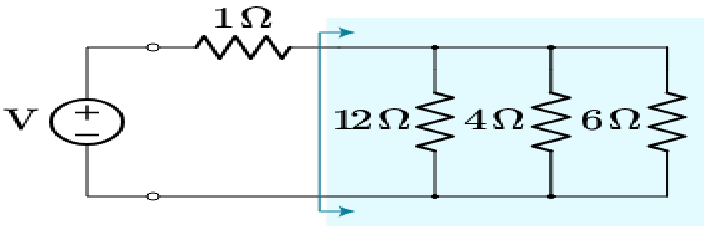


These series resistors can be replaced by an equivalent resistance of: ______ Ω\OmegaΩ.

show answer



Step 4. This step is a bit more challenging. We have three resistors in parallel.



These three resistors can be replaced by their parallel combination.

The resulting equivalent resistor is: ______ Ω\OmegaΩ.

hint

Because we have three resistors in parallel, use the full parallel resistor equation,

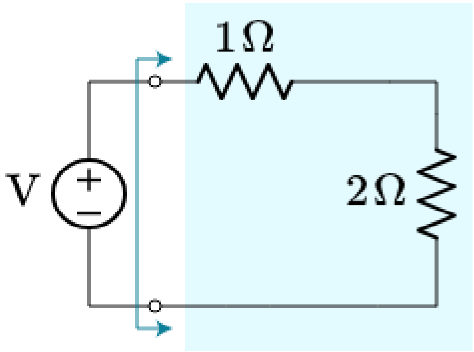
1Rparallel=1R1+1R2+1R3\dfrac{1}{\text R_{\text{parallel}}} = \dfrac{1}{\text{R1}} +\dfrac{1}{\text{R2}} + \dfrac{1}{\text{R3}}Rparallel1=R11+R21+R31

show answer

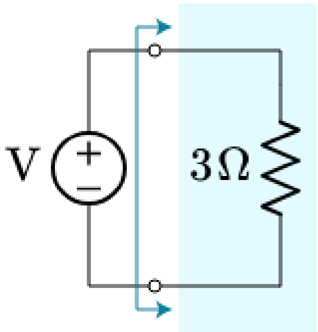
1Rparallel=(112 Ω+14 Ω+16 Ω)=(112+312+212)=12\dfrac{1}{\text R_{\text{parallel}}} = \left (\dfrac{1}{12\,\Omega} +\dfrac{1}{4\,\Omega} + \dfrac{1}{6\,\Omega}\right) = \left (\dfrac{1}{12} +\dfrac{3}{12} + \dfrac{2}{12} \right)= \dfrac{1}{2}Rparallel1=(12Ω1+4Ω1+6Ω1)=(121+123+122)=21

So the equivalent resistance is the reciprocal of 12\dfrac{1}{2}21, or 2 Ω2\,\Omega2Ω.

Step 5. We are down to the last two series resistors,



You can do this one in your head



We are left with a single $3\,\Omega$ resistor. As far as the voltage source can tell, this one resistor is equivalent to the entire

Q1-Find the resistance of an aluminum wire that has a length of 1000 m and a diameter of 1.626 mm. The wire is at 20 C^0 with resistivity of 2.83*10-8Ω.m ?

Q2-A platinum coil has a resistance of 3.146 Ω at 400 C and 3.767 Ω at 1000C. Find the resistance at 0 ^0C ?

Q3- Find the equivalent resistance Δ→Y and Y → Δ transformation ?

