ECE 2200/10 Lecture 1 Introduction to Electrical Engineering for non-majors

A. Stolp
12/30/11
8/24/15

2200 = 1/2 semester (Mining, Mat. Sci.)

ECE 2200 Without the Physics is hard, Plan on it!

2200, Decide today when you want to take the **final**:
Final is **after** official end of class unless you ask for different accomodation today.

Make sure you are registered for the <u>right</u> <u>class</u> (2200 or 2210) and that you have the right syllabus.

2210 = Full semester (Mechanical, Chemical, etc.)

2210 Final wednesday, December 15, 8:00am

Friday labs: Will have to attend lab and watch video in same week or attend on reading day.

BOTH

Regularly check the calendar on for this class on Canvas. Watch your Canvas anouncements.
Be prepared to download and print weekly packets, which include notes and homeworks.

Homeworks are due by 11:59 pm of the due date on Canvas.
Make sure you have a way to scan your paper or do your work on a tablet so that you will can submit a .pdf file

WARNING: HWs are often due on non-class days.

Most labs start next week. Need a lab notebook and a U-card with $16 for labs.

How to survive

1. Easiest way to get through school is to actually learn and retain what you are asked to learn.
   Even if you're too busy, don't lose your good study practices.
   What you "just get by" on today will cost you later.

   Don't fall for the "I'll never need to know this" trap. Sure, much of what you learn you may not use, but you will need some of it, some day, either in the current class, future classes, or maybe sometime in your career. Don't waste time second-guessing the curriculum, It'll still be easier to just do your best to learn and retain what is covered.

2. Don't fall for the "traps".
   Homework answers, Problem session solutions, Posted solutions, Lecture notes.

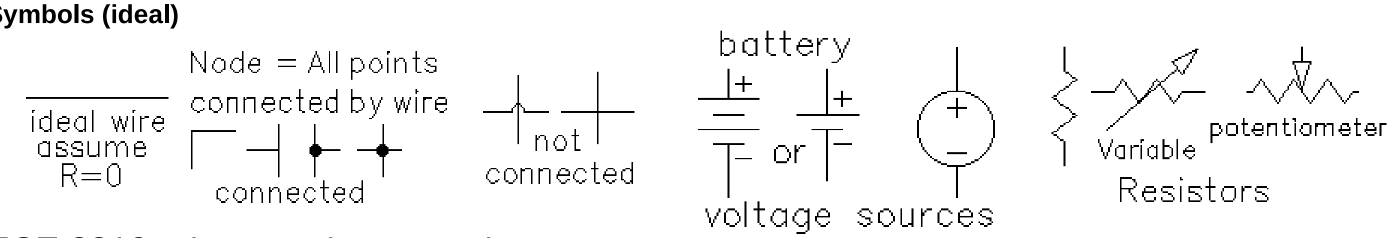
3. KEEP UP! Use calendar.

4. Make "permanent notes" after you've finished a subject or section and feel that you know it.

Lecture

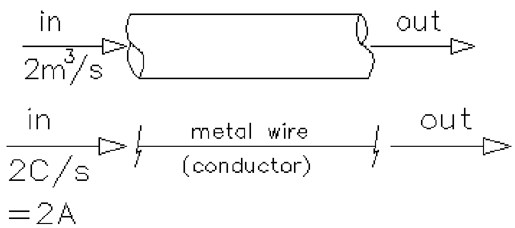
Basic electrical quantities	Letter used	Units	Fluid Analogy
Charge, actually moves	Q	Coulomb (C)	m^3
Current, like fluid flow	$I = \frac{Q}{sec}$	Amp (A, mA, µA,...)	$\frac{m^3}{sec}$
Voltage, like pressure	V or E	volt (V, mV, kV,...)	$Pa = 1 \cdot \frac{N}{m^2}$
Resistance	$R = \frac{V}{I}$	Ohm (Ω, kΩ, MΩ,...)	
Conductance	$G = \frac{1}{R}$	Siemens (S, also mho, old unit)	
Power = energy/time	$P = V \cdot I$	Watt (W, mW, kW, MW,...)	W

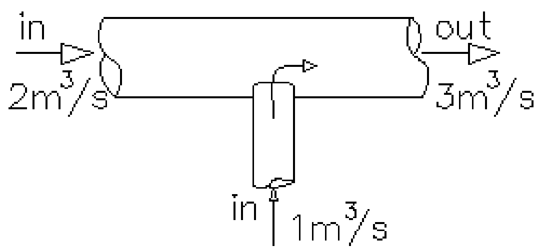
Symbols (ideal)

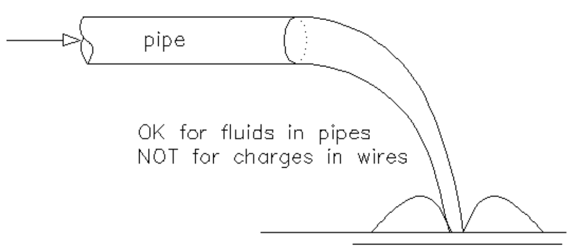


KCL, **K**irchhoff's **C**urrent **L**aw

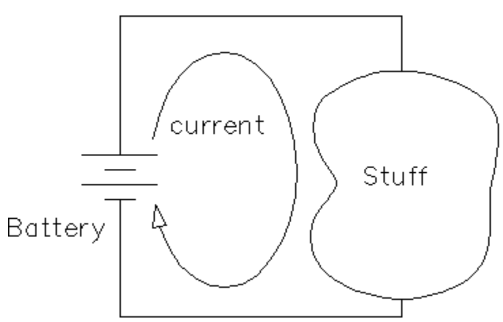
$I_{in} = I_{out}$ of any point, part, or section







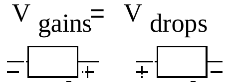
Battery also obeys KCL
No accumulation of charge anywhere,
so it must circulate around.
Leads to the concept of a "Circuit"



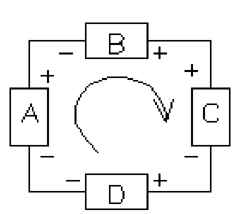
A circuit

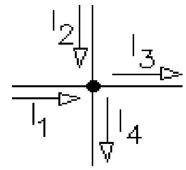
Voltage is like pressure
KVL, **K**irchhoff's **V**oltage **L**aw

