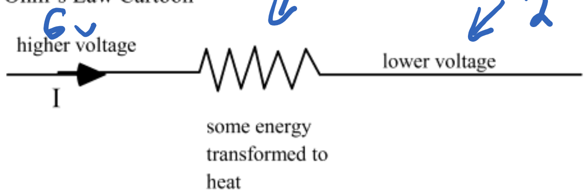
Lesson 2: Joule's Law and Electric Power

A. Electrical Power

•recall that as charges flow through a circuit device (like a resistor or lightbulb), they lose energy due to collisions with the atoms in the wire.

Show Ohm's Law Cartoon



$V = \frac{PE}{\varepsilon}$

This energy lost by the charges is transformed into heat energy. The energy lost by charges is related to voltage drop since PE = q V.

•example 1: a) fill in the steps below to find an expression for the rate at which the charges lose energy (power)
b) check the units in this relationship

a) Power = $\frac{\text{energy loss}}{\text{time}}$

$P = \frac{qV}{t}$ (energy loss = qV)

$P = \frac{q}{t} V$ (grouping)

$P = IV$ (since $I = \frac{q}{t}$)

$P = VI$

b) Power= energy drop per coulomb of charge × coulombs of charge per second

•so the rate at which electrical energy is transformed to heat energy is given by:

Joule's Law

$P = VI$	V=voltage drop across circuit device (volt=J/C) I= current through device (A=C/s) P=power = rate of energy transformation (Watt=J/s)

•example 2: use Ohm's Law (V = I R) and find two more relationships for the power dissipation in a resistor

$P = IRI$

$P = I^2R$

$P = V\left(\frac{V}{R}\right)$

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

So, basically if we know and 2 of [V, I, R, and P] we can figure out all 4 of them.

Show Spiderman comic

•technical comment: in finding the energy lost by the charges, we should really use the work energy theorem:

$(KE + PE)_i + W_{n\text{-}c} = (KE + PE)_f$

$W = \Delta PE + \Delta KE$

Once flow is established however, charges flow through a circuit at constant speed, so the KE_i and KE_f are the same. Substituting PE = qV

$$KE + qV_i + W_{n\text{-}c} = KE + qV_f$$

Solving for work, we find

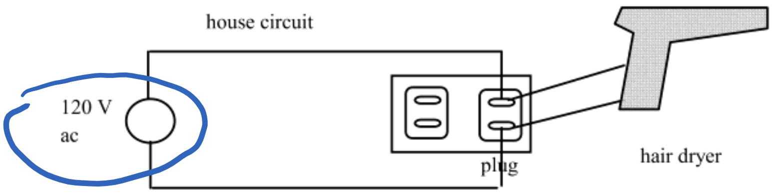
$$W_{n\text{-}c} = q(V_f - V_i) = q\,\Delta V = \text{charge (voltage drop)}$$

And as we have already remarked, we write V in place of the more correct ΔV when we are studying circuits

So this is why we can say work= energy loss = qV

•example 3: find the current in your house wires if you plug in a 1400 W hair dryer

$P = VI$



$I = ?$ $P = 1400\ W$ $V = 120\ V$

$$I = \frac{P}{V} = \frac{1400}{120} = 11.7\ A$$

•example 4: mix and match the following appliances with their power ratings:

appliance		approximate power use
computer	800 W	~~0.1 W~~
light bulb (average)	60 W	~~1200 W (1.2 kW)~~
hot water heater	3200 W	~~150 W~~
microwave (large)	1200 W	~~800 W~~
clock	0.1 W	~~60~~ W
clothes dryer	4800 W	~~4800~~ W
kitchen fan	150 W	~~3200 W~~

B. Electrical Energy

•Since Power $= \frac{\text{energy}}{\text{time}} = \frac{E}{t} = \frac{J}{s}$ we can solve for energy and find

$$E = Pt$$

E=electrical energy used (J)
=work done/heat energy produced
P= power (Watt)
t = time(sec)

•since the Joule is a relatively small unit of electrical energy, it is common to use a larger unit, the "kiloWatt-hour" (P t)

1 kiloWatt-hour = 1000 Watt (3600 seconds) $= 3.6 \times 10^6$ J

A typical household will use 1000-3000 kWhr of electrical energy in a month!

