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EEE1A Tutorial #1 (held in Week 2)

Show your working where this is possible. Your preparation will be marked at the start of the tutorial.

1.5. Given that the current $i(t)$ is the rate of change of charge, find an expression for the current if the charge flowing through a wire is given by

(a) $q(t) = 3 - 5t + 3t^2$ coulombs

(b) $q(t) = 6 \sin(100t)$ coulombs

1.8. The amount of charge a battery can store is often expressed as ampere-hours (Ah) rather than Coulombs. 1Ah corresponds to a current of 1A for one hour (or 2A for half an hour etc).

(a) What is 1Ah in coulombs?

(b) Consider a battery which has a capacity of 10Ah. This can ideally deliver a current of 1A for 10hrs or 2A for 5hrs etc. How many hours can it deliver a current of 3.5A?

(c) A small MP3 audio player uses a AAA size rechargeable battery with a capacity of 0.9Ah (or 900mAh). The MP3 player draws a current of 50mA. If the rechargeable battery is fully charged, how long can the MP3 player be used for?

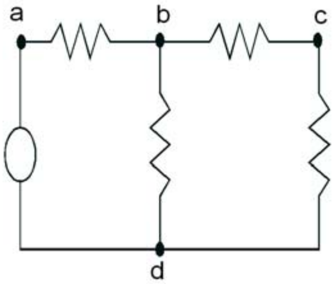
1.9. You are designing a solar-powered garden light. This uses a light-emitting diode (LED) which requires a current of 18mA. During the summer the light is typically on for 10 hours but in the winter it is on for 15 hours a day. During the day the solar panel produces a maximum current of 50 mA.

(a) What is the smallest battery capacity you should use in the light? Why would you generally use more than this in practice?

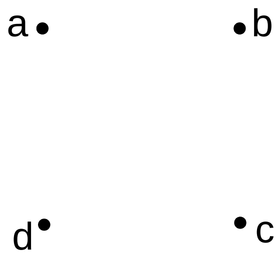
(b) After a winter's night, what is the length of time it would take the battery to recharge if the solar panel is producing maximum current? You can assume the battery was fully-charged at the start of the night.

1.10. Remember a node is a point in a circuit where two or more elements join:

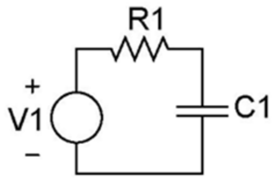
(a) The circuit below has four nodes, labeled a, b, c and d. Redraw the circuit using the template on the right, so it is clear that there are only four nodes (hint: see Slides A.2.5 of the lecture notes).

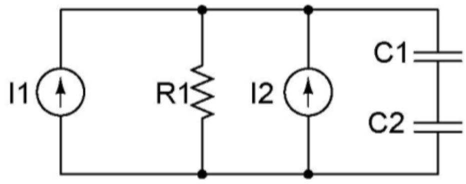


CIRCUIT

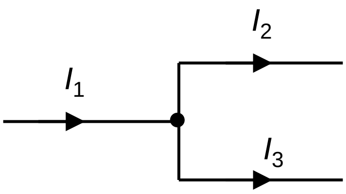


(b) Circle the nodes in the following two circuits and indicate how many nodes there are in the boxes below.





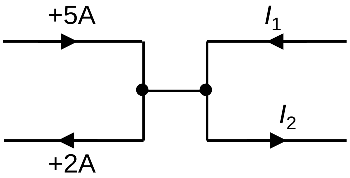
1.12. Consider the circuit shown below.



(a) Given the conservation of charge (i.e. charge cannot be created or destroyed), find an expression for I_1 in terms of I_2 and I_3.

(b) Hence if it is known that I_1 = 3A and I_2 = -5A and find I_3.

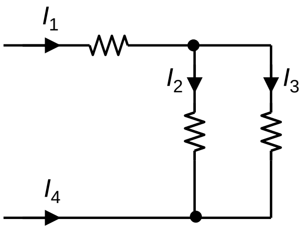
1.13. Consider the circuit shown below.



(a) If I_1 = -5A, find I_2.

(b) If I_1 = 0A, find I_2.

