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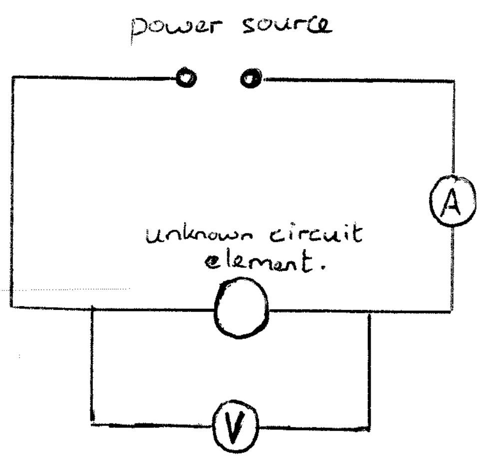
20 points

11) Describe an experiment that you will design to find out whether the resistance of a particular circuit element is independent of the voltage across it. Make sure that you describe the experiment and how you will make a judgment clearly enough so some other person can repeat the experiment and understand the judgment.

I would set up the following circuit:



The power source allows me to vary the potential difference across the circuit element. I can measure this potential difference with the voltmeter connected as shown. I can measure the current through the circuit element with the ammeter connected as shown. I would vary the power source & record (V) and (A) readings.

I would then plot a graph of current versus potential difference. If I obtained a straight line passing through the origin, I would conclude the circuit element is "Ohmic" (ie: its resistance is the same no matter what the potential difference across it is.) resistance $R = 1/\text{slope}$.

If the graph does not produce a straight line or does not pass through the origin, I would conclude that the resistance depends on the potential difference across the given circuit element.

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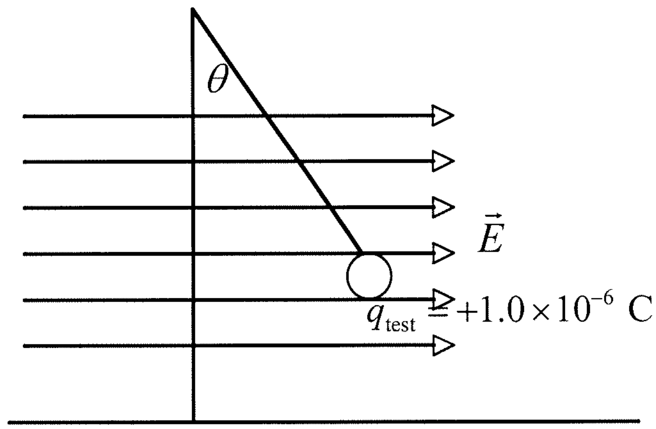
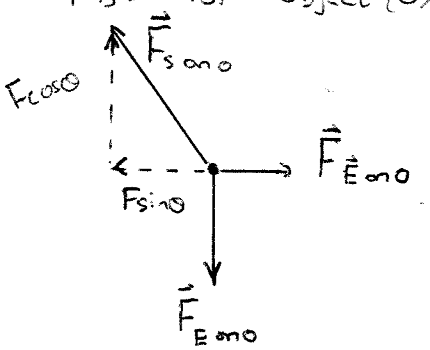
12) You decide to measure the electric field at some point. Armed with your trusty test charge (a metal ball of mass m = 0.02 kg and charge $q_{test} = 1\times10^{-6}$ C) attached to a string, you hang it vertically from an insulating stand in the electric field and find that the string makes an angle of θ = 37° with the vertical. What is the electric field at this point?



FBD for object (o)



Apply Newton's Laws in the x & y dir. separately:

x dir: $F_{s\ on\ o}\sin\theta = F_{\vec{E}\ on\ o}$

$= q_t E$ ①

y dir: $F_{s\ on\ o}\cos\theta = F_{E\ on\ o}$

$= m_o g$ ②

To find $\vec{E}$, I can take the quotient of the two equations:

①/② ⇒ $\tan\theta = q_t E / m_o g$

$$\Rightarrow E = \frac{m_o g \tan\theta}{q_t} = \frac{(0.02\,kg)(10\,m/s^2)\tan 37^\circ}{1\times10^{-6}\,C}$$

