Lecture 13

April 30, 2012

2. A jeweller needs to melt a .5 kg block of silver at 20 °C, in order to pour into her molds. How much heat is needed to achieve this in kJ?

3. Solar energy is incident on a parking lot with intensity 1000 W/m^2, and 75 % of it is absorbed. After 8 hours of exposure, how much energy per squared meter has been absorbed? Express your answer in Btu/m^2 and in calorie/m^2.

After 8 hours of exposure the energy absorbed per squared meter will be (remember that W=J/s)

$$0.75 \times \frac{1000\ \mathrm{J}}{\mathrm{s\ m^2}} \times \frac{3600\ \mathrm{s}}{1\ \mathrm{hr}} \times 8\ \mathrm{hr} = 2.16 \times 10^7\ \mathrm{J/m^2}$$

Convert this to Btu/m^2

1 J = 9.49×10^{-4} Btu

Answer= 1.9×10^4 Btu/m^2

Continuation: If 50 % of the solar energy (again with intensity 1000 W/m^2) incident on a 3 m x 3 m surface for 30 minutes is used to heat up 10 kg of water, how much is the increase in the water temperature?

On a surface of 3 x 3 = 9 m^2, the solar energy deposited in 30 minutes is

$$\frac{1000 \text{ J}}{\text{s m}^2} \times \frac{60 \text{ s}}{1 \text{ min}} \times 30 \text{ min} \times 9 \text{ m}^2 = 1.62 \times 10^7 \text{ J} = 1.62 \times 10^4 \text{ kJ}$$

where we used 1 kJ = 1000 J. Now, 50% of this energy is used to heat up the water:

$$Q = 0.5 \times 1.62 \times 10^4 \text{ kJ} = 8.1 \times 10^3 \text{ kJ}$$

To find the increase in the water temperature, use Q=m C ΔT,
where C is the heat capacity of water, m the mass and ΔT the increase in temperature.
Solve for ΔT.

$$\Delta T = \frac{Q}{mC} = \frac{8.1 \times 10^3 \text{ kJ}}{10 \text{ kg} \times 4.2 \text{ kJ/kg}^0\text{C}} = 193\ ^0\text{C}$$

4. An ideal heat pump takes in work at the rate of 3000 Btu/second and delivers heat at the rate of 5000 Btu/second. What is the power that it absorbs from the environment? What is its coefficient of performance? If the pump is non ideal, would its coefficient of performance decrease or increase?

Let's call P_{input} the input power (3000 Btu/s), P_C the power absorbed from the environment and P_H the power delivered. In terms of W, Q_C, $Q_H$$ these powers are simply P_{input}=W/time, e.g. P_C=Q_C/time, P_H=Q_H/time. We find

$$P_C = P_H - P_{input} = 2000 \text{ Btu/s}$$

The coefficient of performance is

$$\text{C.O.P.} = \frac{Q_H}{W} = \frac{P_H}{P_{input}} = \frac{5000}{3000} = \frac{5}{3}$$

If the pump were not ideal, the coefficient of performance would decrease

Next set of topics:

Electric Energy Concepts

Electrical Laws (Ohm's law, Joule Heating)

Faraday's law and the Generation of electricity

Transmission of electricity (transformers)

Current, Voltage, Resistance
Joule Heating.

Appliances and
their evaluation

Later in a two weeks Solar cells and their efficiency, basics of quantum theory

Supplementary notes to RK on web

Common Denominator

Coal, Petroleum, Natural Gas, Nuclear, Hydro all end up creating electricity
Electricity is a crucial part of the energy enterprise giving it portability.

Electricity Basics:

Electrostatics:

Rubbing generates electrical potential, Lightening, ...

