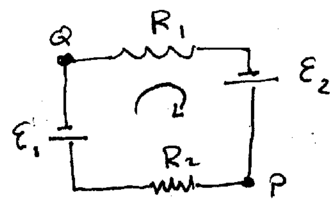
PHYS 195 : WEEK 10 SOLUTIONS

(1) FOR THE CIRCUIT  WE HAVE CLOCKWISE ORIENTATION FROM Q, IN A

$$\Sigma V = 0 = -IR_1 + \mathcal{E}_2 - IR_2 - \mathcal{E}_1$$

$$\Rightarrow \quad I = -\frac{\mathcal{E}_1 - \mathcal{E}_2}{R_1 + R_2} = -\frac{150 - 50}{3 + 2} = -20\text{ A}$$

SO A CURRENT OF 20 A FLOWS COUNTER-CLOCKWISE *

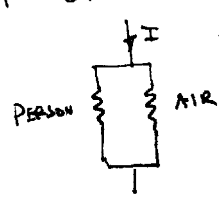
HENCE THE POTENTIAL AT Q, V_Q,

$$V_Q = V_P - IR_2 + \mathcal{E}_1 = 100 - (-20)(2) - 150$$

$$= -10\text{ V} \quad \left(= V_P - \mathcal{E}_2 - |I| R_1 \right)$$

(2) SEE * ABOVE

(3) THE 5000 A CURRENT PASSES EITHER THROUGH THE AIR OR THROUGH A BIT OF AIR THEN THE PERSON SO

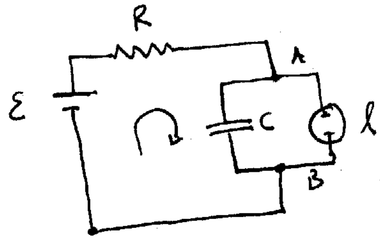


AND THE POTENTIAL DROP IS THE SAME FOR EITHER PATH. THUS, $I_P R_P = I_A R_A$. NOW $R \propto$ LENGTH (SEE EQUIN 26-16) SO, BECAUSE THE RESISTANCE OF THE PERSON IS ESSENTIALLY ZERO, $I_P d = I_A h$

$$\Rightarrow \quad I_P = I_A \frac{h}{d} \qquad \text{AND} \qquad I_P + I_A = I \Rightarrow I_A\left(1 + \frac{h}{d}\right) = I$$

$$\therefore \quad I_P = I \frac{\frac{h}{d}}{1 + \frac{h}{d}} = 5000 \frac{\frac{1}{.4}}{1 + \frac{1}{.4}} = 5000 \frac{2.5}{3.5} \simeq 3571 \simeq 3.6\text{ kA}$$

(4) WE HAVE



SO THERE'S A POTENTIAL DROP ACROSS A AND B. BOTH CAPACITOR AND LIGHT HAVE THIS SAME POTENTIAL DROP. ALSO, UNTIL THIS POTENTIAL REACHES V_L THE LIGHT PLAYS NO ROLE IN THE CIRCUIT. FROM KIRCHHOFF'S LOOP RULE WE HAVE, AROUND THE LOOP

$$\sum V = 0 = \mathcal{E} - IR - \frac{Q}{C} = 0 \quad \text{– AN "RC CIRCUIT"}$$

SINCE $I = \frac{dQ}{dt}$

$$\Rightarrow \quad \frac{dQ}{dt} + \frac{Q}{RC} = \mathcal{E}$$

SOLVING FOR Q GIVES $Q(t) = Q_0(1 - e^{-t/RC})$. WHEN WE WAIT FOR A LONG TIME

$$Q(t \to \infty) = Q_0 = C\mathcal{E}$$

SO $Q(t) = C\mathcal{E}(1 - e^{-t/RC})$ AND $V_{AB} = \mathcal{E}(1 - e^{-t/RC})$

NOW WE'RE SUPPOSED TO WAIT A $1/2$ SECOND $(t = 0.5s)$ FOR $V_{AB} = V_L$

SO $V_L = \mathcal{E}(1 - e^{-1/RC2})$

SINCE $\mathcal{E} = 95V$ AND $C = 0.15 \times 10^{-6}$ F WE HAVE

$$72 = 95\left[1 - e^{-1/R(.15\mu F)(2)}\right]$$

I LIKE SOLVING ~~THESE~~ ~~ALGEBRA~~ ALGEBRAICALLY FIRST SO

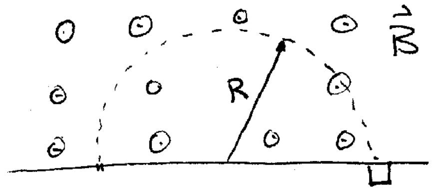
$$\frac{V_L}{\mathcal{E}} - 1 = -e^{-t_0/RC} \quad \Rightarrow \quad -\frac{t}{RC} = \ln\left(1 - \frac{V_L}{\mathcal{E}}\right)$$