$= 1.5\times10^5$ N/C

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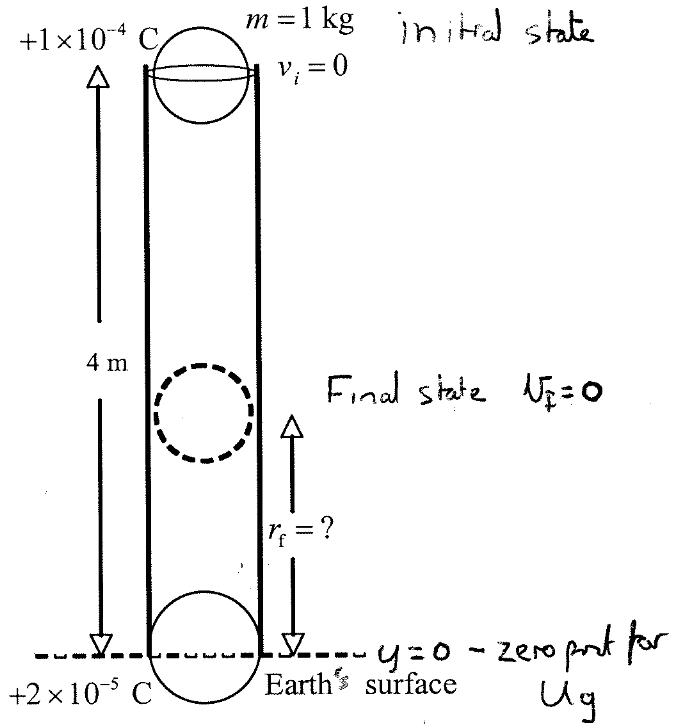
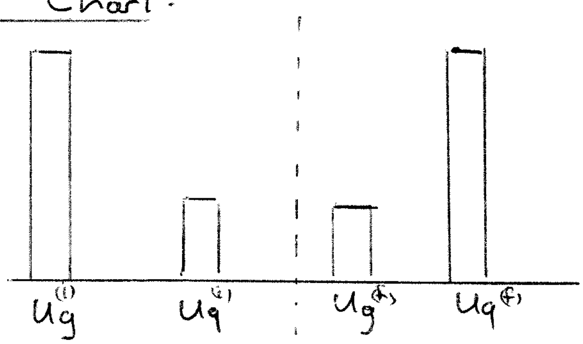
13) A metal ball of mass 1 kg and charge $+1\times10^{-4}$ C is released from rest and falls down a 4 m long plastic tube. It falls down towards another charged metal ball $+2\times10^{-5}$ C placed at the bottom end of the tube, and is fixed to the earth. At the initial release point the two balls are 4 m apart. What is the closest distance that the falling ball gets to the fixed ball? Remember to identify initial and final states and draw an energy bar chart.



Note that at its lowest point all the gravitational potential energy and kinetic energy of the falling ball should have turned into Electrical potential energy U_q. Therefore $v_f = 0$

Bar Chart:



$$U_g^{(i)} + U_q^{(i)} = U_g^{(f)} + U_q^{(f)}$$

$$\Rightarrow mgr_i + \frac{kq_1q_2}{r_i} = mgr_f + \frac{kq_1q_2}{r_f}$$

$$\Rightarrow (1\text{ kg})(10\text{ m/s}^2)(4\text{m}) + \frac{(9\times10^9)(1\times10^{-4})(2\times10^{-5})}{4\text{m}} = (1)(10)(r_f) + \frac{(9\times10^9)(1\times10^{-4})(2\times10^{-5})}{r_f}$$

$$\Rightarrow 40\text{J} + 4.5\text{J} = 10r_f + 18/r_f$$

$$\Rightarrow 10r_f^2 + - 44.5r_f + 18 = 0 \Rightarrow r_f = \frac{44.5 \pm \sqrt{(44.5)^2 - (4)(10)(18)}}{2(10)}$$

$$\Rightarrow r_f = 0.45\text{m or } 4\text{m}.$$

4m is the original state, so 0.45m is the final posn.