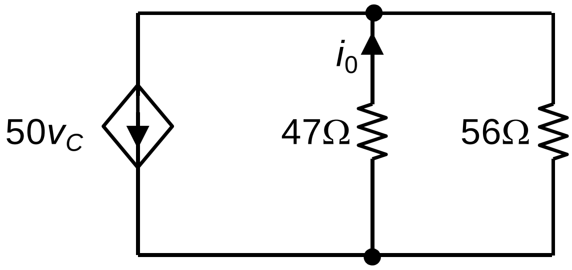
1.14. Consider the circuit below.



(a) If current I_1 = 3A and I_2 = 1A, then find I_3 and I_4.

(b) If current $I_2 = 2 \times I_3$ and I_4 = 4A, then find I_1, I_2 and I_3.

1.15. In the circuit below, label a current i_x along with its arrow such that the following KCL equation is satisfied: $i_x = i_0 - 50v_c$. Note the symbol of the diamond with the arrow in it is called a *voltage-controlled current source*, which we will cover later in the course. The key thing you need to know to answer this question is that the current flowing through the current source is in the direction of the arrow and has a magnitude of ($50v_C$) amps.



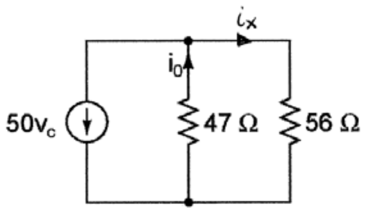
Brainteaser (optional question, not required to get full marks).

- Background : As will be discussed in Slides A5.5 of the notes, resistors come in only certain "preferred" values, for instance, values in the sequence: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68 and 82. Thus resistors are readily available in values such as 1Ω, 10Ω, 100Ω, 1kΩ, 12kΩ, 820kΩ and 2.2MΩ, however if you wanted a 10.5Ω or 130Ω resistor, these will either not be available or else significantly more expensive.
- Question : When resistors are put in "series" their total effective resistance is the sum of each value. Thus a 10Ω resistor in series with a 12Ω resistor is equivalent to a 10+12 = 22Ω, which just happens to be another "preferred" value. How many other series combinations of two preferred resistors can you find which produce another preferred value? I could find six others, perhaps you can find more!

1)
2)
3)
4)
5)
6)
?

Numerical Solutions

Ans : 1.5. (a) $i(t) = -5 + 6t$ A (b) 600 cos(100t) amps
Ans : 1.8. (a) 3600 C or 3.6 kC, (b) 2.857 hours, (c) 18 hours
Ans : 1.9. (a) 270mAhr. (b) 5.4 hours
Ans : 1.10. (a) see lecture notes slides A2.5, (b) 3, (c) 3
Ans : 1.12. (a) $I_1 = I_2 + I_3$, (b) $I_3 = 8$A
Ans : 1.13. (a) $I_2 = -2$A, (b) $I_2 = 3$A
Ans : 1.14. (a) $I_3 = 2$A $I_4 = -3$A, (b) $I_1 = -4$A, $I_2 = -2.667$A $I_3 = -1.333$A
Ans : 1.15.



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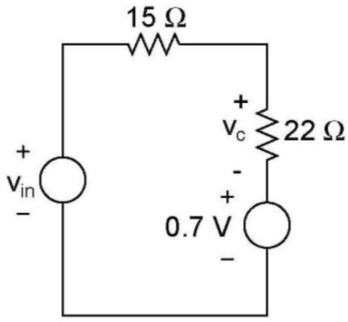
EEE1A Tutorial #2 (held in Week 3)

Show your working where this is possible. Your preparation will be marked at the start of the tutorial.