$V_{gains} = V_{drops}$



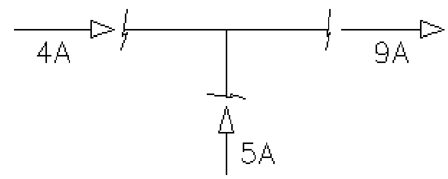
around any loop

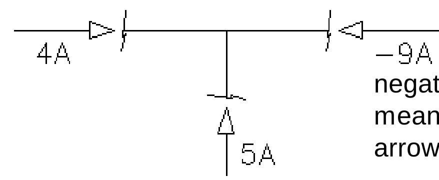




$I_{in} = I_{out}$

$I_1 + I_2 = I_3 + I_4$





negative current
means the direction
arrow is wrong

Conductors Nonconductors

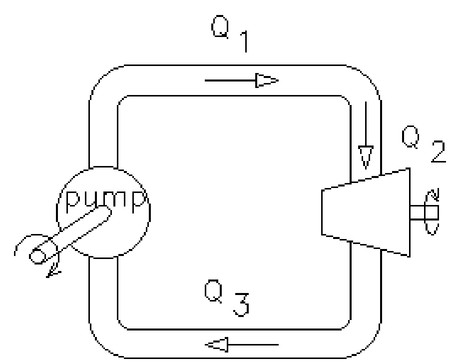
Massless fluid in our analogy
No gravity effects No Bernoulli effects

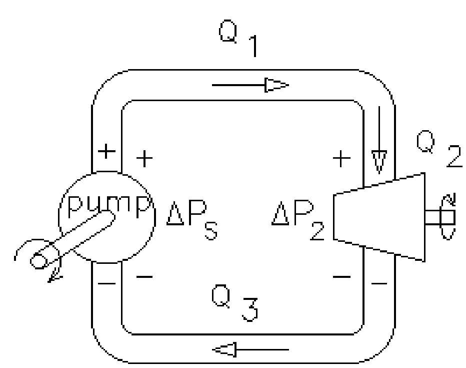
Reasonable because:

Electron mass is $9.11 \cdot 10^{-31} \cdot kg$

Election charge is $-1.6 \cdot 10^{-16} \cdot C$

Negative charge flows
in negative direction

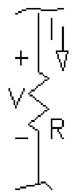




A. Stolp
1/28/06,
9/5/08

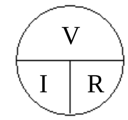
Ohm's law (resistors)

$V = I \cdot R$



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

$R = \dfrac{V}{I}$ definition of resistance and the unit "Ω"



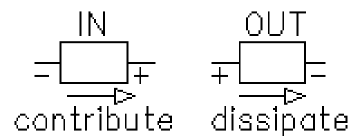
Power

flow $\dfrac{m^3}{sec}$ pressure $\dfrac{N}{m^3}$ flow x pressure: $\dfrac{m^3}{sec}\cdot\dfrac{N}{m^2} = \dfrac{m}{sec}\cdot\dfrac{N}{1} = \dfrac{N\cdot m}{sec} = \dfrac{Joule}{sec} = W$ = power

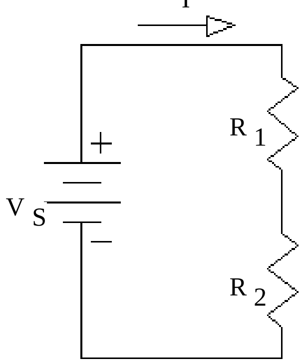
same for electricity power $P = I \cdot V$

Power dissipated by resistors: $P = V \cdot I = \dfrac{V^2}{R} = I^2 \cdot R$

$P_{IN} = P_{OUT}$

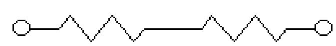


Series Resistors



$V_T = V_1 + V_2$

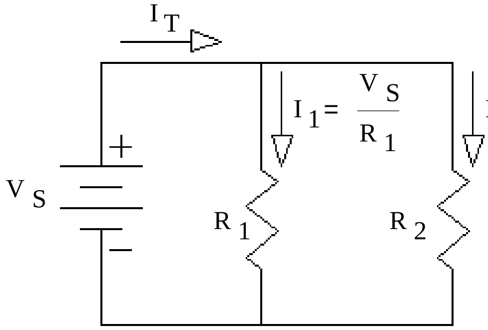
$R_{eq} = \dfrac{V_T}{I} = \dfrac{V_1 + V_2}{I} = \dfrac{V_1}{I} + \dfrac{V_2}{I} = R_1 + R_2$



$R_{eq} = R_1 + R_2$

Resistors are in series if and only if exactly the **same current** flows through each resistor.

Parallel Resistors

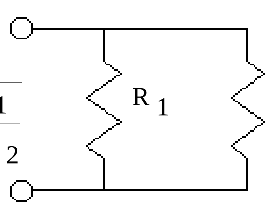


$I_1 = \dfrac{V_S}{R_1}$ $I_2 = \dfrac{V_S}{R_2}$

$I_T = \dfrac{V_S}{R_1} + \dfrac{V_S}{R_2}$

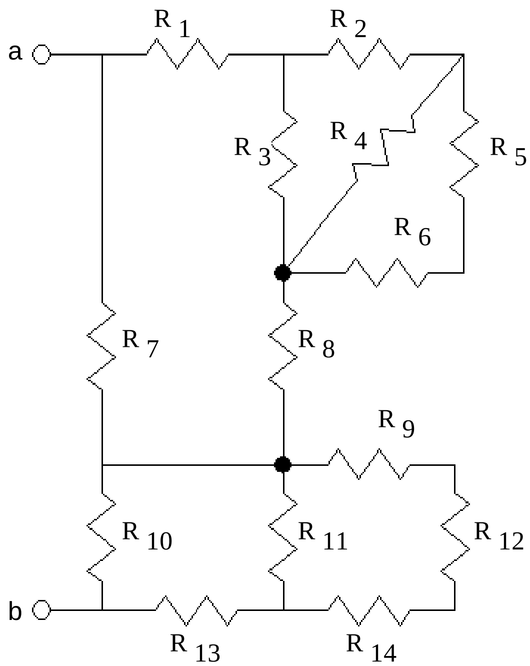
$R_{eq} = \dfrac{V_S}{I_T} = \dfrac{V_S}{\dfrac{V_S}{R_1} + \dfrac{V_S}{R_1}} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}}$

$R_{eq} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}}$



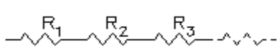
Resistors are in parallel if and only if the **same voltage** is across each resistor.

Series and Parallel



All resistor-only networks can be reduced to a single equivalent, but not always by means of series and parallel concepts.