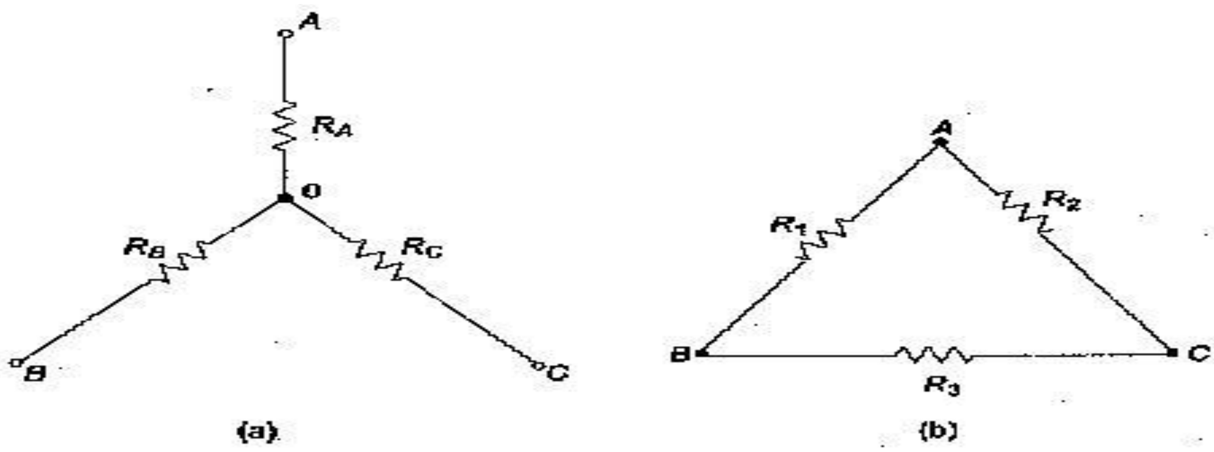


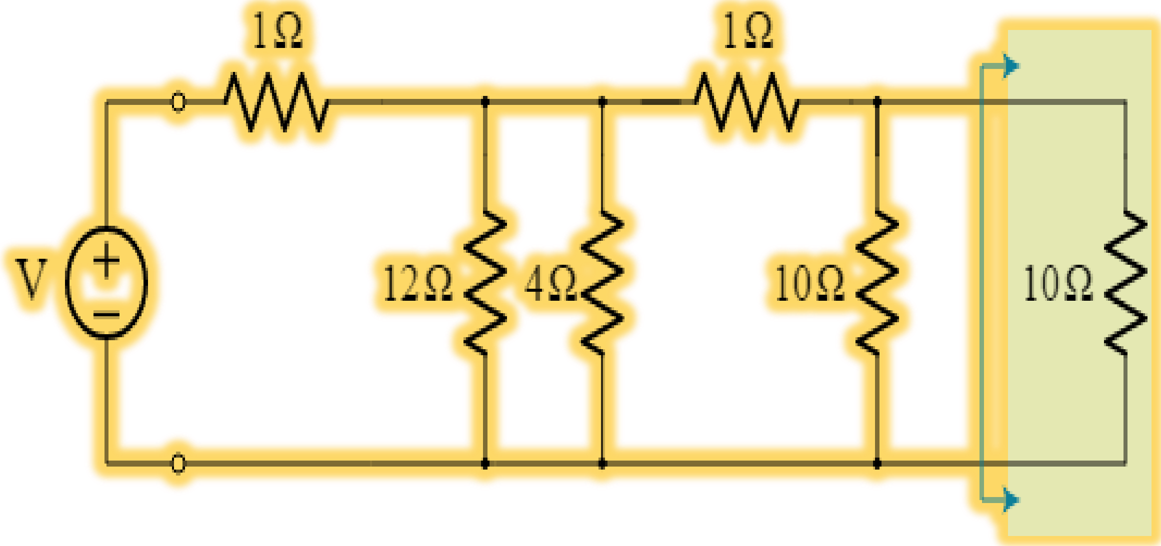
Fig. 3.1

Q4- A rectangular carbon block has dimensions 1.0 cm * 1.0 cm * 50 cm.

i-What is the resistance measured between the two square ends?

