Name: _____

Class: _____

Due Date: _____

B.5 Current and Circuits

Understandings

- Cells provide a source of emf.
- Chemical cells and solar cells as the energy source in circuits.
- Circuit diagrams represent the arrangement of components in a circuit.
- Direct current (dc) I as a flow of charge carriers as given by $I = \frac{\Delta q}{\Delta t}$.
- The electric potential difference V is the work done per unit charge on moving a positive charge between two points along the path of the current as given by $V = \frac{W}{q}$.
- The properties of electrical conductors and insulators in terms of mobility or charge carriers.
- Electric resistance and its origin.
- Electrical resistance R as given by $R = \frac{V}{I}$.
- Resistance as given by $\rho = \frac{RA}{L}$.
- Ohm's law.
- The ohmic and non-ohmic behavior of electrical conductors, including the heating effect of resistors.
- Electrical power P dissipated by a resistor as given by $P = IV = I^2R = \frac{V^2}{R}$.
- The combinations of resistors in series and parallel circuits.

Series circuits	Parallel circuits
$I = I_1 = I_2 = \cdots$	$I = I_1 + I_2 + \cdots$
$V = V_1 + V_2 + \cdots$	$V = V_1 = V_2 = \cdots$
$R_s = R_1 + R_2 + \cdots$	$\frac{1}{R_\mathrm{p}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

- Electric cells are characterized by their emf ε and internal resistance r as given by $\varepsilon = I(R + r)$.

- Resistors can have variable resistance.

Equations

$$I = \frac{\Delta q}{\Delta t}$$

$$V = \frac{W}{q}$$

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

$$\rho = \frac{RA}{L}$$

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

Series circuits	Parallel circuits
$I = I_1 = I_2 = \cdots$ $V = V_1 + V_2 + \cdots$ $R_s = R_1 + R_2 + \cdots$	$I = I_1 + I_2 + \cdots$ $V = V_1 = V_2 = \cdots$ $\frac{1}{R_s} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

$$\varepsilon = I(R + r)$$

If you are interested in learning more about electricity and magnetism then please read the book *Electricity and Magnetism* by Edward M. Purcell and David J. Morin.

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. C: Define *electric potential difference*. Units?

2. C: What are the units of *voltage*?

3. C: **Use a pencil and ruler!** The work done in moving a charge is given by the equation $W = q \times \Delta V$. Draw and label a diagram to describe this equation.

4. C: What is *charge q*? Units?

5. C: Define *electric current I* and state its equation and units. Do not confuse *current I* with *impulse* $\vec{J}$!

6. C: What is the relationship in magnitude and direction between *electron flow* and *current* in a conductor?

7. C: Define resistance. Give the units of *resistance* Ω.

8. C: What is the resistance of an ideal wire?

9. C: Define *resistor*. Do resistors increase or decrease the current in a circuit? Why is it necessary to have a resistor in a circuit?

10. C: Define *resistivity* ρ. Do not confuse resistivity ρ with density ρ!

11. C: What is the *resistance* of a non-ideal wire directly proportional to?

12. C: What is the resistance of a non-ideal wire inversely proportional to?

13. E: A piece of wire 40.0 cm long is measured to have a resistance of 7.20 Ω. What will be the resistance of an otherwise identical wire which has a length of 120. cm?

14. E: A piece of wire, which has a diameter of 0.500 mm, is measured to have a resistance of 8.40 Ω. What will be the resistance of an otherwise identical wire which has a diameter of 0.250 mm?

15. C: Define *Ohm's Law*. Draw a current vs. voltage graph of a resistor obeying Ohm's law.

16. C: What does a *thermistor* do? Draw a *resistance vs. temperature* graph of a thermistor.

17. C: What does a *light-dependent resistor* (LDR) do?

18. C: What does a *potentiometer* do?

19. C: Define *non-ohmic*.

20. C: Give three versions of the equation for *electrical power.*

21. E: A current of 0.870 Amperes flows through a certain light bulb when it is attached to a 115. Volt power supply. How much power does this light bulb dissipate?