Voltage Divider



series: $R_{eq} = R_1 + R_2 + R_3 + \ldots$

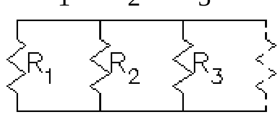
Exactly the **same current** through each resistor

Voltage divider:

$$V_{Rn} = V_{total} \cdot \frac{R_n}{R_1 + R_2 + R_3 + \ldots}$$

Current Divider

parallel: $R_{eq} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots}$

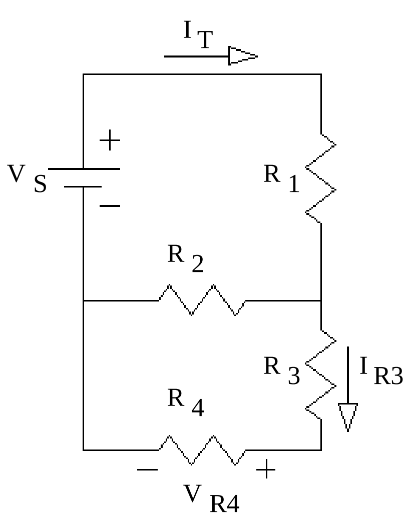


Exactly the **same voltage** across each resistor

current divider:

$$I_{Rn} = I_{total} \cdot \frac{\dfrac{1}{R_n}}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots}$$

May have to combine some resistors first to get series and parallel resistors to use with divider expressions.

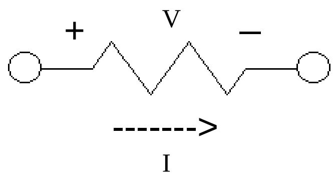


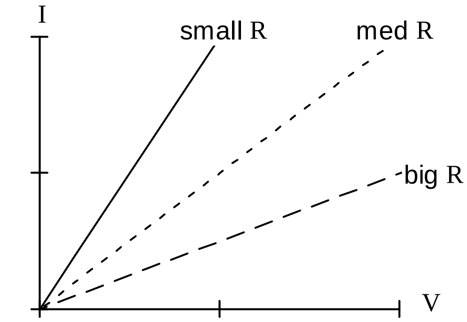
$V_{R4} =$

$I_T =$

$I_{R3} =$

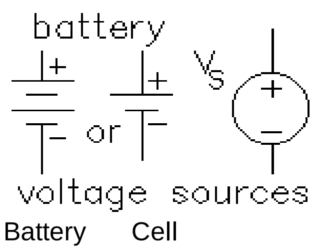
Resistors

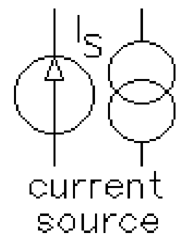




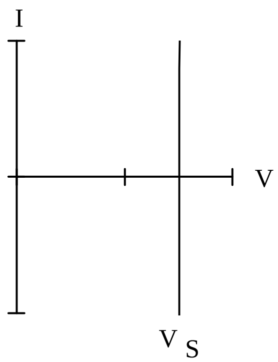
$$R = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I}$$

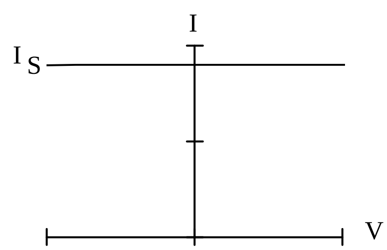
Sources

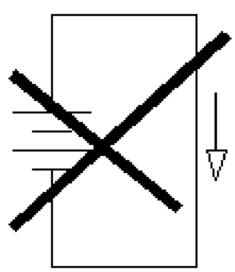




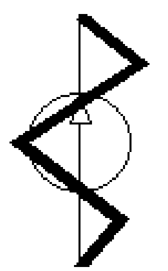
Less intuitive, less like sources
we are used to seeing.



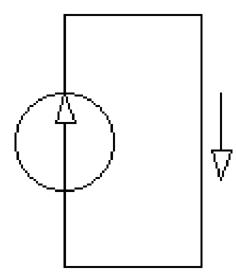




Doesn't make sense with
for ideal voltage sources
and ideal wires

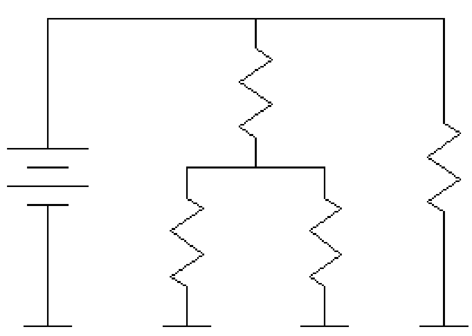


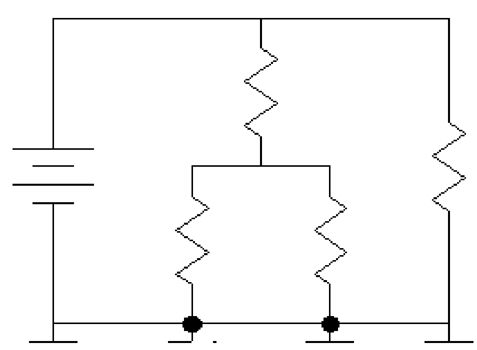
Doesn't make sense
for ideal current sources

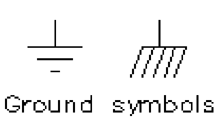


Must have a path for the
current to flow

Ground



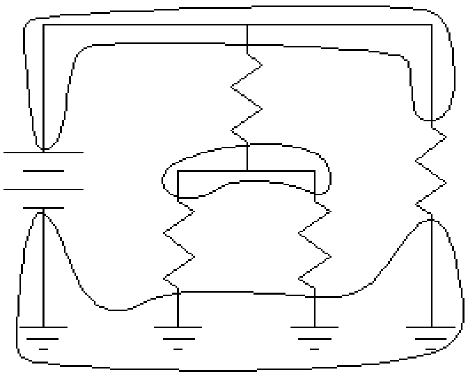




Ground is considered zero volts and is a reference for other voltages.

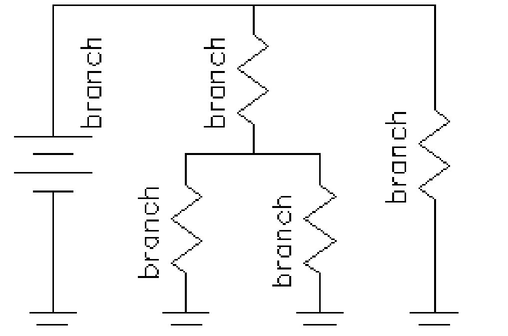
Nodes & Branches

Node = all points connected by wire, all at same voltage (potential)