Q Coulomb

Unit of
charge is a
Coulomb

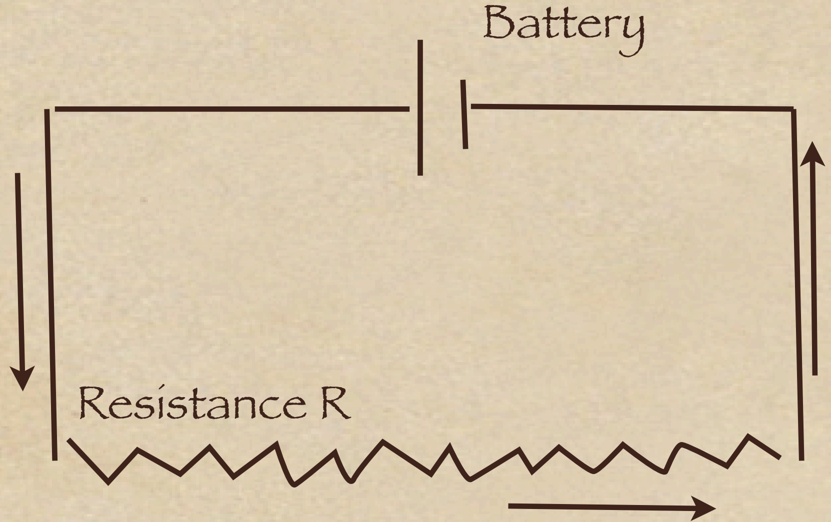
Like charges repel
Opposite charges attract
F is the force between two charges
k is the Coulomb force constant.

$$F(R) = k\frac{Q_1 Q_2}{R^2}$$

$$[k] = 8.99 \times 10^9 \text{ Newton Meter}^2/\text{Coulomb}^2$$

Moving charges give currents: electrodynamics

Current:



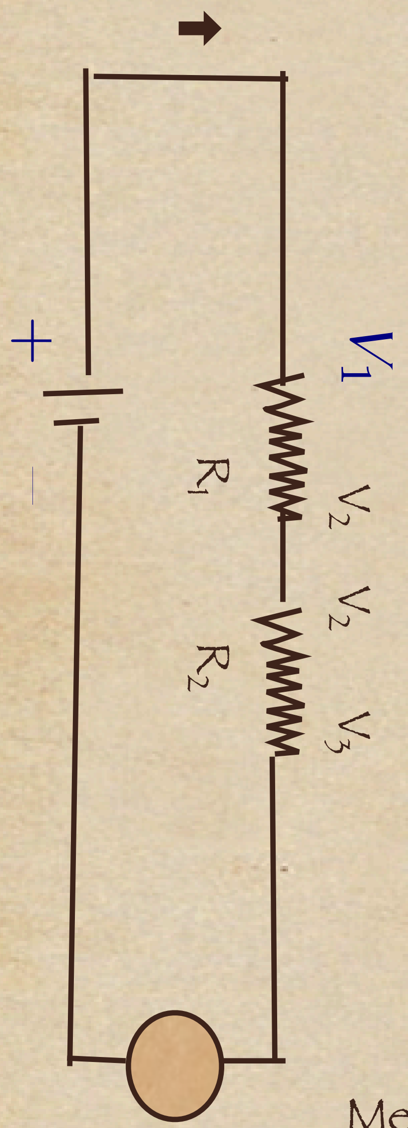
I Ampere = Coulomb/sec

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

Useful Analogy: Charge "Q" is the total quantity of water in a tank.
Current "I" is the amount of water flowing through a pipe per second
Unlike charge, the current has a direction. We may speak of Q as a scalar and I as a vector.