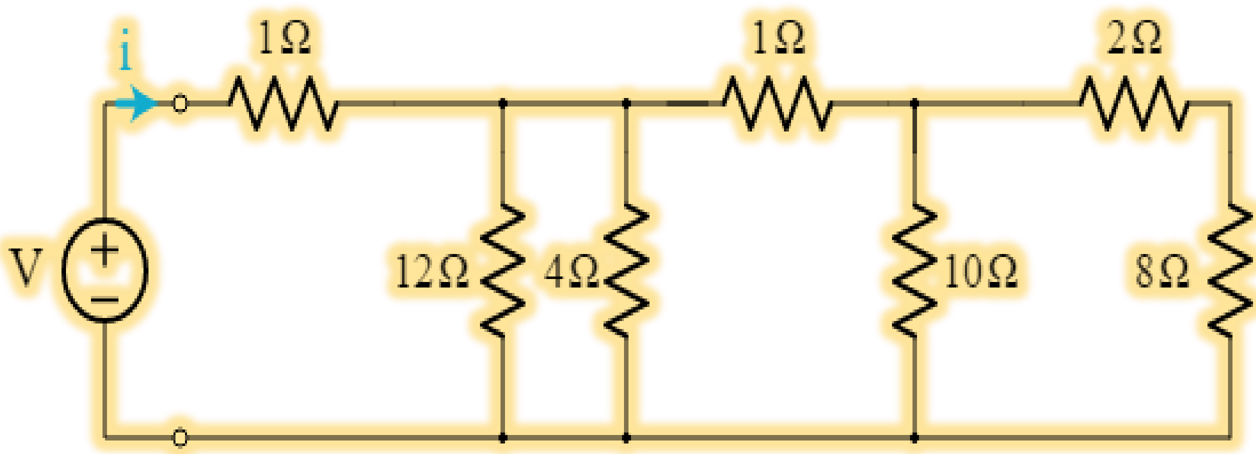
ii- Between two opposing rectangular faces / Resistivity of carbon at 20^{0}C is 3.5*10-5 Ω.m.

Q5- Simplifying resistor networks of the circuit?



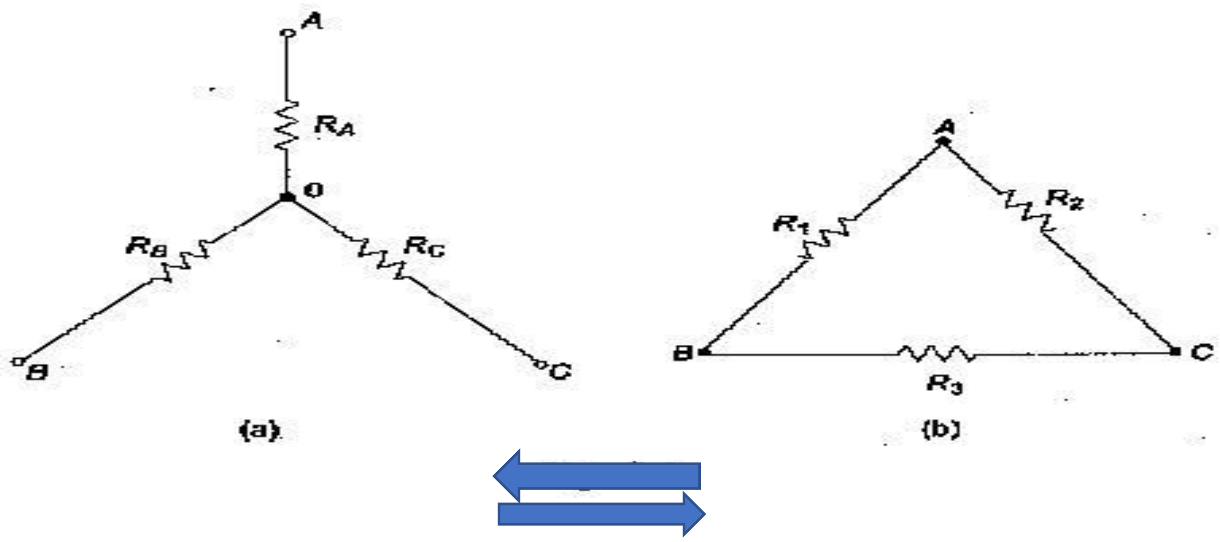
Q6-A coil consists of 2000 turns of copper wire having a cross-sectional area of $0.8mm^2$. The mean length per turn is 80cm and the resistivity of copper is 0.02μΩ-m. Find the resistance of the coil and power absorbed by the coil when connect across 110V d.c. supply?

Q7-Simplifying resistor networks of the circuit?



