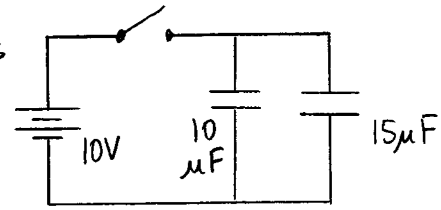
1) Some shorter questions:

(a) Find the total electric charge that flows out of the battery when the switch is closed. The capacitors are initially uncharged.



When we close the switch there will be 10 volts across each capacitor. So the charge on #1 will be

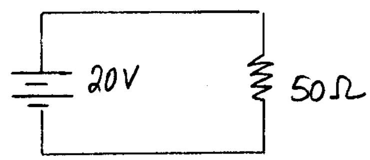
$$Q_1 = C_1 \Delta V = (10\mu F)\cdot(10v) = 100\mu C$$

and the charge on # 2 will be

$$Q_2 = C_2 \Delta V = 150\mu C$$

The total charge from the battery is ∴ → $\boxed{250\mu C}$

(b) How many electrons flow past any given point in this circuit in 1 minute? The electron's charge is -1.6×10^{-19} C.



20 volts across 50Ω ⇒

$$I = V/R = 20V/50\Omega = 0.4A = 0.4\ C/s$$

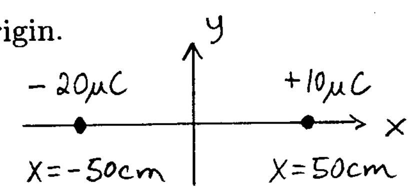
In 60 seconds we get

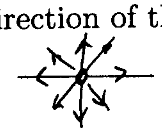
$$Q_{TOT} = (0.4\ C/s)\cdot(60s) = 24C$$

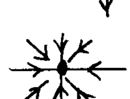
If N is the # of electrons then $Q_{TOT} = N \cdot q_e$

$$N = 24C / 1.6\times10^{-19}C$$ → $\boxed{1.5\times10^{20}}$

(c) Find the magnitude and direction of the electric field at the origin.



DIRECTION: + charge  ⇒ to left @ origin

− charge  also to left @ origin

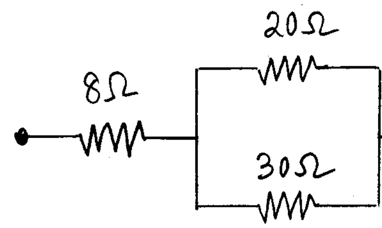
So add the two fields, with $E = \frac{1}{4\pi\epsilon_0}\frac{|q|}{r^2}$

$$E = \frac{1}{4\pi\epsilon_0}\left[\frac{10\mu C}{(0.5m)^2} + \frac{20\mu C}{(0.5m)^2}\right] = (8.99\times10^9)\ \frac{30\times10^{-6}}{(0.5)^2}$$

Magnitude: 1.08×10^6 N/C

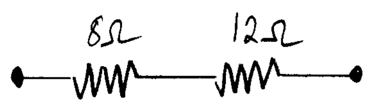
Direction: left

2) (a) Find the effective resistance of the resistor network shown.



① Add 20Ω and 30Ω in parallel

$$\frac{1}{R_{eq}} = \frac{1}{20\Omega} + \frac{1}{30\Omega} = \frac{5}{60\Omega} \qquad R_{eq} = 12.0\Omega$$

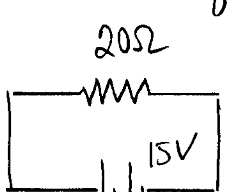


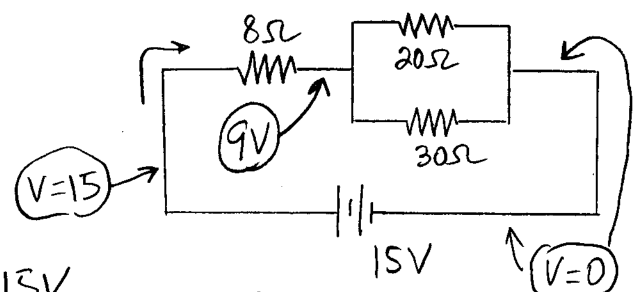
② Add 8Ω and 12Ω in series

$$R_{TOT} = R_1 + R_2 = 20\Omega$$

$\boxed{20\Omega}$

(b) Find the current flowing through each of the resistors if a 15 volt battery is connected across the network. The equivalent circuit is