2.6. Consider the circuit below.

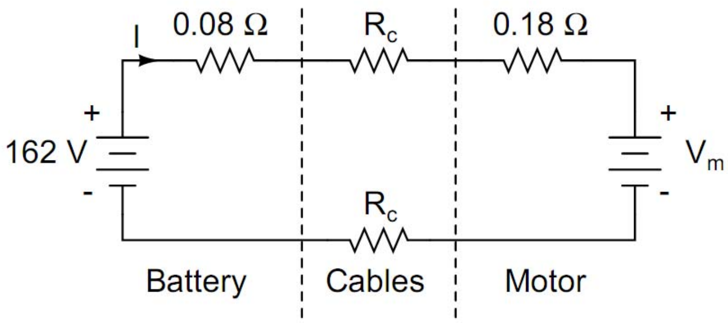
(a) Label a voltage v_x (across the 15 Ω resistor) along with its + and - symbols such that the following KVL equation is satisfied: $v_c = v_{in} – 0.7 – v_x$.



(b) How many nodes does the circuit have? (You can also think of nodes as points on the circuit which have different voltages).

2.18. The Citroën Berlingo is a popular delivery vehicle in France and the UK. The Electrique model has a 28 kW electric motor powered by a 162 V, 270 Ah battery. This gives it a range of 100 km and a top speed of 95 km/h. A scheme called regenerative braking is used in which the motor is used as a generator to slow the car. This returns some energy back to the battery.

The figure below shows a simple model of the electrical drive system on an electric car like a Berlingo. The motor is modelled as a V_m voltage source and a 0.18 Ω resistance. The battery is equivalent to a 162 V voltage source and a 0.08 Ω resistance. The cables between the battery and the engine each present a resistance shown as R_c.



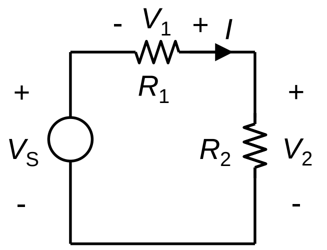
(d) If the current I is -150 A and the 4 resistors in the above figure are absorbing a total of 6.3 kW. What is the power flowing into the motor (that is, the voltage source V_m)? Hint : sum of powers absorbed by all elements in a circuit must be zero.

(e) In the previous part, if the car is running on a flat, smooth road, is the car:

- accelerating hard:
- decelerating hard: or
- running at approximately constant speed?

(g) The information given above indicates the car has a range of 100 km with a fully-charged battery. Assume this range is based on a constant speed of 50 kph. Calculate the length of time it takes to drive 100 km at this speed. Hence find the current required to discharge the 270 Ahr battery completely in this time. Hence estimate the power being supplied by the battery (the 162V voltage source).

2.19. Consider the circuit below.



(a) Find an equation relating the three voltages.

(b) Write Ohm's law for resistors R_1 and R_2 in terms of the corresponding voltages and currents.

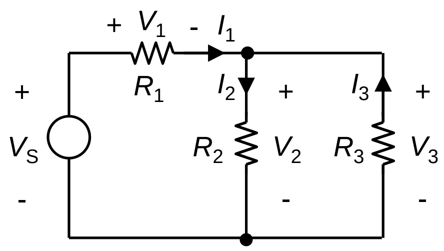
(c) Use the above two results to find an expression for I in terms of V_S, R_1 and R_2. This equation tells us that two resistors in "series" (that is, one after the other, or sharing the same current) are equivalent to a bigger resistance whose value is equal to the sum of the two resistances.

(d) Use the results from parts (b) and (c) to find an expression for V_2 in terms of V_S, R_1 and R_2. This equation is also called the "voltage divider" equation. We will talk more about it later.

(e) Write equations for the power absorbed in each of the three circuit elements in terms of the circuit voltages and currents.

(f) If $V_S = 9\text{V}$, $R_1 = 2\text{k}\Omega$ and $R_2 = 3\text{k}\Omega$, use the above results to find I, V_1 and V_2. Also find the power absorbed in each of the three circuit elements. Which elements are absorbing power and which are producing power?

2.20. Consider the circuit below.



(a) Use Kirchhoff's current law to find a relationship between I_1, I_2 and I_3.

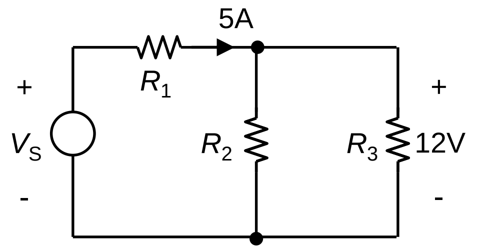
(b) Use Kirchhoff's voltage law to find two voltage equations, one for the left loop (V_S, V_1 and V_2) and one for the right loop (V_2 and V_3)

(c) Use Ohm's law to write equations for the three resistors.