22. E: A 25.0 Ω resistor is connected to a 5.70 Volt battery with negligible internal resistance.

    a. What will be the current flowing through the resistor?

    b. How much power will be dissipated in this resistor?

23. E: A certain light bulb is designed to dissipate 5.00 W of power when attached to a 12.0 V source. What is the resistance of the light bulb filament?

24. E: A 25.0 Ω resistor and a 75.0 Ω resistor are connected in series across a 12.0 V source. How much power will be consumed by the 25.0 Ω resistor?

25. E: A 55.0 Ω resistor is attached to a 12.0 V power supply. This resistor is then immersed in a Styrofoam cup containing 25.0 g of water initially at a temperature of 22.5°C for a period of 150. s.

    a. How much power is being delivered to the resistor?

    b. How much energy will be delivered to the water during these 150. s?

    c. What will be the final temperature of the water?

26.C: Define *electromotive force emf*. What are its units?

27.C: State *Kirchhoff's loop rule*. Which conservation rule does this law obey?

28.State *Kirchhoff's junction rule*. Which conservation rule does this law obey?

29.C: Resistors in series have the same _____.

30.C: Resistors in parallel have the same _____.

31.C: How can we simplify many *resistors in series*?

32.C: How can we simplify many *resistors in parallel*?

33.C: What does an *ammeter* do? Draw its symbol. What is a characteristic of an *ideal ammeter*? How/Where do we insert an *ammeter* in a circuit?

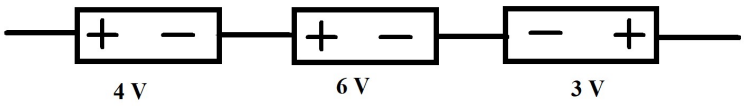
34.C: What does a *voltmeter* do? Draw its symbol. What is a characteristic of an *ideal voltmeter*? How/Where do we insert a *voltmeter* in a circuit?

35.E: Six 2.02 Volt cells are connected in series. What will be the total emf produced?

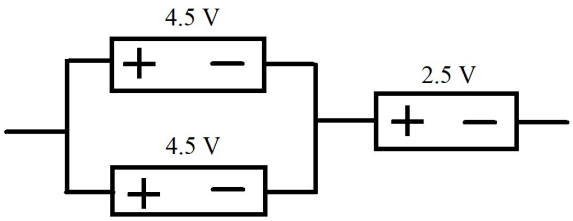
36.E: What will be the emf produced by four 1.50 Volt cells connected in series?

37.E: What will be the emf produced by three 6.00 Volt batteries connected in parallel?

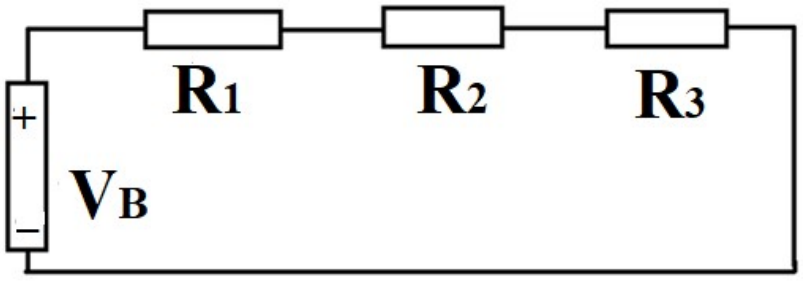
38.E: What will be the emf produced by the combination of cells below?



39.E: What will be the emf produced by the combination of cells below?



40.E: Solve for the unknowns. Give your answers in reduced fractions.