Q8-A coil of copper wire has a resistance of 100Ω when its temperature is 0 C^0. Determine its resistance at 70 C^0 if the temperature coefficient of resistance of copper at 0 C^0 is 0.0043/C^0.

Q9-Find the equivalent resistance Δ→Y and Y → Δ transformation ?



Q10- A potential difference of 250 V is applied to a field winding at 150C and the current is 5 A. what will be the mean temperature of the winding when current has fallen to 3.91 A, applied voltage being constant.
Assume α_

Thévenin's Theorem

Thévenin's theorem is named after Léon Charles Thévenin. It states that:

Any single port linear network can be reduced to a simple voltage source, E_{th}, in series with an internal impedance Z_{th}.Any single port linear network can be reduced to a simple voltage source, Eth, in series with an internal impedance Zth.

It is important to note that a Thévenin equivalent is valid only at a particular frequency. If the system frequency is changed, the reactance and impedance values will change and the resulting E_{th}Eth and Z_{th}Zth values will be altered. Consequently, these equivalents are generally not appropriate for a circuit using multiple sources with differing frequencies[1]. A generic example of a Thévenin equivalent is shown in Figure 5.4.15.4.1.

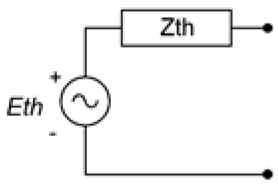


Figure 5.4.15.4.1: Generic Thévenin equivalent circuit.

The phrase "single port network" means that the original circuit is cut in such a way that only two connections exist to the remainder of the circuit. That remainder may be a single component or a large multi-component sub-circuit. E_{th}Eth is the open circuit voltage at the port and Z_{th}Zth is the impedance looking back into the port (i.e., the equivalent that now drives the remainder). As there are many ways to cut a typical circuit, there are many possible Thévenin equivalents. Consider the circuit shown in Figure 5.4.25.4.2.

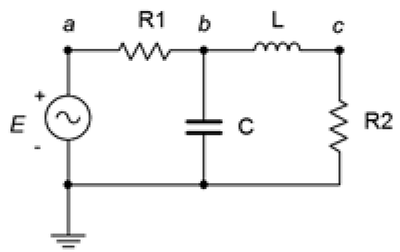


Figure 5.4.25.4.2: Circuit under consideration for a Thévenin equivalent.

Suppose we want to find the Thévenin equivalent that drives R_2R2. We cut the circuit immediately to the left of R_2R2. That is, The first step is to make the cut, removing the remainder of the circuit. In this case the remainder is just R_2R2. We then determine the open circuit output voltage at the cut points (i.e., at the open port). This voltage is called the Thévenin voltage, E_{th}Eth. This is shown in Figure 5.4.35.4.3. In a circuit such as this, basic series-parallel analysis techniques may be used to find E_{th}Eth. In this circuit, due to the open, no current flows through the inductor, LL, and thus no voltage is developed across it. Therefore, E_{th}Eth must equal the voltage developed across the capacitor, CC.

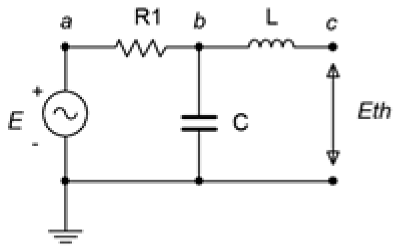


Figure 5.4.35.4.3: E_{th}Eth,the open circuit output voltage.

The second part is finding the Thévenin impedance, Z_{th}Zth. Beginning with the “cut” circuit, replace all sources with their ideal internal impedance (thus shorting voltage sources and opening current sources). From the perspective of the cut point, look back into the circuit and simplify to determine its equivalent impedance. This is shown in Figure 5.4.45.4.4. Looking in from where the cut was made (right side), we see that R_1R1 and X_CXC are in parallel, and this combination is then in series with X_LXL. Thus, Z_{th}Zth is equal to $jX_L+(R1||-jX_C)$jXL+(R1||−jXC).