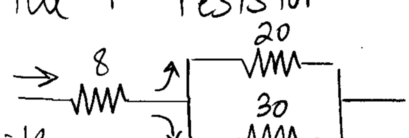




so the battery supplies $I = \frac{V}{R} = \frac{15V}{20\Omega} = 0.75\text{ A}$

All the current from the battery goes thru the 1st resistor

So $I_{8\Omega} = 0.75A$ That current then splits, with part going each way



To see what happens find voltages. (see drawing above) using the fact that the voltage drop across 8Ω will be

$\Delta V = I \cdot R = 0.75A \cdot 8\Omega = 6\text{ Volts} \Rightarrow V$ drops from +15V to +9V. So

$$I_{20\Omega} = 9V/20\Omega = 0.45A$$

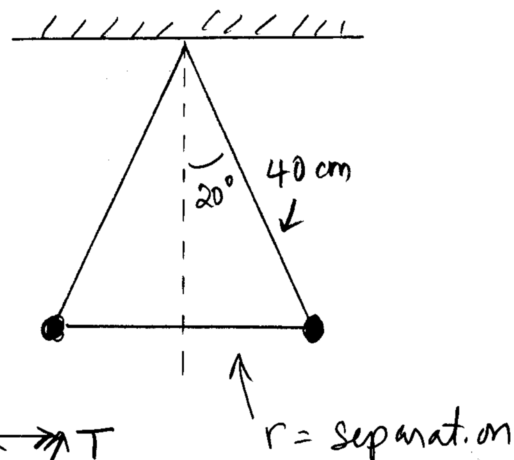
$$I_{30\Omega} = 9V/30\Omega = 0.3A$$

8Ω: $\boxed{0.75\text{ A}}$

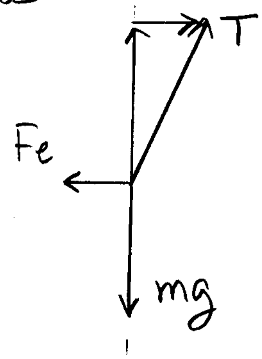
20Ω: $\boxed{0.45\text{ A}}$

30Ω: $\boxed{0.30\text{ A}}$

3) Two small conducting balls hang from strings of length $l = 40\,\text{cm}$ as shown in the drawing. Each ball has a mass of 200 g, and each carries the same positive charge q. The strings make angles of 20° with the vertical. Find q.



Make a free-body diagram for one mass. Then resolve T into components



$mg = T\cos\theta \Rightarrow T = mg/\cos\theta$

$F_e = T\sin\theta = \left(\frac{mg}{\cos\theta}\right)\cdot\sin\theta$

$F_e = (0.2\,\text{kg})(9.8\,\text{m/s}^2)\sin 20^\circ/\cos 20^\circ$

$= 0.713\,\text{N}$

Point charges $\Rightarrow$ $F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2} \Rightarrow q^2 = 4\pi\epsilon_0 F_e r^2$

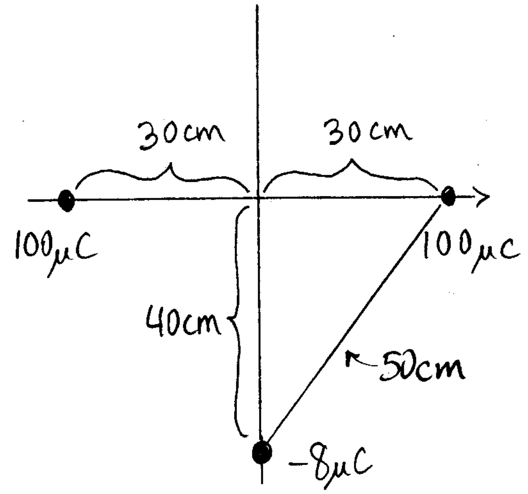
where $r = \text{separation} = 2\cdot l\sin\theta = 2(0.4\,\text{m})\sin 20^\circ$

$= 0.274\,\text{m}.$

$q^2 = \left(\frac{1}{8.99\times10^9}\right)(0.713\,\text{N})(0.274\,\text{m})^2 \Rightarrow q = 2.44\times10^{-6}\,\text{C}$

$\boxed{2.44\,\mu\text{C}}$

4) Two 100 μC point charges are located (and held fixed) on the x-axis as shown in the drawing. A third point charge (mass 50 g, charge $-8\,\mu$C), initially at rest, is released from a point on the y-axis 40 cm below the origin. Assume that the charges are on a frictionless horizontal surface (no gravity). What speed will the object have when it reaches the origin?