(d) Using the equations from parts (a) to (c), and given that V_S = 12V, R_1 = 4Ω, R_2 = 8Ω, and R_3 = 10Ω, solve for all the voltages and currents in the circuit. Hint : as a first step, substitute the results from part (c) into part (b). With the KCL equation from part (a), you should now have three equations with three unknowns I_1, I_2 and I_3 (voltages V_1, V_2 and V_3 should no longer appear in these equations and you know the values for V_S, R_1, R_2 and R_3). Substitute the known values of V_S, R_1, R_2 and R_3 and solve the equations to find I_1, I_2 and I_3 and hence all the circuit voltages and currents.

Also find the power absorbed by each circuit element.

2.21. Consider the circuit below where R_1 = 6Ω, R_2 = 3Ω, and R_3 = 12Ω. Hint : remember the relations $P = I^2R$ and $P = V^2/R$.

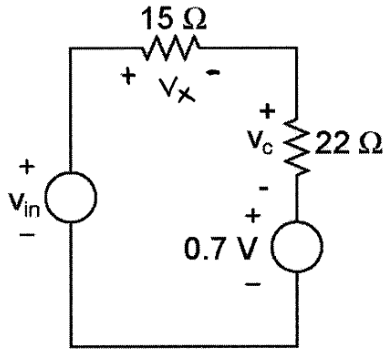


(a) Find the power absorbed in each resistor.

(b) Using the results from part (a), find the power absorbed by the voltage source and hence the voltage V_S.

Answers

Ans : 2.6. 4 nodes



Ans 2.18. (d) -30.60kW (e) decelerating hard. (g) 2 hours, 135A, 21.87 kW

Ans : 2.19 (a) $V_S + V_1 = V_2$ (or equivalent equation) (b) $V_1 = - I R_1$, $V_2 = I R_2$, (c) $I = V_S / (R_1 + R_2)$, (d) $V_2 = V_S \times R_2/ (R_1 + R_2)$, (e) P(in V_S) = $-V_S I$, P(in R_1) = $-V_1 I$, P(in R_2) = $+V_2 I$, (f) I = 1.8 mA, V_1 = -3.6V, V_2 = 5.4V, P(in V_S) = -16.2mW, P(in R_1) = +6.48mW, P(in R_2) = +9.72mW. The voltage source is producing power and the two resistors are absorbing power.

Ans : 2.20 (a) $I_1 + I_3 = I_2$ (b) $- V_S + V_1 + V_2 = 0$ or $V_S = V_1 + V_2$, $- V_2 + V_3 = 0$ or $V_2 = V_3$ (c) $V_1 = I R_1$, $V_2 = I R_2$, $V_3 = -I R_3$ (d) $V_2 = V_3$ = 6.316V, V_1 = 5.684V, I_1 = 1.421A, I_2 = 0.7895A, I_3 = -0.6316A. P(in V_S) = -17.05W, P(in R_1) = 8.077W, P(in R_2) = +4.986W, P(in R_3) = +3.989W

Ans : 2.21 (a) P(in R_1) = +150W, P(in R_2) = +48W, P(in R_3) = +12W, (b) -210W, V_S = +42V

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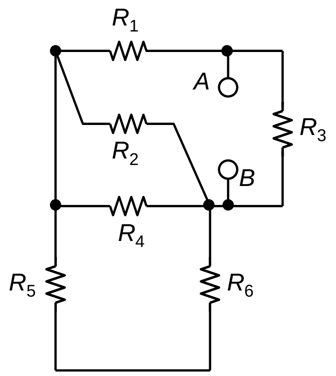
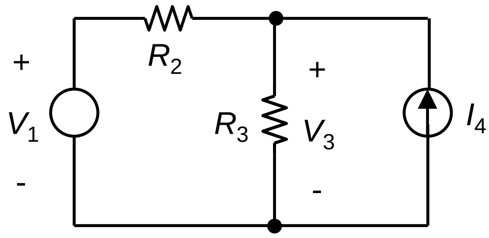
EEE1A Tutorial #3 (held in Week 4)

Show your working where this is possible. Your preparation will be marked at the start of the tutorial.