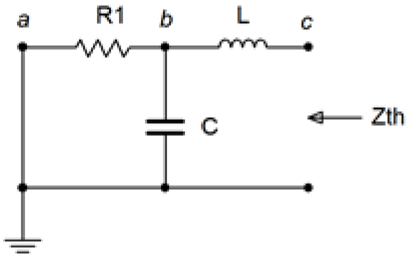


Figure 5.4.45.4.4: Finding Z_{th}Zth.

As noted earlier, the original circuit could be cut in a number of different ways. We might, for example, want to determine the Thévenin equivalent that drives CC in the original circuit of Figure 5.4.25.4.2. The new port location appears in Figure 5.4.55.4.5.

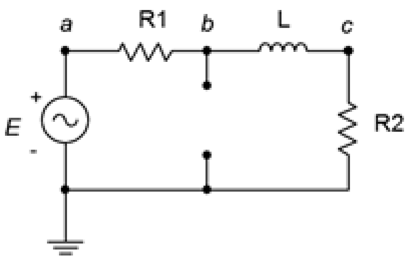


Figure 5.4.55.4.5: An alternate port location.

Clearly, this will result in different values for both E_{th}Eth and Z_{th}Zth. For example, Z_{th}Zth is now $R_1||(R_2+jX_L)$R1||(R2+jXL).

A common error is to find Z_{th}Zth from the wrong perspective, namely, finding the impedance that the source drives. This is flatly incorrect. Remember, Z_{th}Zth is found by looking into the port and simplifying whatever is seen from there. One way to remember this is that it is possible to create equivalents for multi-source circuits. In that instance, there isn't a single driving source, so finding its load impedance is nonsensical.

Measuring the Thévenin Equivalent in the Laboratory

In a laboratory situation, the Thévenin equivalent can be found quickly and efficiently with the proper tools. First, the circuit is “cut”, leaving just the portion to be Thévenized. The voltage at the cut points is measured with an oscilloscope. This is E_{th}. All of the sources are then replaced with their internal impedance, ideally shorting voltage sources and opening current sources[2]. An LCR impedance meter can then be connected to the port to read Z_{th}. If an impedance meter is not available, then the source(s) are left in place and an LCR substitution box is placed at the cut points. The box is adjusted so that the voltage across it is equal to half of E_{th}. By the voltage divider rule, the value of the substitution box must be equal to Z_{th}. In this case, the substitution box will yield either an inductance or capacitance value which can then be turned into a reactance given the frequency.

Example 5.4.1

For the circuit of Figure 5.4.6, determine the Thévenin equivalent that drives the 300 Ω resistor and find v_c. Assume the source angle is 0°.

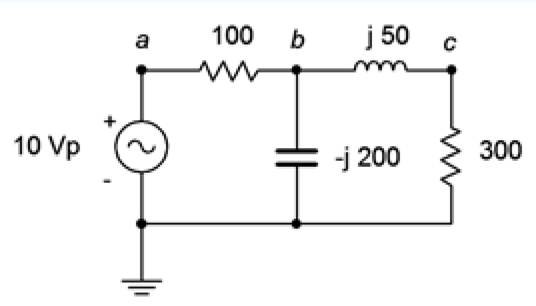


Figure 5.4.6: Circuit for Example 5.4.1.

First, let's find E_{th}, the open circuit output voltage. We cut the circuit so that the 300 Ω resistor is removed. Then we determine the voltage at the cut points. This circuit is shown in Figure 5.4.7.

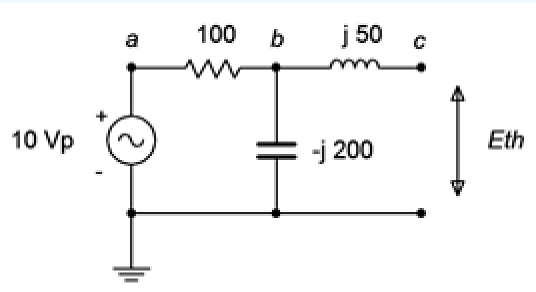


Figure 5.4.7: Circuit for finding E_{th} for Example 5.4.1.