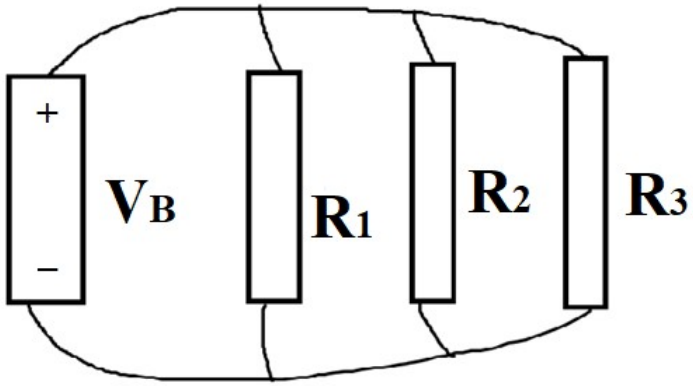
	Given: $V_B = 10\ V$ $R_1 = 2\Omega$ $R_2 = 4\Omega$ $R_3 = 6\Omega$

$R_{equivalent} =$ $I_{battery} =$	$V_1 =$ $V_2 =$ $V_3 =$	$I_1 =$ $I_2 =$ $I_3 =$

What will happen to the current leaving the battery if the number of resistors in series increases? Will the current increase, decrease, or stay the same?

What will happen to the overall resistance of the circuit if the number of resistors in series increases? Will the overall resistance increase, decrease, or stay the same?

41.E: Solve for the unknowns. Give your answers in reduced fractions.



Given:

$V_B = 10\ V$

$R_1 = 2\ \Omega$

$R_2 = 4\ \Omega$

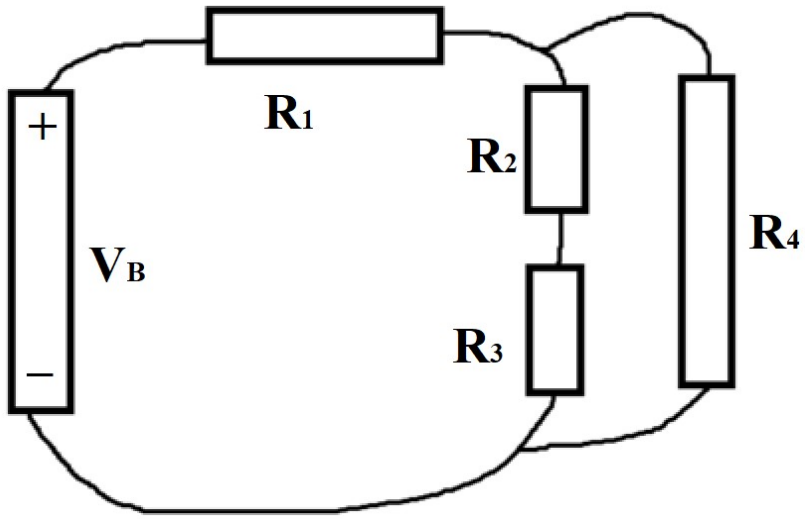
$R_3 = 6\ \Omega$

$R_{\text{equivalent}} =$ $I_{\text{battery}} =$	$V_1 =$ $V_2 =$ $V_3 =$	$I_1 =$ $I_2 =$ $I_3 =$

What will happen to the current leaving the battery if the number of resistors in parallel increases? Will the current increase, decrease, or stay the same?

What will happen to the overall resistance of the circuit if the number of resistors in parallel increases? Will the overall resistance increase, decrease, or stay the same?

42.E: Solve for the unknowns. Give your answers in reduced fractions.



Given:

$V_B = 10\ V$

$R_1 = 2\ \Omega$

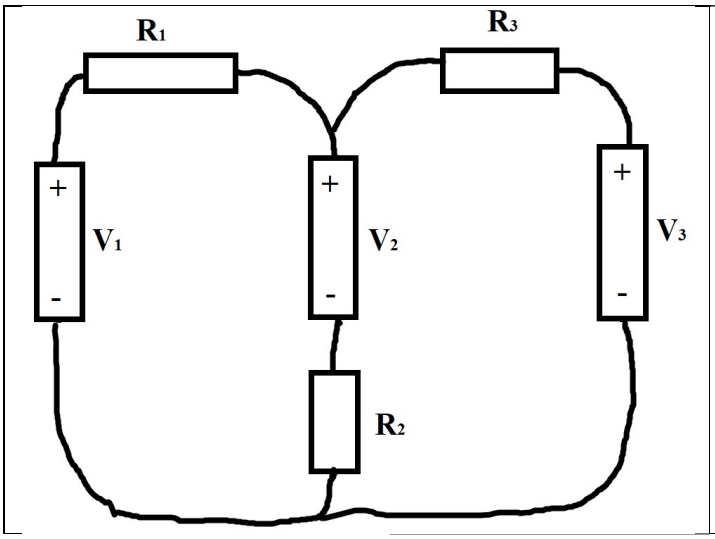
$R_2 = 4\ \Omega$

$R_3 = 6\ \Omega$

$R_4 = 8\ \Omega$

$R_{\text{equivalent}} =$	$V_1 =$	$I_1 =$
	$V_2 =$	$I_2 =$
$I_{\text{battery}} =$	$V_3 =$	$I_3 =$
	$V_4 =$	$I_4 =$

43.E: Solve for the unknowns. Give your answers in reduced fractions.



$V_1 = 6\ \text{V}$

$V_2 = 11\ \text{V}$

$V_3 = 17\ \text{V}$

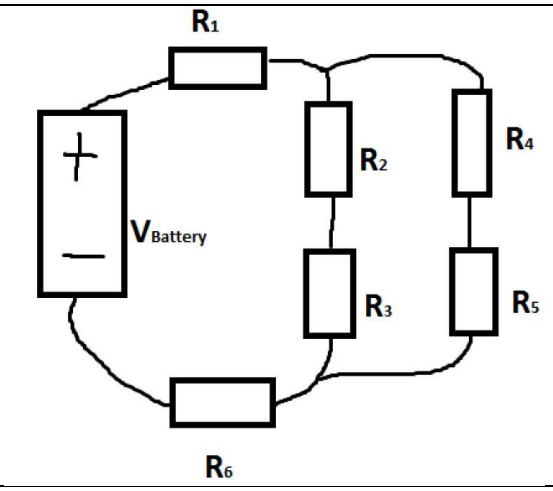
$R_1 = 3\ \Omega$

$R_2 = 1\ \Omega$

$R_3 = 4\ \Omega$

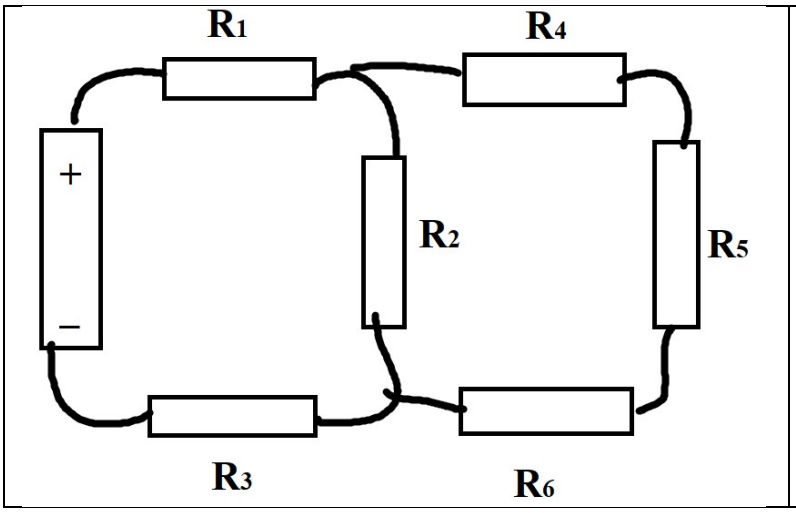
$I_1 =$	$V_1 =$
$I_2 =$	$V_2 =$
$I_3 =$	$V_3 =$

44.E: Solve for the unknowns. Give your answers in reduced fractions.

	$V_{\text{battery}} = 10\ \text{V}$ $R_1 = 1\ \Omega$ $R_2 = 2\ \Omega$ $R_3 = 3\ \Omega$ $R_4 = 4\ \Omega$ $R_5 = 5\ \Omega$ $R_6 = 6\ \Omega$

$R_{\text{equivalent}} =$			$I_{\text{battery}} =$		
$I_1 =$	$I_2 =$	$I_3 =$	$I_4 =$	$I_5 =$	$I_6 =$
$V_1 =$	$V_2 =$	$V_3 =$	$V_4 =$	$V_5 =$	$V_6 =$

45.E: Solve for the unknowns. Give your answers in reduced fractions.