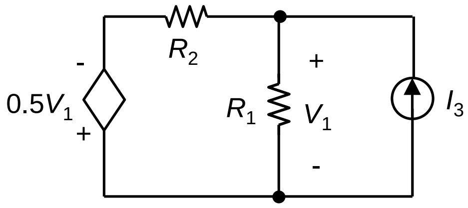


2.13. Consider the figure on the right. Write an expression for the equivalent resistance R_{AB} for the network between terminals A and B. Use the notation $R_X//R_Y$ to represent parallel resistances.

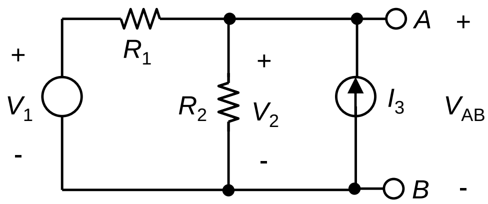


2.24. Consider the circuit on the right. Given V_1 = 12V, R_2 = 6Ω, R_3 = 4Ω and I_4 = 1A, find V_3 by applying KVL, KCL and Ohm's law. Hint : as first step, define the voltage across R_2 and the three currents in the circuit. Note the polarity of the voltage and the directions of the currents can be chosen arbitrarily, they will not affect the answer for V_3.

3.9. Consider the circuit on the right. It has a controlled voltage source in it. If R_1 = 10 ohms, R_2 = 20 ohms and I_3 = 2A, find V_1 using KVL, KCL and Ohm's law and the same approach you used in Q2.24.



3.10. Consider the figure on the right where V_1 = 5V, R_1 = 4 kilo-ohms, R_2 = 12 kilo-ohms and I_3 = 3 mA.



(a) Find the (open-circuit) voltage V_{AB} using superposition drawing appropriate circuit diagrams showing each source acting alone.

(b) Redraw the circuit with both sources set to zero and hence find the Thevenin resistance R_{th} between terminals *A* and *B*.

(c) Apply a short-circuit between terminals *A* and *B* (i.e. join the two terminals with a wire). Using superposition, what is the value of the current I_{AB} flowing from terminal *A* to terminal *B*? For each case draw an appropriate circuit diagram.

(d) Verify that at terminals *A* and *B*, the ratio of the open-circuit voltage (from part a) to the short-circuit current (from part c) is equal to the Thevenin resistance.

(e) Using the above results, draw a Thevenin equivalent circuit and Norton equivalent circuit.

(f) Use the Thevenin equivalent circuit to calculate the voltage V_{AB} if a resistor of value 4.7 kilo-ohms is connected to the circuit between terminals *A* and *B*.

Solutions

Ans : 2.13. $R_3//[R_1 + R_2//R_4//(R_5+R_6)]$

Ans : 2.24 +7.2V [Hint : write KVL for left loop linking V_1, V_3 and voltage drop across R_2; write KCL for the top right node linking current in R_2, current in R_3 and I_4; then write Ohm's law equations for R_2 and R_3.]

Ans : 3.9 V_1 = 11.43V [current in R_1 is 8/7A = 1.143A flowing downwards, current in R_2 = 6/7A = 0.8571A flowing to the left]

Ans : 3.10. (a) show circuit diagrams with the current source replaced by an open-circuit, and the voltage source replaced by a short-circuit, V_{AB} = 12.75V [= 3.75V + 9V] (b) Show circuit with R_1 and R_2 in parallel. R_{th} = 3kΩ (c) show appropriate circuit diagrams, I_{AB} = 4.25mA (d) From parts a and c, R_{th} = 12.75V/4.25mA = 3 kΩ which corresponds to the answer from part b. (e) Show appropriate circuit diagrams, for Thevenin circuit (V_{th} = 12.75V, R_{th} = 3kΩ), for Norton circuit (I_n = 4.25mA, R_{th} = 3kΩ), (f) V_{AB} = +7.782V