There is no current flowing through the inductor due to the open. Therefore, the voltage across the inductor is zero. Consequently, E_{th} is the voltage across the capacitor, and that can be found with a voltage divider.

$$E_{th} = E \frac{X_C}{X_C + R_1}$$

$$E_{th} = 10\angle 0^{\circ} V \frac{-j200\Omega}{-j200\Omega + 100\Omega}$$

$$E_{th} = 8.944\angle -26.6^{\circ} V \text{ or } 8 - j4 V$$

To find Z_{th}, we replace the source with a short and then look back in from the cut points. The equivalent circuit is shown in Figure 5.4.8. The inductor is in series with the parallel combination of the resistor and capacitor.

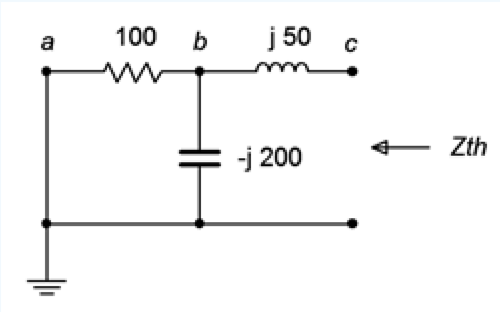


Figure 5.4.8: Circuit for finding Z_{th} for Example 5.4.1.

$$Z_{left2} = \frac{R \times jX_C}{R - jX_C}$$

$$Z_{left2} = \frac{100\,\Omega \times (-j200\,\Omega)}{100\,\Omega - j200\,\Omega}$$

$$Z_{left2} = 89.44\angle -26.6^\circ\,\Omega$$

$$Z_{th} = Z_{left2} + X_L$$

$$Z_{th} = 89.44\angle -26.6^\circ\,\Omega + j50\,\Omega$$

$$Z_{th} = 80.62\angle 7.12^\circ\,\Omega \text{ or } 80 + j10\,\Omega$$

The completed equivalent is shown in Figure 5.4.9.

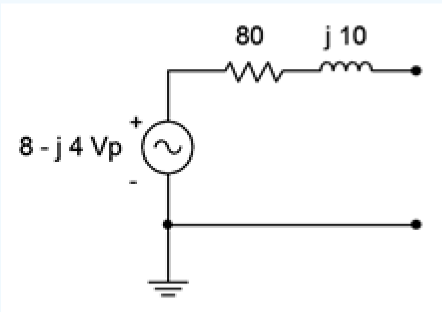


Figure 5.4.9: Completed equivalent for Example 5.4.1.

The voltage across the 300 Ω resistor can be found directly:

$$v_{R2} = E_{th}\frac{R_2}{Z_{th} + R_2}$$

$$v_{R2} = 8 - j4\,V \frac{300\,\Omega}{80 + j10\,\Omega + 300\,\Omega}$$

$$v_{R2} = 7.06\angle -28.1^\circ\,V$$

This value can be verified by following a standard series-parallel simplification. For example, the impedance of the three rightmost components $(181.4\angle -53.97^\circ\,\Omega)$ forms a voltage divider with the 100 Ω resistor and the 10 volt source. This leads to v_b $(7.156\angle -18.61^\circ$ volts). A second divider can then be used between v_b, the inductor and the 300 Ω resistor to find v_c, which is $7.06\angle -28.1^\circ$ volts as expected. The big advantage of using the Thévenin equivalent is that we can easily find v_c for any other value of load because we need only analyze the simpler equivalent circuit rather than the original.

Thévenin's theorem can also be used on multi-source circuits. The technique for finding Z_{th} does not change, however, finding E_{th} is a little more involved, as illustrated in the next example.

Example $5.4.2$

Find v_b for the circuit of Figure $5.4.10$ using Thévenin's theorem.