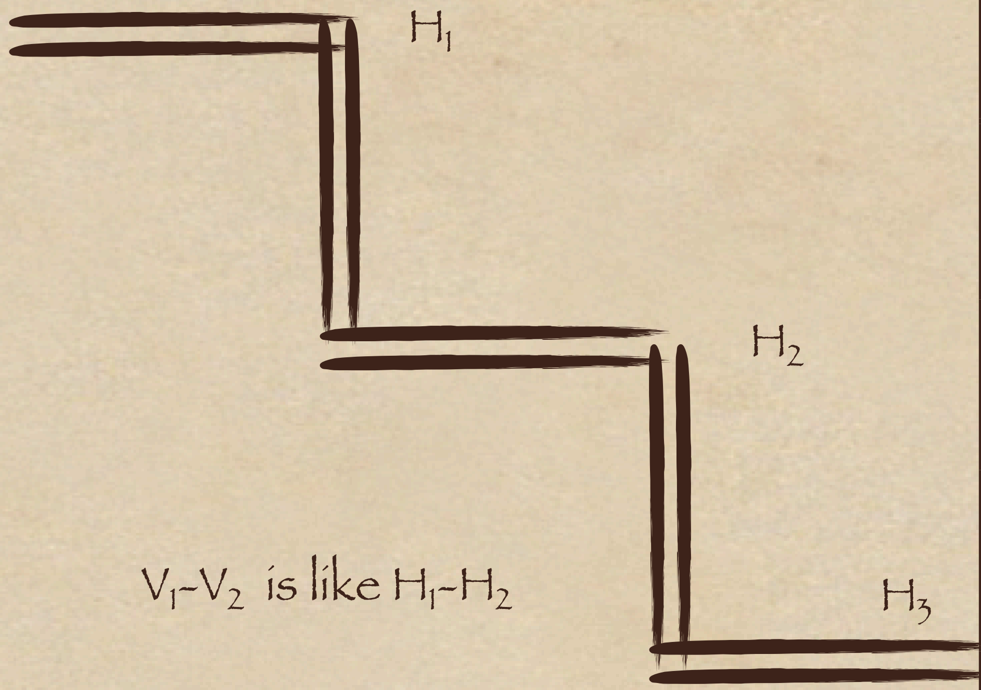
Example1: 100 Coulombs in 10 seconds gives a current of 10 amperes

Example2 : A bulb has a flow of 1 amp and is used for 10 minutes. Total charge = 600 seconds x 1 ampere = 600 Coulombs



Measures current

(Ammeter)



Water flow

in a terrace

V_1-V_2 is like H_1-H_2

V_2-V_3 is like H_2-H_3

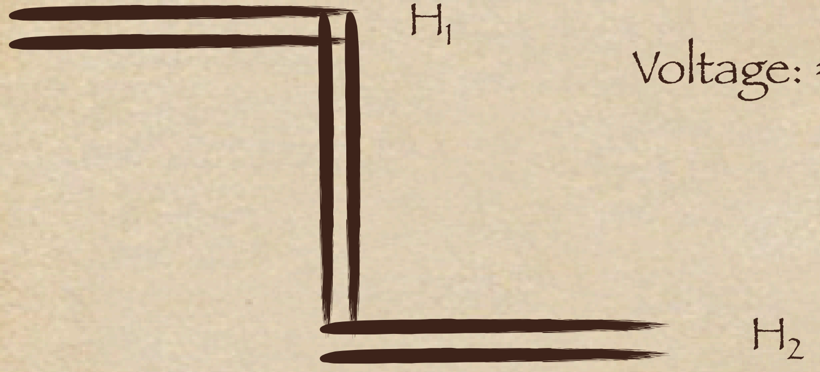
Battery voltage is the total potential drop

$V = V_1 - V_3$

Water	Electricity
Total water in tank	Charge Q in battery [Coulomb]
Rate of flow of water in a pipe	Current I [Amperes]
Height of tank	Potential V [Volts]
Height difference	Potential difference
Constriction of pipe carrying water	Resistance R [Ohms]
Work done in forcing water through a pipe	Work done in pushing charge through a
Rate of doing work is power {watts}	Rate of doing work is power P {watts}

Water flow

in a terrace



Voltage: = potential difference

Analogy is to a height difference in water:

$V_1 - V_2 = H_1 - H_2$

Voltage= potential difference

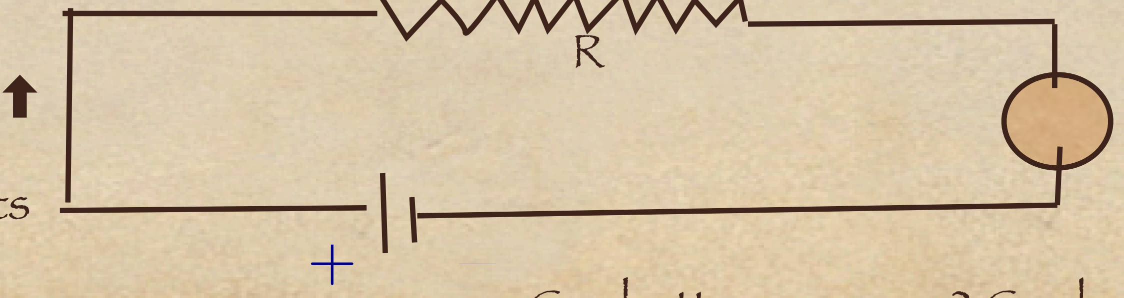
W= work done in moving a charge against a potential

$$V = V_1 - V_2$$

$$W = V \times Q$$

Measures current

(Ammeter)



$$[V] = Joules/Coulomb$$

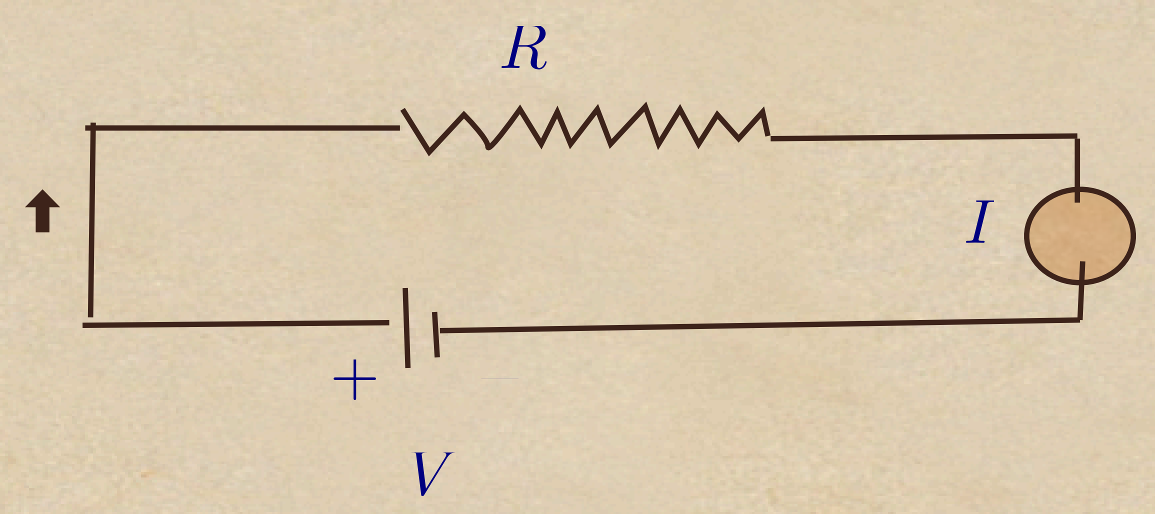
$$[V] = Volt$$

Car battery : 12 Volts

Cells: 1.5 Volts

Car battery passes 2 Coulombs charge doing 24 J work.

Resistance and Ohm's law



$$V = I \times R$$

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

$$[R] = Ohms \rightarrow \Omega$$

$$[R] = \text{Volts/Ampere}$$

True for most metallic wires

R= resistance of the wire

Example : Battery 12 V, connect to resistance 1 Ohm gives current of 12 ampere.
by changing the resistance, we change the current in this situation