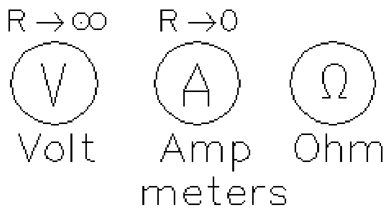


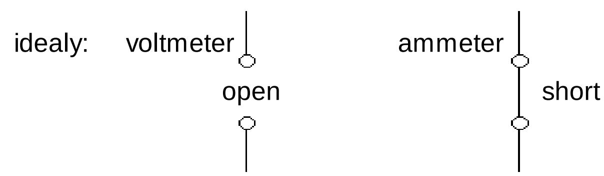
ground is a node

Branch = all parts with the same current



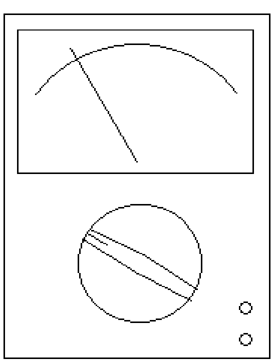
Meters



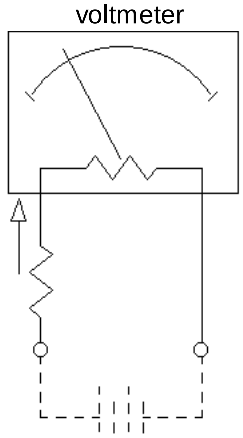


Analog meters

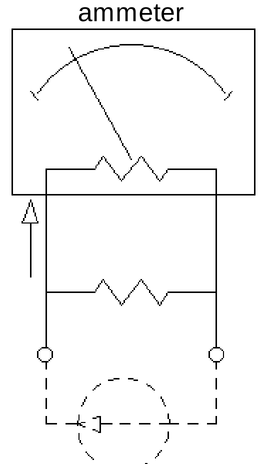
multimeter



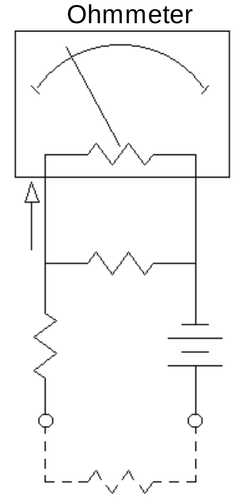
voltmeter



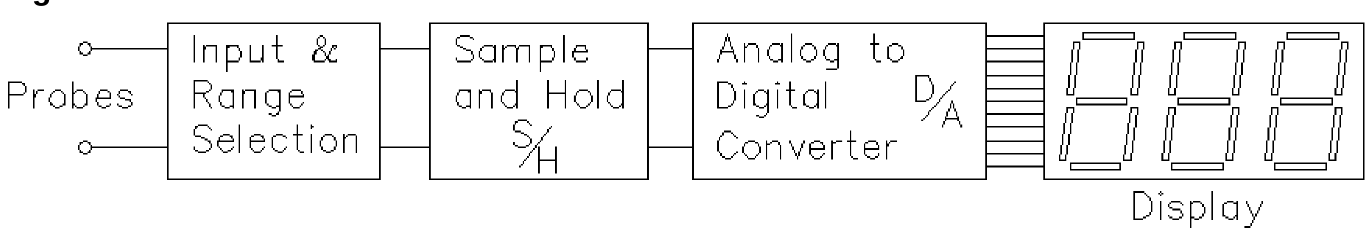
ammeter



Ohmmeter



Digital meter



Name___________________________

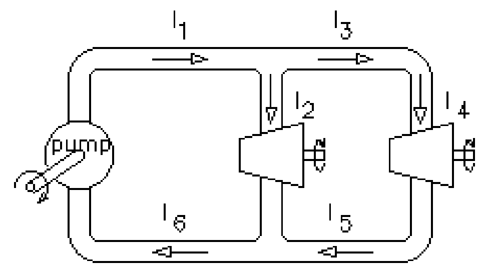
a5

ECE 2210 / 00   homework # 1   Due: Mon, 8/30/21

Scan your homework and convert to a pdf file. Turn in on Canvas. Homework is due by 11:59 p.m. on the due date.

The following problems are not meant to be hard. You should be able to do most of them in your head with no special formulas or calculations. In fact you should find them rather dumb and trivial. That's the point, I want to drill these concepts into your head so that you'll find them easy.

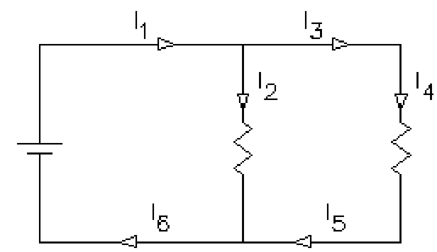
1. The figure at right shows a hydraulic system with a pump that converts rotational energy to fluid energy and two turbines which convert that energy back to rotational energy. Do NOT assume that the turbines are equal in size. This is a closed system containing an incompressible fluid with no places for that fluid to collect; i.e. flow in = flow out of any point or object. Kirchhoff's current law applies. The volumetric fluid flows are indicated by the arrows.



$I_1 := 0.01 \cdot \frac{m^3}{s}$ $I_2 := 0.007 \cdot \frac{m^3}{s}$

I_3 = _________ I_4 = _________ I_5 = _________ I_6 = _________

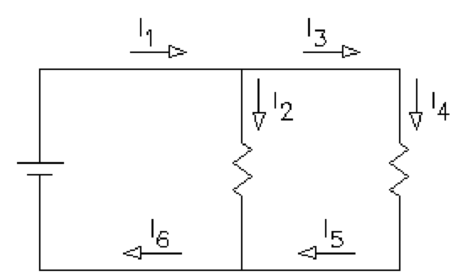
2. The figure at right shows an electrical circuit with a battery that converts chemical energy to electrical energy and two resistors which convert that electrical energy to heat energy. Do NOT assume that the resistors are equal in size. *All* electrical circuits are closed systems containing incompressible charges with no places for those charges to collect; i.e. flow in = flow out of any point or object. Kirchhoff's current law applies. . The electrical currents are indicated by the arrows.



$I_1 := 0.01 \cdot A$ $I_2 := 0.007 \cdot A$

I_3 = _________ I_4 = _________ I_5 = _________ I_6 = _________

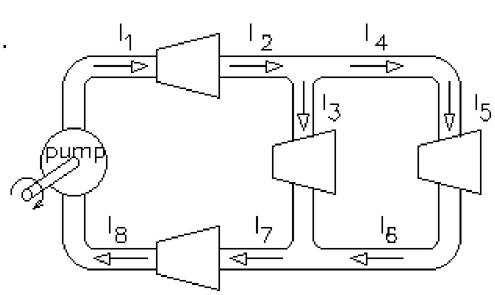
3. The figure at right shows a similar electrical circuit only now the electrical currents are indicated by the arrows next to the wires. This is a more common way to show the current flow because a little arrow in the wire is too easily confused with the electrical symbol for a diode. You'll learn about diodes later.



$I_2 := 20 \cdot mA$ $I_5 := 14 \cdot mA$

I_6 = _________ I_1 = _________ I_3 = _________ I_4 = _________

4.

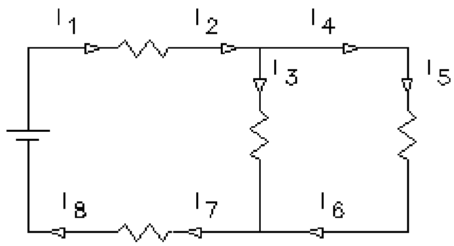


$I_3 := 0.004 \cdot \frac{m^3}{s}$ $I_5 := 0.001 \cdot \frac{m^3}{s}$ I_4 = _________

I_2 = _________ I_1 = _________ I_6 = _________

I_7 = _________ I_8 = _________

5.