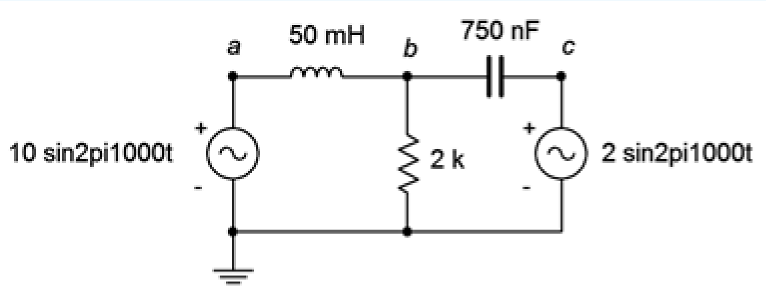


Figure $5.4.10$: Circuit for Example $5.4.2$.

This circuit is similar to the one used in Example 5.3.2 (Figure 5.3.5). The difference here is that the second source uses the same frequency as the first source. The reactance values are:

$$X_L = j314.2\Omega$$

$$X_C = -j212.2\Omega$$

The voltage across the 2 kΩ is v_b, so we'll treat that resistor as the load in order to define the equivalent circuit. This is redrawn in Figure $5.4.11$.

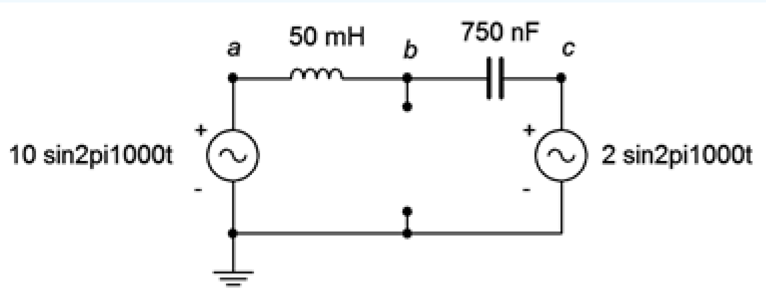


Figure $5.4.11$: Circuit for finding equivalents for Figure $5.4.10$.

To find Z_{th}, we short the two sources. We're left with the inductor and capacitor in parallel. If this is confusing, remember that we are looking from node b to ground (the cut points), so they are not in series. That is, if a sensing current entered at node b, it could split left and right, indicating parallel paths, not a series connection.

$$Z_{th} = \frac{-jX_C \times jX_L}{-jX_C + jX_L}$$

$$Z_{th} = \frac{-j212.2\,\Omega \times j314.2\,\Omega}{-j212.2\,\Omega + j314.2\,\Omega}$$

$$Z_{th} = -j653.7\,\Omega$$

We have a few options to find E_{th}. Superposition could be used, each circuit requiring a voltage divider. Alternately, the equivalent is basically a series loop as far as finding v_b is concerned. Thus, we could find the voltage across the inductor and subtract that from the left source (assuming a reference current direction of clockwise). Finding the inductor voltage requires either a voltage divider or finding the current. Neither approach is considerably less work than the other, and it's probably a good idea to get in a little more practice using superposition, so...

Considering the left source, we short the right source and find v_b.

$$v_{bR} = E_1 \frac{X_C}{X_C + X_L}$$

$$v_{bR} = 10\angle 0^\circ\,\text{V} \frac{-j212.2\,\Omega}{-j212.2\,\Omega + j314.2\,\Omega}$$

$$v_{bR} = 20.84\angle 180^\circ\,\text{V or } -20.84\angle 0^\circ\,\text{V}$$

For the right source, we short the left source and find v_b. Then we add the two contributions to find the final voltage. Note that both sources will produce a reference polarity of + to − from top to bottom.

$$v_{bL} = E_2 \frac{X_C}{X_C + X_L}$$

$$v_{bL} = 2\angle 0^\circ\,\text{V} \frac{j314.2\,\Omega}{-j212.2\,\Omega + j314.2\,\Omega}$$

$$v_{bL} = 6.16\angle 0^\circ\,\text{V}$$

The sum of the two is $-20.84\angle 0^\circ + 6.16\angle 0^\circ$, or $14.68\angle 180^\circ$ volts. The Thévenin equivalent is a source of $14.68\angle 180^\circ$ volts in series with an impedance of $-j653.7\,\Omega$.