We will use conservation of energy,

$$(KE + PE)_i = (KE + PE)_f$$

In this problem the 100 μC charges produce a field that the -8μC charge moves in. We can find PE using $PE = qV$ where V is the electric potential

@ starting point $V = 2 \times \frac{1}{4\pi\epsilon_0} \frac{100\mu C}{0.5m} = 3.6 \times 10^6$ volts

@ origin $V = 2 \times \frac{1}{4\pi\epsilon_0} \frac{100\mu C}{0.3m} = 6.0 \times 10^6$ volts

$$KE_f = KE_i + PE_i - PE_f$$

$$= 0 + (-8\mu C)(3.6 \times 10^6\,V) - (-8\mu C)(6.0 \times 10^6\,V)$$

$$= 19.2\,J = \frac{1}{2} m v^2$$

$$v = \left[2\,(19.2\,J) \,/\, 0.05\,kg\right]^{\frac{1}{2}} = 27.7\,m/s$$

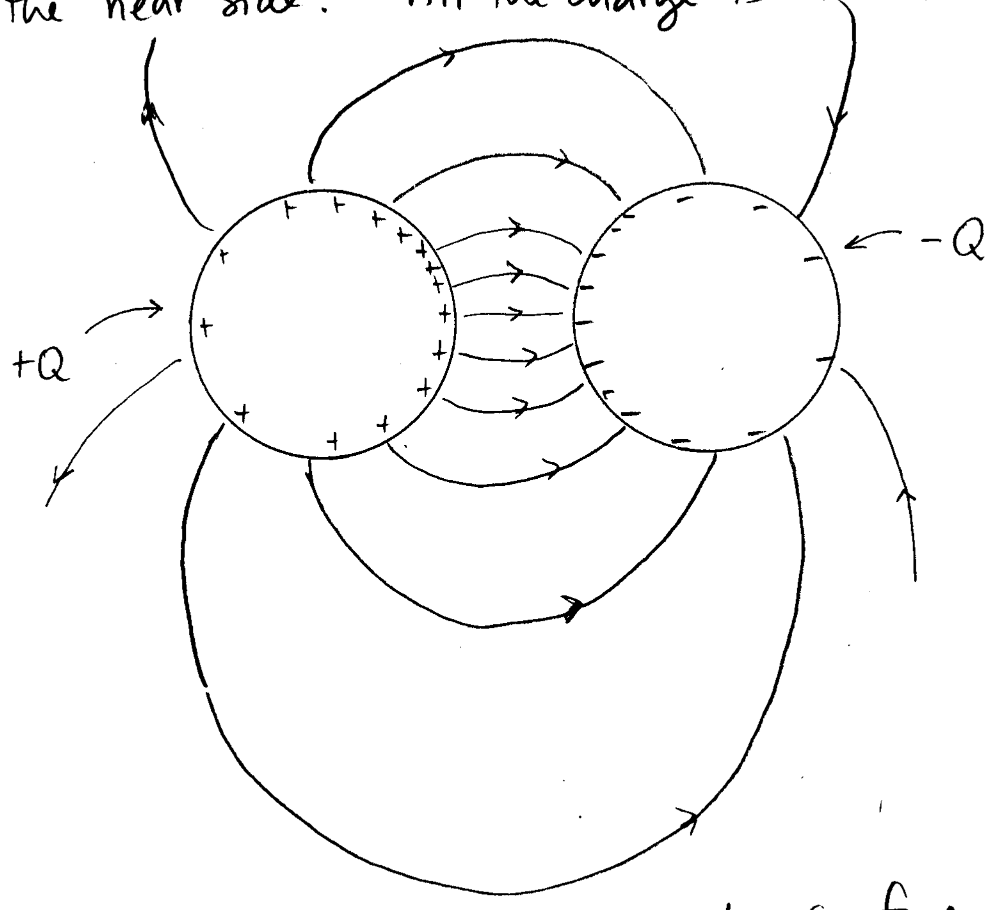
$\boxed{27.7\,m/s}$

5) Two large spherical conductors are located near each other. One has total charge $+Q$ and the other total charge $-Q$.

(a) Use symbols $+ + +$ and $- - -$ to show how you think the charge would be distributed on the conductors.

(b) On the same drawing, make a sketch showing what you think the electric field lines will look like in this situation.

The + and - charges attract, so there is more charge on the near side. All the charge is on the surface.



- Field lines are $\perp$ to conductor surface.
- Fields originate on + and end on - $\Rightarrow$ wherever there is charge there are field lines