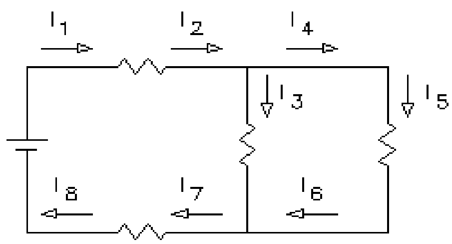


$I_3 := 4.5 \cdot mA$ $I_5 := 1.2 \cdot mA$ I_4 = ________

I_2 = ________ I_1 = ________ I_6 = ________

I_7 = ________ I_8 = ________

6. Again, a similar electrical circuit with the electrical current arrows in the more common position, next to the wires.

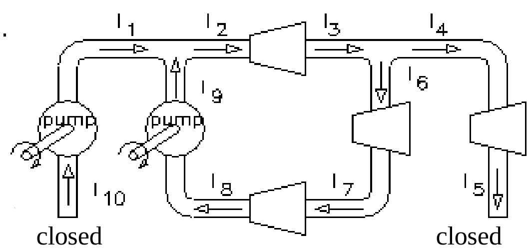


$I_6 := 0.03 \cdot A$ $I_7 := 0.08 \cdot A$ I_8 = ________

I_1 = ________ I_2 = ________ I_3 = ________

I_4 = ________ I_5 = ________

7.

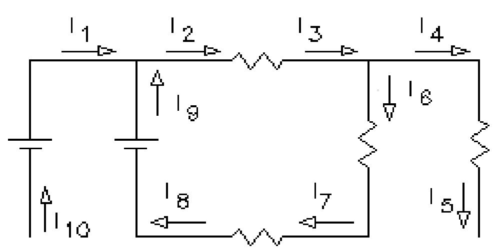


$I_9 := 0.04 \cdot \frac{m^3}{s}$ I_1 = ________ I_2 = ________

I_3 = ________ I_4 = ________ I_5 = ________

I_6 = ________ I_7 = ________ I_8 = ________ I_7 = ________ I_{10} = ________

8.

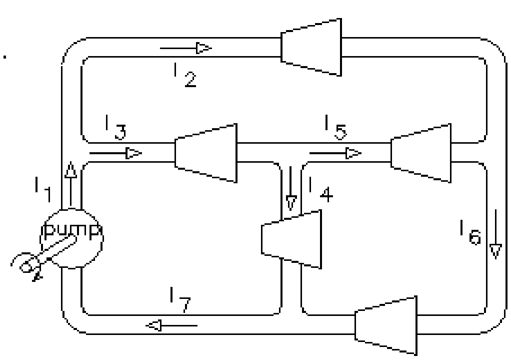


$I_9 := 0.06 \cdot A$ I_1 = ________ I_2 = ________

I_3 = ________ I_4 = ________ I_5 = ________

I_6 = ________ I_7 = ________ I_8 = ________ I_7 = ________ I_{10} = ________

9.



$I_4 := 0.05 \cdot \frac{m^3}{s}$ $I_5 := 0.014 \cdot \frac{m^3}{s}$ $I_6 := 0.03 \cdot \frac{m^3}{s}$

I_1 = ________ I_2 = ________

I_3 = ________ I_7 = ________

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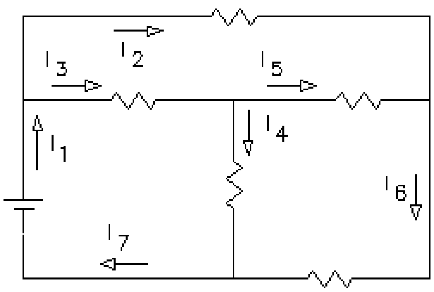
10.

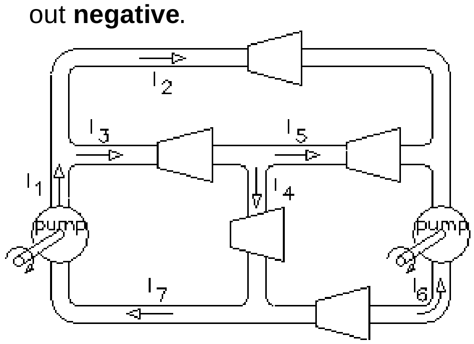


$I_4 := 20 \cdot mA$ $\quad I_5 := 10 \cdot mA$ $\quad I_6 := 22 \cdot mA$

I_1 = ________ $\quad I_2$ = ________

I_3 = ________ $\quad I_7$ = ________

11. Careful here, there are now two pumps. Also, given the flow arrows shown, one or more of the flows must come out **negative**.



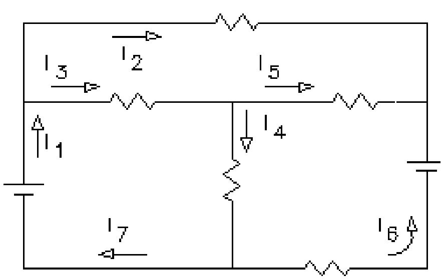
$I_2 := 0.005 \cdot \frac{m^3}{s}$ $\quad I_6 := 0.03 \cdot \frac{m^3}{s}$ $\quad I_7 := 0.015 \cdot \frac{m^3}{s}$

I_1 = ________ $\quad I_3$ = ________

I_4 = ________ $\quad I_5$ = ________

12. What does a negative fluid flow physically mean?

13.



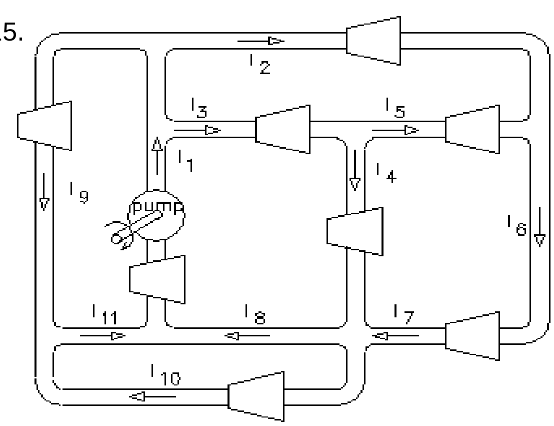
$I_1 := 0.01 \cdot A$ $\quad I_5 := -20 \cdot mA$ $\quad I_6 := 35 \cdot mA$

I_2 = ________ $\quad I_3$ = ________

I_4 = ________ $\quad I_7$ = ________

14. What does a negative electrical current physically mean?

15.