To find the voltage across the 2 kΩ resistor, we apply it to the equivalent circuit and solve.

$$v_b = E_{th} \frac{R}{R + Z_{th}}$$

$$v_b = 14.68\angle 180^\circ\,\text{V} \frac{2\,\text{k}\Omega}{2\,\text{k}\Omega + (-j653.7\,\Omega)}$$

$$v_b = 13.95\angle -161.9^\circ\,\text{V}$$

Computer Simulation

To verify the results of the preceding example, the circuit of Figure 5.4.10 is captured in a simulator, as shown in Figure 5.4.12.

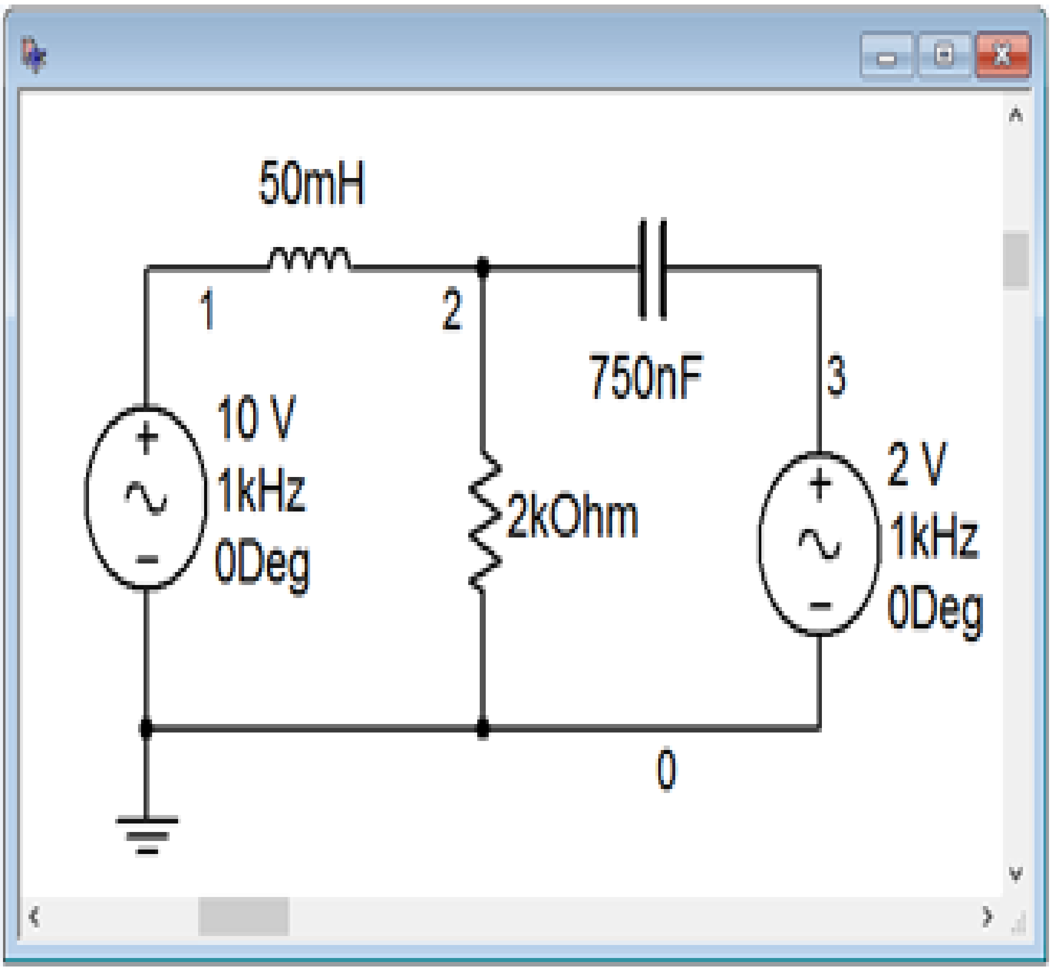


Figure 5.4.125.4.12: The circuit of Figure 5.4.105.4.10 captured in a simulator.

Next, a transient analysis is run, plotting the voltage at node 2, which corresponds to vbvb in the original circuit. The result is shown in Figure 5.4.135.4.13. The plot is delayed by 0.1 seconds in order to get past the initial turn-on transient