AND $$R = \frac{-t}{C \ln\left(1 - \frac{V_L}{\mathcal{E}}\right)} = \frac{-1/2}{(0.15\mu F)\ln\left(1 - \frac{72}{95}\right)} \simeq 2.35 \times 10^6\ \Omega$$

(5) A MASS SPECTROMETER

FOR A CHARGE IN

A "$\perp$" ~~MAGN~~ B-FIELD



$$ma = m\frac{v^2}{r} = qvB$$

$$\Rightarrow R = \frac{mv}{qB}.$$ TO ACCELERATE THESE CHARGES WE CAN

USE ENERGY $\Delta K = \Delta U \Rightarrow \frac{1}{2}mv^2 = qV \Rightarrow v = \sqrt{\frac{2qV}{m}}$

HENCE, $R = \frac{m}{qB}\sqrt{\frac{2qV}{m}} = \sqrt{\frac{2mV}{q}}\,\frac{1}{B}$ AND

(a) $B = \left(\frac{1}{R}\right)\sqrt{\frac{2mV}{q}} = \left(\frac{1}{1}\right)\sqrt{\frac{(2)(3.92\times10^{-25})(100\,kV)}{3.2\times10^{-19}}} \simeq \underline{0.495\ T}$

(b) $I = \frac{dQ}{dt} = \frac{100\,mg}{3.92\times10^{-25}\,kg}\Big|\frac{3.20\times10^{-19}\,C}{hr}\Big| \simeq 8.16\times10\ C/hr$

$\simeq 2.27\times10^{-2}\ A$

(c) THE IONS ARE MOVING AT A PRETTY GOOD CLIP. EACH ION HAS

$$E = qV$$

AND THERE ARE $\frac{100\,mg}{hr}\cdot\frac{1}{3.92\times10^{-25}\,kg}$ OF THEM PER HOUR

SO

$$E_{THERMAL} = qV\cdot\frac{100\,mg}{3.92\times10^{-25}\,kg}\cdot 1\,hr \simeq 8.16\times10^{6}\ J$$

(6) THOMSON'S EXPERIMENT.

(a.) SEE SCHEMATIC

(b.) THE e⁻ ENTERS THE E-FIELD WITH $V = V_x$ AND SEES A FORCE $F = qE$ UPWARDS ($q_{e^-} = -e$)

SO

$$F_y = qE = m a_y$$

IN TIME t IT COVERS A DISTANCE IN THE y-DIRECTION OF

$$y = \frac{1}{2}\frac{qE}{m}t^2$$

IT TAKES $t = \frac{x}{V_x}$ TO COVER A DISTANCE x

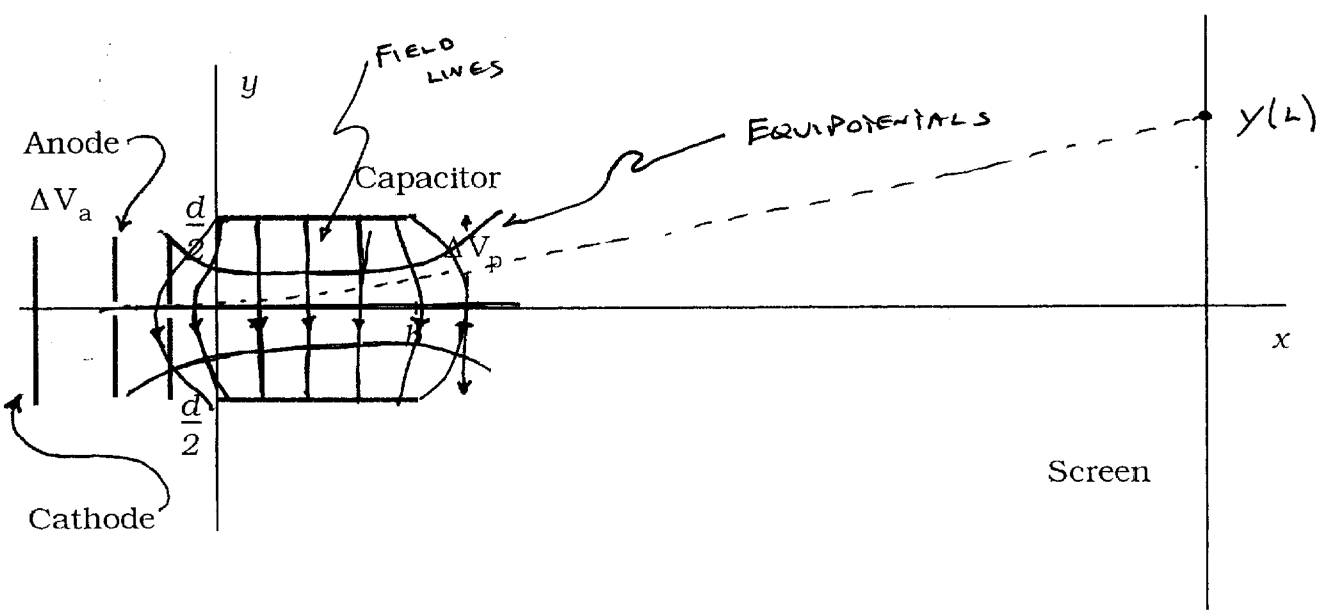
$$\therefore \quad y = \frac{1}{2}\frac{qE}{m}\frac{x^2}{V_x^2}$$ AS EXPECTED

(c.) SEE SCHEMATIC.