$V_{\text{battery}} = 30\ \text{V}$

$R_1 = 1\ \Omega$

$R_2 = 2\ \Omega$

$R_3 = 3\ \Omega$

$R_4 = 4\ \Omega$

$R_5 = 5\ \Omega$

$R_6 = 6\ \Omega$

$R_{\text{equivalent}} =$			$I_{\text{battery}} =$		
$I_1 =$	$I_2 =$	$I_3 =$	$I_4 =$	$I_5 =$	$I_6 =$
$V_1 =$	$V_2 =$	$V_3 =$	$V_4 =$	$V_5 =$	$V_6 =$

46. C: What is a *potential/voltage divider*?

47. C: Define *internal resistance r*. Units?

48. C: Define the following variables for the equation $\varepsilon = I(R + r)$. Draw an image to describe this equation.

49. E: A dry cell has an emf of 3.04 V. Its terminal potential drops to zero when a current of 50.0 A passes through it. What is its internal resistance?

50. E: A cell has an emf of 145 V. This means that its terminal voltage is 145 V when no current flows through it. When the terminal potential is 120. V the current through the circuit is 25.0 A.

    a. What is the internal resistance of the cell?

    b. What will be the terminal potential when the current is 12.0 A?

51. E: A cell with internal resistance is connected to a 3.00 Ω resistor. Determine the internal resistance r of the cell if the current going through it is 2.00 Amps when its ε is 12.0 V.

52.E: A battery with internal resistance is connected to a variable resistor. When the resistor has a resistance R of 12.0 Ω the current is 2.00 Amps. When the resistor has a resistance R of 6.00 Ω the current is 3.00 Amps. Determine the emf ε and internal resistance r of the battery.

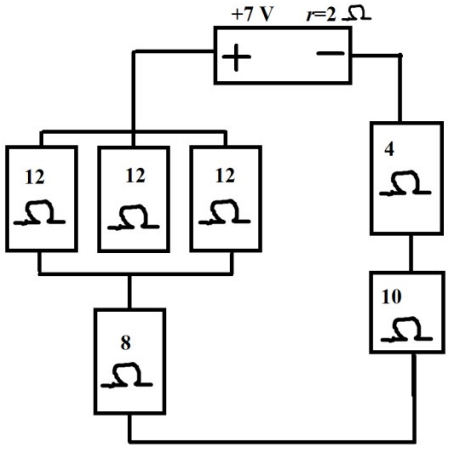
53.E: While attached to a 2.00 Ω resistance the terminal voltage of a battery is measured to be 5.20 V. The open circuit voltage of this same battery is measured to be 6.70 V.

a. What is the internal resistance of the battery?

b. What will be the maximum current that can be delivered by the battery?

54.E: A battery is known to have an emf of 4.60 Volts and an internal resistance of 2.20 Ω. What will be the terminal voltage of this battery while connected to a load of 7.80 Ω?

55.E: Consider the circuit below:



a. What is the total resistance of this circuit?

b. What will be the total current flowing through this circuit?

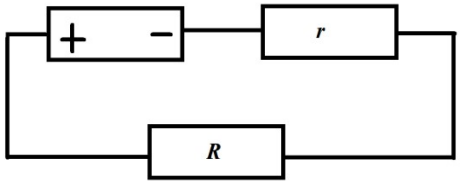
c. What will be the current flowing through each 12.0 Ω resistor?

d. What will be the voltage drop across each of the 12.0 Ω resistors?

e. What will be the terminal voltage of the battery?

f. What will be the voltage drop across the 10.0 Ω resistor?

56.E: A battery, which has an emf of 6.00 V and an internal resistance $r = 0.500\ \Omega$, is connected to a load which has a resistance of $R = 3.50\ \Omega$.



a. What will be the current flowing in this circuit?

b. What will be the voltage drop across the load?

c. How much power is being supplied by the battery?

d. How much power is being consumed by the load?

e. How much power is being consumed by the internal resistance of the battery?

f. With what efficiency is power being delivered to the load in this circuit?