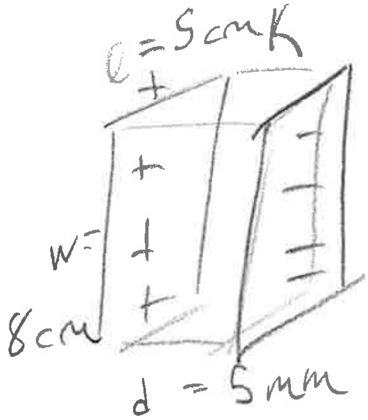
Warm up Problem



$$C = K \varepsilon_0 \frac{A}{d}$$

$$A = l \cdot w$$

$$C = K \frac{\varepsilon_0 l w}{d}$$

$$K = \frac{C d}{\varepsilon_0 l w}$$

$$C \geq 34.7\,pF$$

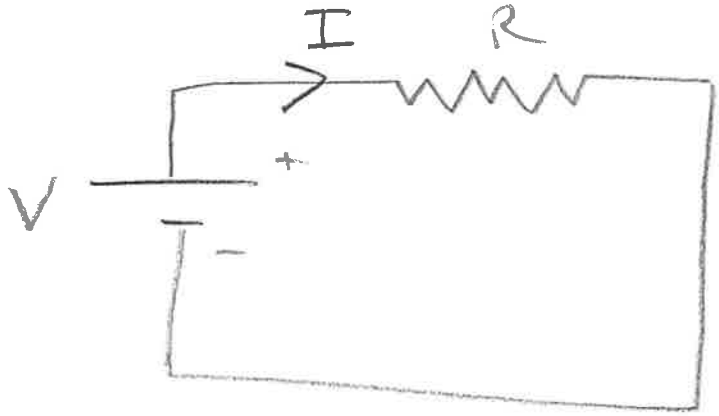
$$K \geq 4.90$$

Barkelite, Neoprene rubber, pyrex glass, Strontium titanite, water

$$C = \varepsilon_0 \frac{A}{d}$$

$$\boxed{C = 7.08\,pF}$$

Circuits



Symbols

 – battery

 – resistor

 – wire

 – capacitor

- current is the flow of positive charges.

Ohm's Law

$$V = IR$$

V – voltage (V)

I – current (Amps)

R – resistance (Ω ohms)

$1\,A = 1\,C/s$

$1\,\Omega = 1\,Js/C^2$

Ohm's Law Example

A 12V car battery delivers 2.5A through a vehicles headlights. What is the resistance of the lights?

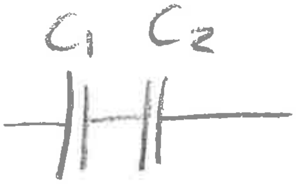
$$V = IR$$

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

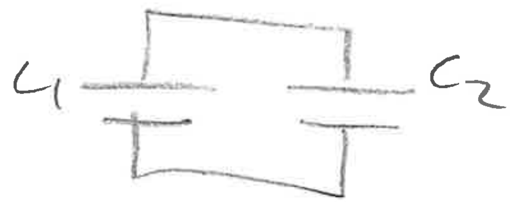
$$\boxed{R = 4.8\,\Omega}$$

Capacitors in Series and Parallel

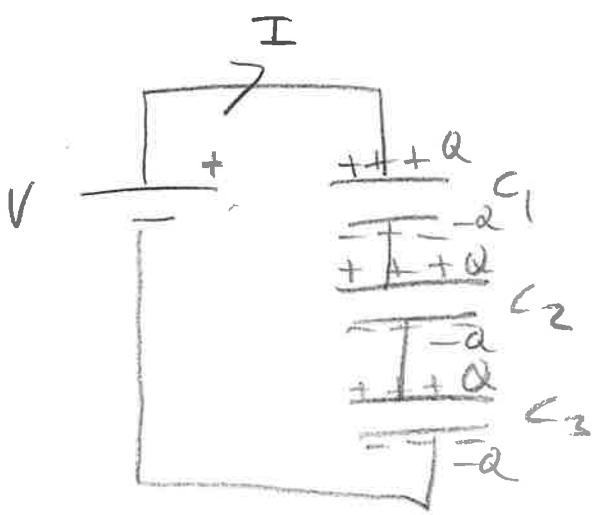
Series



Parallel



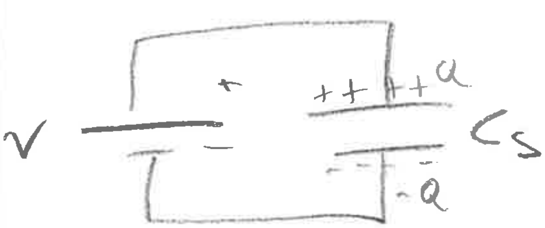
Series



- capacitors have same charge (by conservation of charge).

simplifies to

$$V = V_1 + V_2 + V_3$$



$$V = V_S$$

$$V = \frac{Q}{C}$$

$$\frac{Q}{C_S} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots}$$

capacitors in series.