$I_4 := 0.05 \cdot \frac{m^3}{s}$ $\quad I_5 := 0.03 \cdot \frac{m^3}{s}$ $\quad I_7 := 0.045 \cdot \frac{m^3}{s}$

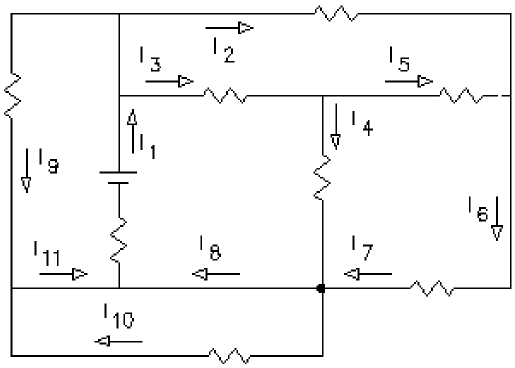
$I_9 := 0.06 \cdot \frac{m^3}{s}$ $\quad I_1$ = ________

I_2 = ________ $\quad I_3$ = ________

I_6 = ________ $\quad I_8$ = ________

I_{10} = ________ $\quad I_{11}$ = ________

16.



$I_1 := 100 \cdot mA$ $I_2 := 50 \cdot mA$ $I_3 := 30 \cdot mA$

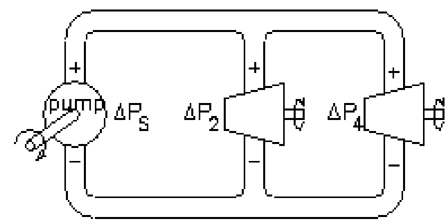
$I_6 := 66 \cdot mA$ I_4 = __________

I_5 = __________ I_7 = __________

I_8 = __________ I_9 = __________

I_{10} = __________ I_{11} = __________

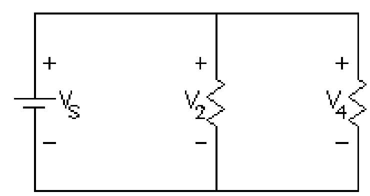
17. The figure at right shows the pressure differentials across elements in a hydraulic system. The side indicated by the + sign is the higher pressure side. Conversely, - indicates the lower pressure. ΔP_S is the pressure difference supplied by the pump (S for **S**ource). ΔP_2 is the pressure difference driving the left turbine and ΔP_4 is the pressure difference driving the right turbine. Assume no pressure losses or discontinuities in the pipes, joints, or corners; i.e. all connected pipes are at exactly the same pressure. Finally, the fluid has no mass, so gravity and Bernoulli can go take a hike.



$\Delta P_S := 12 \cdot \frac{N}{m^2} = 12 \cdot Pa$ ΔP_2 = __________ ΔP_4 = __________

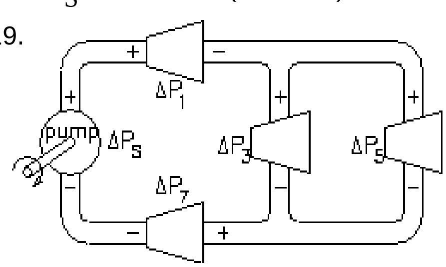
Yes, I know that these are ridiculously low pressures for a hydraulic system.

18. The figure at right shows the voltage differentials across elements in an electrical circuit. The side indicated by the + sign is the higher voltage side. Conversely, - indicates the lower voltage. V_S is the voltage supplied by the battery. V_2 is the voltage across the left resistor and V_4 is the voltage across the right resistor. You may assume no voltage drops across any of the wires or connections in practically *all* electrical schematics; i.e. all connected wires are at exactly the same voltage (electrical potential).



$V_S := 12 \cdot V$ (V = volts) V_2 = __________ V_4 = __________

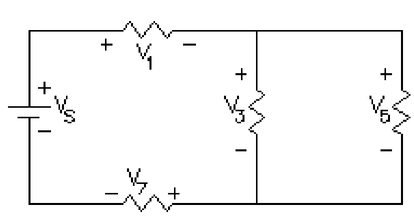
19.



$\Delta P_S := 400 \cdot kPa$ $\Delta P_1 := 180 \cdot kPa$ $\Delta P_3 := 100 \cdot kPa$

ΔP_5 = __________ ΔP_7 = __________

20.



$V_1 := 10 \cdot V$ $V_5 := 3 \cdot V$ $V_7 := 2 \cdot V$

V_S = __________ V_3 = __________

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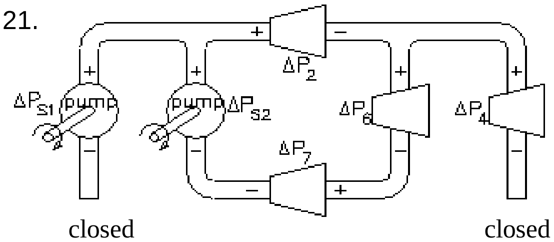
21.

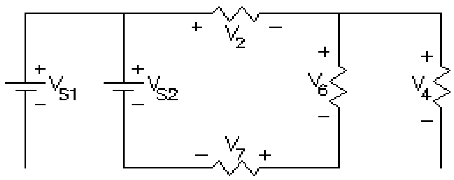


$\Delta P_{S1} := 200 \cdot kPa$ $\Delta P_{S2} := 150 \cdot kPa$

$\Delta P_{2} := 50 \cdot kPa$ $\Delta P_{6} := 60 \cdot kPa$

ΔP_{4} = ___________ ΔP_{7} = ___________

22.

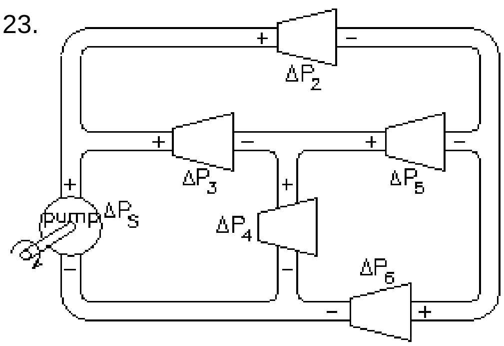


$V_{S1} := 6 \cdot V$ $V_{2} := 2 \cdot V$

$V_{6} := 2.4 \cdot V$ $V_{7} := 3.2 \cdot V$

V_{S2} = ___________ V_{4} = ___________

23.



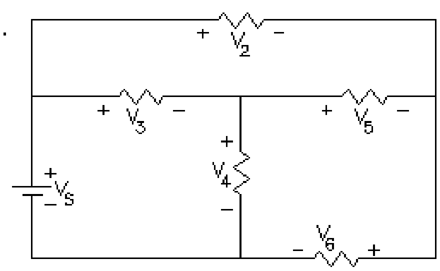
$\Delta P_{3} := 120 \cdot kPa$ $\Delta P_{4} := 80 \cdot kPa$ $\Delta P_{6} := 110 \cdot kPa$

ΔP_{S} = ___________ ΔP_{2} = ___________

ΔP_{5} = ___________

24. What does a negative pressure difference physically mean?

25.