•example 5: a) if a 60. W bulb is left on all month (30. days, 24 hrs per day) find the amount of energy it will use in Joules

b) repeat a) in kiloWatt-hours

c) given that BC Hydro charges about 6.0 cents per kWhr, find the cost of leaving the bulb on all month

a) $P = \frac{W}{t} \Rightarrow E = Pt = (60)(30 \times 24 \times 60 \times 60)$

$E = 155{,}520{,}000$ J

b) $155{,}520{,}000 \text{ J} \times \frac{1 \text{ kWh}}{3.6 \times 10^6 \text{ J}} = 43.2$ kWh

c) $43.2 \text{ kWh} \times \frac{\$.06}{\text{kWh}} = \$2.59$

•example 6: A 60. Watt lightbulb is connected to 120 Volts AC. It produces 58 J of heat and light every second. It is left on for 8 hours. Electricity costs 6.0 cents per kWhr. Find

a) current thru bulb b) resistance of bulb (assume ohmic)

c) energy used d) cost of energy use

a) $I = ?$ $V = 120$ $P = 60\ W$ $P = VI$

$I = \frac{P}{V} = \frac{60}{120} = 0.50\ A$

b) $R = ?$ $V = IR \rightarrow R = \frac{V}{I} = \frac{120}{0.50} = 240\ \Omega$

c) $E = Pt = (60)(8 \times 60 \times 60) = 1{,}728{,}000\ J$

$E = 1728000\ J \times \frac{1\ kwh}{3.6 \times 10^6\ J} = 0.48\ kwh$

d) $0.48\ kwh \times \frac{\$.06}{kwh} = \$.03$

Lesson 2 Joule's Law Unit 7 Circuitry Name: __________

Exercises

1) A 120 V source is connected to a 300. W resistor. Find
   a) the current
   b) the resistance
   c) the heat energy produced in 20. minutes

(2.5A; 48 Ω; 3.6×10^5J or 0.10 kWhr)

2) A 120. V source is connected to a 1500. W kettle. Find
   a) the current
   b) the resistance
   c) the energy (in kWhr) used in a day
   d) if energy costs 5.20 cents per kWhr, how much would it cost to run the kettle for a day
   (12.5 A; 9.60Ω; 36.0 kWhr; $1.87)

3) A 220. Watt computer is connected to 110. volts of alternating current and left on all month. Find
a) the resistance b) current c) energy used per 30 day month
d) cost of electricity (5.50 cents/ kWhr) (55.0Ω;2.00A; 158 kWhr; $8.71)

4) It takes 10.0 kJ of energy to cook a hot dog. If a 30.0 ohm hot dog is connected to 120. volts, how long will it take until it is cooked? (20.8 sec)

5.

A. the number of charges stored in a cell.
B. the amount of energy given to a charged object.
C. the charge passing a point in a circuit in a given time.
D. the resistance to the flow of charged particles in a circuit.

Ans: C

6. A 12 V battery transfers 45 C of charge through a light bulb in 5.0 seconds. (a) What current flows through the circuit? (b) What is the resistance of the light bulb? (c) What is the power used by the light bulb?

Ans: (a) 9.0 A (b) 1.33 Ω (c) 108 W

7. A 6 V battery transfers 24 C of charge through a light bulb in 16 seconds. (a) What current flows through the circuit? (b) What is the resistance of the light bulb? (c) What is the power used by the light bulb?

Ans: (a) 1.5 A (b) 4.0 Ω (c) 9.0 W

8. A electric motor with a constant resistance draws 0.60 A when connected to a 4.8 V power source. The motor is now connected to a 9.0 V power source. What is the new current and the power use for the motor?

Ans: I = 1.13 A, P = 10.1 W

9. A 120 V supply is connected to a heater of resistance 25 Ω. (a) How much power will it use? (b) What must be the resistance of another heater to produce the same power output when connected to a 240 V supply?

Ans: (a) 576 W (b)

10. A 24 V supply is connected to a 15 Ω for 3 minutes. How many coulombs of charge pass through the resistor?

Ans: 288 C

11. Which of the following electric devices has the greatest rate of energy consumption?

ITEM	**VOLTAGE**	**CURRENT**
Video Camera	6.0 V	0.20 A
Radio	4.5 V	0.50 A
Smartphone	3.0 V	0.60 A
Fan	120 V	0.025 A

(Answer: Fan with 3.0 W)

I will send out solutions on Wednesday, as well as the "Whoa Wednesday" YouTube bonus assignment.