- equivalent capacitor is always smaller than smallest constituent capacitor.

Capacitors in series

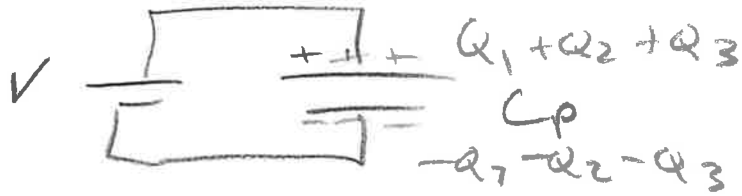
Three capacitors (1μF, 5μF, and 8μF) are connected in series. Find the equivalent capacitance.

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$C_s = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right)^{-1}$$

$$\boxed{C_s = 0.755\,\mu F}$$

capacitors in parallel



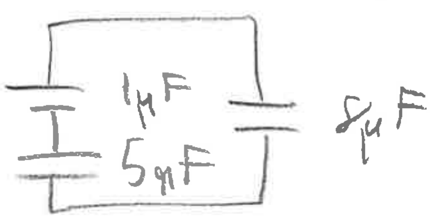
$$Q_1 + Q_2 + Q_3 = Q_p$$

$$C_1 V + C_2 V + C_3 V = C_p V$$

$$\boxed{C_p = C_1 + C_2 + C_3 + \ldots}$$

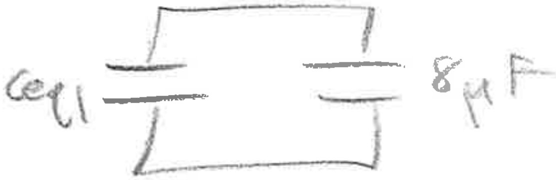
Series and parallel example

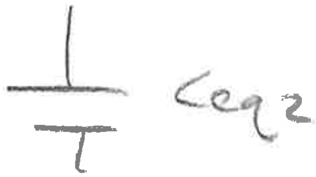
Find the equivalent capacitance.



$$\frac{1}{C_{eq1}} = \frac{1}{5} + \frac{1}{1}$$

$$C_{eq1} = 0.833\,\mu F$$





$$C_{eq2} = C_{eq1} + 8\mu F$$

$$\boxed{C_{eq2} = 8.833\mu F}$$

Current

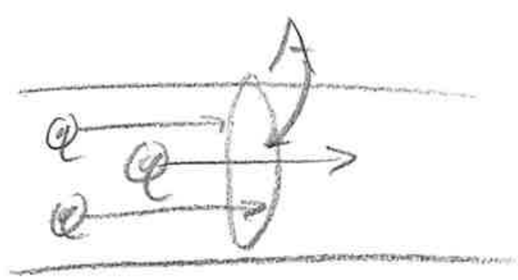
$$I = \frac{\Delta Q}{\Delta t}$$

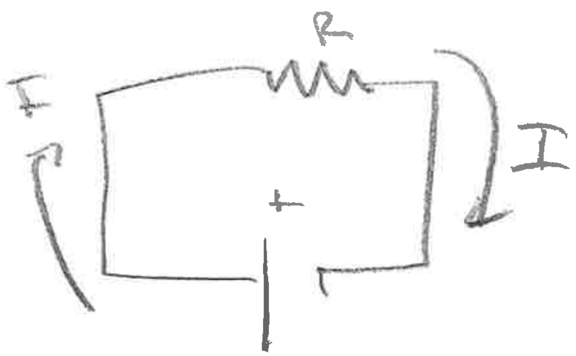
I – current (Amps)

ΔQ – flow of charge (C)

Δt – rate of time (s)