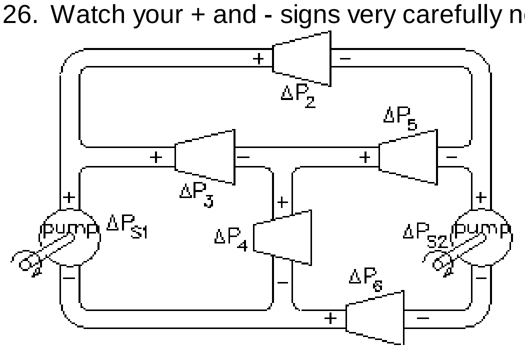


$V_{3} := 2.3 \cdot V$ $V_{5} := 0.5 \cdot V$ $V_{6} := 3.2 \cdot V$

V_{S} = ___________ V_{2} = ___________

V_{4} = ___________

26. Watch your + and - signs very carefully now.



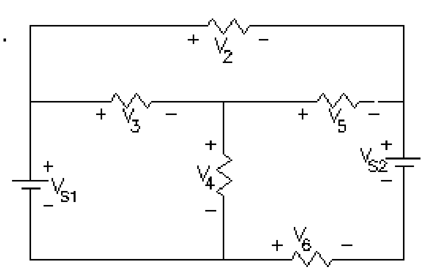
$\Delta P_{2} := 140 \cdot kPa$ $\Delta P_{3} := 230 \cdot kPa$

$\Delta P_{4} := 50 \cdot kPa$ $\Delta P_{6} := 210 \cdot kPa$

ΔP_{S1} = ___________ ΔP_{S2} = ___________

ΔP_{5} = ___________

27.



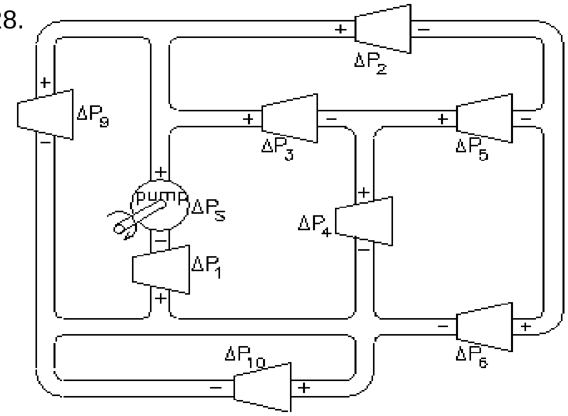
$V_{S1} := 14 \cdot V$ $V_{S2} := 3 \cdot V$ $V_{2} := 6 \cdot V$ $V_{3} := 4 \cdot V$

V_{4} = ___________ V_{5} = ___________

V_{6} = ___________

Think about the current through the 2nd battery. What is happening to that battery?

28.



$\Delta P_1 := 200\cdot kPa$ $\Delta P_2 := 1100\cdot kPa$

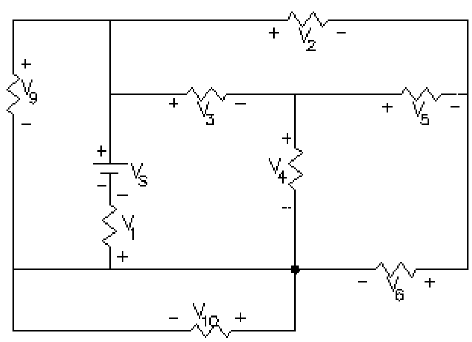
$\Delta P_3 := 600\cdot kPa$ $\Delta P_9 := 1800\cdot kPa$

$\Delta P_S =$ ________ $\Delta P_4 =$ ________

$\Delta P_5 =$ ________ $\Delta P_6 =$ ________

$\Delta P_{10} =$ ________

29.



$V_S := 18\cdot V$ $V_3 := 6\cdot V$ $V_4 := 8\cdot V$ $V_5 := 2\cdot V$

$V_1 =$ ________ $V_2 =$ ________

$V_6 =$ ________ $V_9 =$ ________

$V_{10} =$ ________

Answers

1. $I_3 = I_4 = I_5 := 0.003\cdot\frac{m^3}{s}$, $I_6 := 0.01\cdot\frac{m^3}{s}$

2. $I_3 = I_4 = I_5 := 0.003\cdot A$, $I_6 := 0.01\cdot A$

3. $I_6 = I_1 := 34\cdot mA$, $I_3 = I_4 := 14\cdot mA$

4. $I_4 = I_6 := 0.001\cdot\frac{m^3}{s}$, $I_1 = I_2 = I_7 = I_8 := 0.005\cdot\frac{m^3}{s}$

5. $I_4 = I_6 := 1.2\cdot mA$, $I_1 = I_2 = I_7 = I_8 := 5.7\cdot mA$

6. $I_1 = I_2 = I_8 := 80\cdot mA$, $I_3 := 50\cdot mA$, $I_4 = I_5 := 30\cdot mA$

7. $I_1 = I_{10} = I_4 = I_5 := 0\cdot\frac{m^3}{s}$, $I_2 = I_3 = I_7 = I_8 := 0.04\cdot\frac{m^3}{s}$

8. $I_1 = I_{10} = I_4 = I_5 := 0\cdot A$,
$I_2 = I_3 = I_7 = I_8 := 0.06\cdot A$

9. $I_1 = I_7 := 0.080\cdot\frac{m^3}{s}$, $I_2 := 0.016\cdot\frac{m^3}{s}$, $I_3 := 0.064\cdot\frac{m^3}{s}$

10. $I_1 = I_7 := 42\cdot mA$, $I_2 := 12\cdot mA$, $I_3 := 30\cdot mA$

11. $I_1 := 0.015\cdot\frac{m^3}{s}$, $I_3 := 0.010\cdot\frac{m^3}{s}$, $I_4 := 0.045\cdot\frac{m^3}{s}$, $I_5 := -0.035\cdot\frac{m^3}{s}$

12. Actual flow is in direction opposite to the arrow direction.

13. $I_2 := -15\cdot mA$, $I_3 := 25\cdot mA$, $I_4 := 45\cdot mA$, $I_7 := 10\cdot mA$

14. "

15. $I_1 := 0.155\cdot\frac{m^3}{s}$, $I_2 := 0.015\cdot\frac{m^3}{s}$, $I_3 := 0.080\cdot\frac{m^3}{s}$, $I_6 := 0.045\cdot\frac{m^3}{s}$, $I_8 := 0.095\cdot\frac{m^3}{s}$, $I_{10} := 0\cdot\frac{m^3}{s}$, $I_{11} := 0.060\cdot\frac{m^3}{s}$