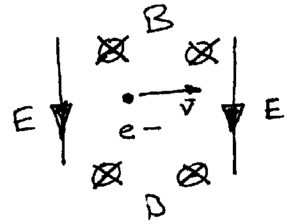
(d.) THIS IS A KEY POINT. THE EXPERIMENT WOULD NOT WORK IF THE BEAM SPREAD OUT INTO AN INDISTINCT ~~Glowing~~ GLOWING REGION. THE KEY IS THAT ALL THE PARTICLES ENTERING THE CAPACITOR HAVE THE SAME

$$\begin{cases} \left.\begin{array}{l} \text{CHARGE } q \\ \text{MASS } m \end{array}\right\} - \text{RESULT OF ASSUMING THAT THE BEAM IS COMPOSED OF PARTICLES. NOW WE CALL THEM ELECTRONS} \\ \text{~~SPEED~~ VELOCITY } \vec{V} \;\} - \text{CHOICE OF EXPERIMENTER} \end{cases}$$

The Thomson Experimental Setup



(e.)



$$F_y = qE \pm q V_x B = 0$$

$$\Rightarrow \boxed{V_x = \frac{E}{B}}$$

SO ALL THE PARTICLES, WHEN THEY ENTER THE CAPACITOR MOVE AT THE SAME VELOCITY.

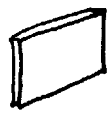
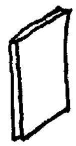
(f.) PLUGGING IN ALL THE NUMBERS I FIND

$$\boxed{\frac{q}{m} = 1.8 \times 10^{11}\ C/kg}$$

AND

$$\boxed{V = 2.2 \times 10^{7}\ ms^{-1}}$$

(7) (a.) TABLE OF RESULTS

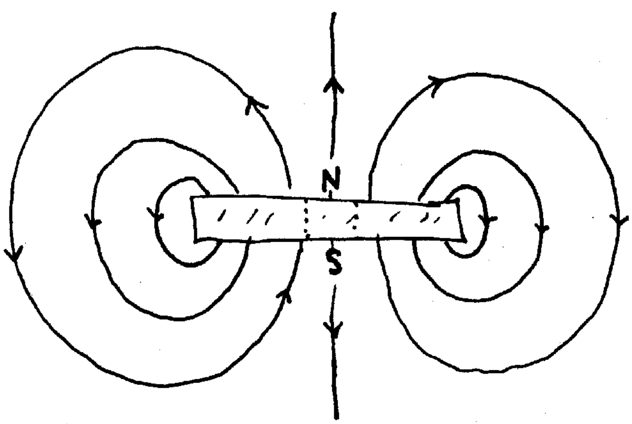
		heights* (mm)	
• 'FLAT'		2.1, 2.3, 2.1 $\rightsquigarrow$	2.2 ± 0.1
• 'ON EDGE'		1.6, 1.55, 1.7 $\rightsquigarrow$	1.6 ± 0.1
• 'VERTICAL'		1.5, 1.5, 1.6 $\rightsquigarrow$	1.5 ± 0.1

* h DEPENDS ON ORIENTATION OF MAGNET AND PAPERCLIP. OFTEN THE P'CLIP ROTATES FIRST OR FLIPS OVER ON LIFTOFF: THIS IS BECAUSE THE P'CLIP HAS A MAGNETIC MOMENT LIKE A CURRENT LOOP OR MAGNET. IN AN INHOMOGENEOUS FIELD IT EXPERIENCES BOTH A TORQUE AND FORCE.

SUMMARY, THE MAGNET HAS THE LARGEST INHOMOGENEITY IN THE 'VERTICAL' ORIENTATION CLOSELY FOLLOWED BY 'ON EDGE'.

(b.) A MAGNET (OR CURRENT LOOP) EXPERIENCES A TORQUE IN A MAGNETIC FIELD. IF THE FIELD IS IN-HOMOGENEOUS THE MAGNET ALSO EXPERIENCES A FORCE. THE PAPERCLIP, BEING LIKE A SMALL MAGNET, IS MOVED BY THE SAME FORCE.

(c.)



SHOULD BE SYMMETRIC