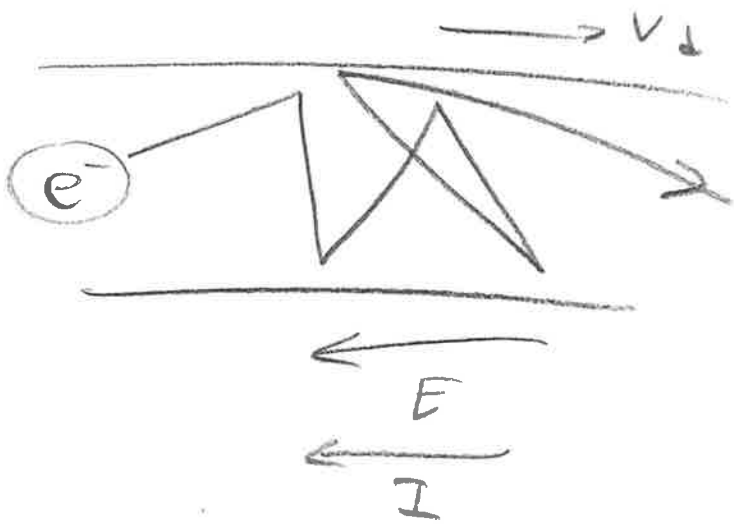
$$1A = 1C/s$$

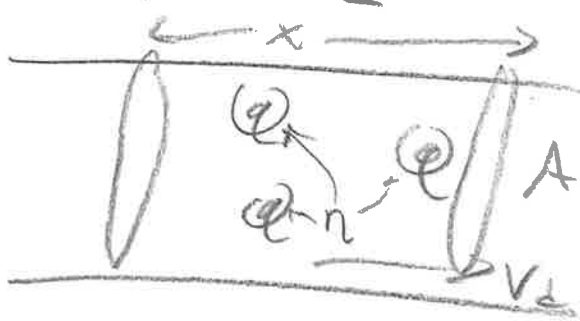




Drift velocity

- Flattening the motion of individual particles to the average, large-scale motion of free charges





n - free charges per volume

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

$$\frac{x}{t} = v_d$$

$$\boxed{I = nqAv_d}$$

I – current (A)

n – free charges per unit volume ($1/m^3$)

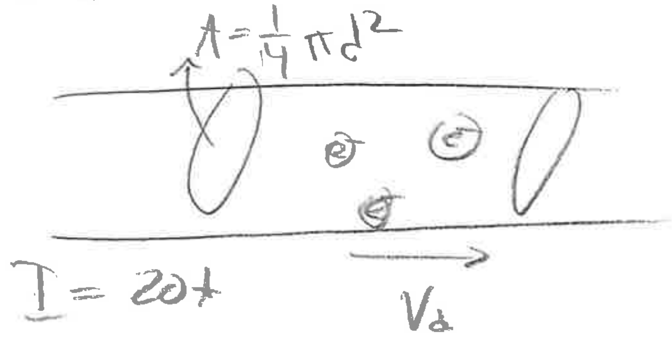
q – charge of particles (almost always 1.6×10^{-19} C)

A – cross-sectional area of wire (m^2)

v_d – drift velocity (m/s)

Drift velocity example

Calculate the drift velocity of electrons in a copper wire with thickness $d = 2.053$ mm carrying 20 A of current. There is $1e^-$ per Cu atom. The density of copper $8800\ kg/m^3$ and has an atomic mass of 63.54 g/mol. Avogadro's number is $6.022 \times 10^{23}\ mol^{-1}$.



$n = 1e^-/atom$

$d = 2.053 \times 10^{-3}$ m

$q = -1.6 \times 10^{-19}$ C

10

$$I = nqAv_d$$

$$V_d = \frac{I}{nqA}$$

$$I = 20$$

$$A = \frac{1}{4}\pi d^2$$

$$n = 1 \cdot n_{cu} = 8800 \frac{\cancel{kg\,Cu}}{1m^3} \times \frac{1000\cancel{g\,Cu}}{1\cancel{kg\,Cu}} \times \frac{1\cancel{mol\,Cu}}{63.54\cancel{g\,Cu}} \times \frac{6.022\times10^{23}\ \text{atoms}\,Cu}{1\cancel{mol\,Cu}}$$

$$n = 8.34\times10^{28}\ e^-/m^3$$

$$q = 1.6\times10^{-19}$$

$$V_d = \frac{4I}{nq\pi d^2}$$

$$\boxed{V_d = 4.53\times10^{-4}\ m/s}$$