16. $I_4 := 14\cdot mA$, $I_5 := 16\cdot mA$, $I_7 := 66\cdot mA$, $I_8 := 80\cdot mA$, $I_9 := 20\cdot mA$, $I_{10} := 0\cdot mA$, $I_{11} := 20\cdot mA$

17. $\Delta P_2 = \Delta P_4 := 12\cdot Pa$

18. $V_2 = V_4 := 12\cdot V$

19. $\Delta P_5 := 100\cdot kPa$, $\Delta P_7 := 120\cdot kPa$

20. $V_S := 15\cdot V$, $V_3 := 3\cdot V$

21. $\Delta P_4 := 0\cdot kPa$, $\Delta P_7 := 40\cdot kPa$

22. $V_{S2} := 7.6\cdot V$, $V_4 := 0\cdot V$

23. $\Delta P_S := 200\cdot kPa$, $\Delta P_2 := 90\cdot kPa$, $\Delta P_5 := -30\cdot kPa$

24. The actual + & - should be reversed from those on drawing

25. $V_S := 6\cdot V$, $V_2 := 2.8\cdot V$, $V_4 := 3.7\cdot V$

26. $\Delta P_{S1} := 280\cdot kPa$, $\Delta P_{S2} := 350\cdot kPa$, $\Delta P_5 := -90\cdot kPa$

27. $V_4 := 10\cdot V$, $V_5 := 2\cdot V$, $V_6 := -5\cdot V$ battery is charging

28. $\Delta P_S := 2000\cdot kPa$, $\Delta P_4 := 1200\cdot kPa$, $\Delta P_5 := 500\cdot kPa$,
$\Delta P_6 := 700\cdot kPa$, $\Delta P_{10} := 0\cdot kPa$

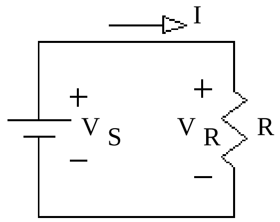
29. $V_1 := 4\cdot V$, $V_2 := 8\cdot V$, $V_6 := 6\cdot V$, $V_9 := 14\cdot V$, $V_{10} := 0\cdot V$

Name___________________________ Due: Thur, 9/2/21 a5

ECE 2210 / 00 homework # 2

You may do the following problems here or on your own paper. But, since you have the answers, **you MUST show your work to get credit**.

1. Ohm's law
   Consider the figure at right
   For each of the cases below, find the missing value.



a) $I := 0.01 \cdot A$ $V_R := 4 \cdot V$ $R = ?$

b) $I := 50 \cdot mA$ $R := 560 \cdot \Omega$ $V_R = ?$

c) $V_R := 12 \cdot V$ $R := 1.5 \cdot k\Omega$ $I = ?$

2. Power and Ohm's law. Same circuit as above. For each of the cases below, find the missing values.

a) $I := 5 \cdot mA$ $R := 2 \cdot k\Omega$ $V_R =$ $P_R =$

b) $V_R := 25 \cdot V$ $R := 100 \cdot \Omega$ $I =$ $P_R =$

c) $V_R := 20 \cdot V$ $I := 0.01 \cdot A$ $R =$ $P_R =$

Ignore the fact that the following items run on AC

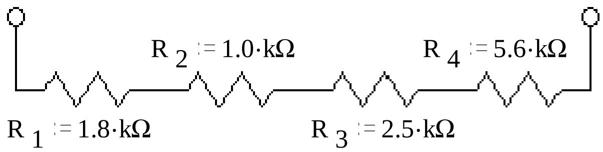
d) $P_R := 900 \cdot W$ Toaster $V_R := 120 \cdot V$ $I =$ $R =$

e) $P_R := 1500 \cdot W$ Hair drier $R := 9.6 \cdot \Omega$ $I =$ $V_S =$

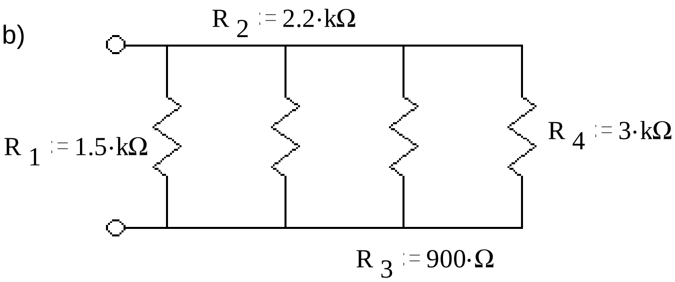
f) $P_R := 2500 \cdot W$ Electric oven $I := 10.5 \cdot A$ $R =$ $V_S =$

3. Find the equivalent resistance of each of these networks, i.e. what would an ohmmeter read if hooked to the terminals.

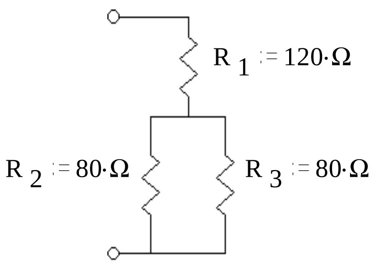
a)



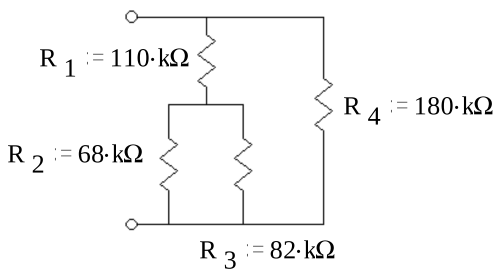
b)



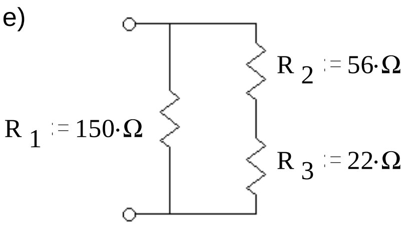
c)



d)



e)



Answers

1. a) $R := 400 \cdot \Omega$ b) $V_R := 28 \cdot V$ c) $I := 8 \cdot mA$

2. a) $V_R := 10 \cdot V$ $P_R := 50 \cdot mW$ b) $I := 0.25 \cdot A$ $P_R := 6.25 \cdot W$ c) $R := 2.0 \cdot k\Omega$ $P_R := 200 \cdot mW$

   d) $I := 7.5 \cdot A$ $R := 16 \cdot \Omega$ e) $I := 12.5 \cdot A$ $V_S := 120 \cdot V$ f) $R := 22.7 \cdot \Omega$ $V_S := 238 \cdot V$

3. a) $R_{eq} := 10.9 \cdot k\Omega$ b) $R_{eq} := 390 \cdot \Omega$ c) $R_{eq} := 160 \cdot \Omega$

   d) $R_{eq} := 81 \cdot k\Omega$ e) $R_{eq} := 51.3 \cdot \Omega$