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Level 2 Physics, 2014

91173 Demonstrate understanding of electricity and electromagnetism

2.00 pm Tuesday 18 November 2014
Credits: Six

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of electricity and electromagnetism.	Demonstrate in-depth understanding of electricity and electromagnetism.	Demonstrate comprehensive understanding of electricity and electromagnetism.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Sheet L2-PHYSR.

In your answers use clear numerical working, words and /or diagrams as required.

Numerical answers should be given with an appropriate SI unit.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–10 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL

30

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QUESTION ONE: MILLIKAN'S OIL DROP EXPERIMENT

Charge on electron: $-1.6 \times 10^{-19} \text{ C}$

Mass of electron: $9.11 \times 10^{-31} \text{ kg}$

Charge on proton: $+1.6 \times 10^{-19} \text{ C}$

Mass of proton: $1.67 \times 10^{-27} \text{ kg}$

In 1909 Robert Millikan performed an experiment to determine the size of the charge on an electron. He put a charge on a tiny drop of oil, and measured how strong an applied electric field had to be in order to stop the oil drop from falling.

Janet is doing a similar experiment. She has an electrically charged oil drop held stationary in an electric field, so that it floats.

The oil drop has a net negative charge of $24 \times 10^{-10} \text{ C}$, and is placed in a uniform electric field of strength 610 N C^{-1} directed vertically. The oil drop "floats" (is held suspended) between the plates. (Assume any buoyancy effect of air to be negligible.)



- (a) Name the forces (including directions) acting on the oil drop while it is suspended between the plates.

Weight force (downwards), Electric field force (upwards), Force of attraction (electrostatic, downwards)

- (b) Calculate the mass of the oil drop. (Use $g = 9.8 \text{ N kg}^{-1}$ and $F = mg$.)

$$F = Eq, E = 610 \text{ N C}^{-1}, q = -24 \times 10^{-10} \text{ C} \quad F = 610 \times 24 \times 10^{-10}$$

$$F = 1.46 \times 10^{-6} \text{ N}$$

$$F = mg \quad 1.46 \times 10^{-6} = m \times 9.8 \quad \frac{1.46 \times 10^{-6}}{9.8} = m \quad m = 1.49 \times 10^{-7} \text{ kg}$$

- (c) Explain what the same charged oil drop would do if the plates were brought closer together.

Assume the charge on the oil drop remains the same, and the voltage across the plates remains unchanged.

If the distance decreased, then the electric field strength would increase, as $E \propto \frac{1}{d}$ (when voltage remained unchanged). As the electric field strength would ~~be~~ increased, the Force would also increase, as ~~the~~ $F \propto E$ (when q remains the same). Therefore, the oil drop would be propelled upwards by the increased Force on the charged particles.
electric

- (d) A free electron and a free proton are placed in identical electrical fields (same electric field strength).

Compare:

$$\frac{F}{E} = \frac{F}{E} = \frac{F}{E}$$

- the strength of the electric force on each particle
- the acceleration of each particle (you may neglect gravity and use $a = \frac{F}{m}$).

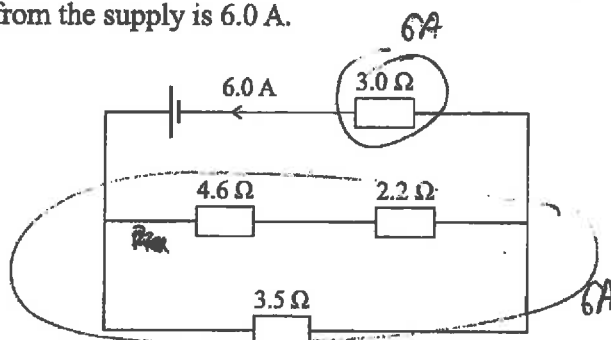
Give reasons to justify your comparisons.

Electric force: ~~For the electron~~, $F = Eq$. When the electric field strength is constant, ~~the~~ $F \propto q$. As the charge on the electron is negative, it would be attracted to the positive end of the electric field, while the As the charges are equal, the electric force would be the same.

Acceleration: As $a = \frac{F}{m}$, when F is constant (as it is), $a \propto \frac{1}{m}$. As the mass of a proton is bigger than the mass of an electron, the proton would accelerate slower. As the charges are also opposite (the charge on an electron is negative), they would be attracted to opposite sides of the electric field.

QUESTION TWO: RESISTORS IN A DC CIRCUIT

Sandra is investigating electrical circuits in the lab. She connects various resistors in combination. The current drawn from the supply is 6.0 A.



$$S. V < I =$$

$$P. V = I <$$

$$V = 31.86$$

- (a) Calculate the effective resistance of the circuit.

$$R_T = R_1 + R_2 \quad R_1 = 3.0 \Omega$$
~~$$R_2 = \frac{1}{\frac{1}{4.6 + 2.2} + \frac{1}{3.5}} = 2.31 \Omega$$~~

$$R_T = 3 + 2.31 = 5.31$$

- (b) Calculate the size of the voltage across the 3.5 Ω resistor.

~~$$V = I \times R = 6 \times 3.5 = 21 \text{ V}$$~~

$$V_T = I \times R_T = 6 \times 5.31 = 31.86$$

$$V_{3.5\Omega} = V_T - V_{3.0\Omega} = 31.86 - (6 \times 3) = 13.86 \text{ V}$$

- (c) Express your answer to Question Two (b) to the correct number of significant figures.

Give a reason for your choice of significant figures.

$$14 \text{ V (2sf)}$$

The lowest number of significant figures in the calculation was 2 sf.

- (d) Explain which resistor, the $4.6\ \Omega$ or the $2.2\ \Omega$ resistor, would convert the greater amount of energy per second into heat.

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~~Across the series path (with both resistors), the voltage is 13.86 . This splits across the resistors. The current across the branch is $\frac{13.86}{(4.6+2.2)} \times 6 = 2.04\text{ A}$. The voltage across the $4.6\ \Omega$ resistor ~~is~~ ^{would} thus have a higher voltage.~~

Across the branch with those two resistors, the current is constant but the voltage splits. As the current is constant, $V \propto R$, so the voltage is higher for the $4.6\ \Omega$ resistor. As $P = IV$, when current is constant, $P \propto V$. Therefore, as the $4.6\ \Omega$ resistor has a higher voltage, it would have higher power, so the $4.6\ \Omega$ resistor converts a greater amount of energy per second into heat.

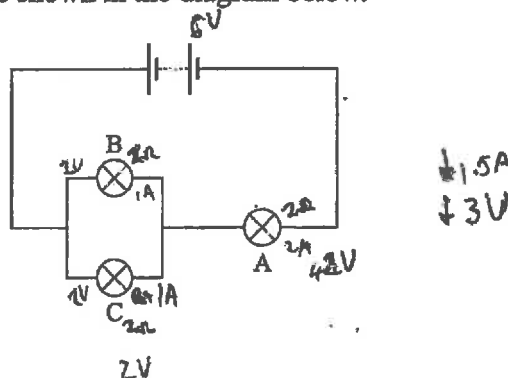
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QUESTION THREE: LAMPS AND RESISTORS IN A DC CIRCUIT

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Stephen connects identical lamps, as shown in the diagram below.



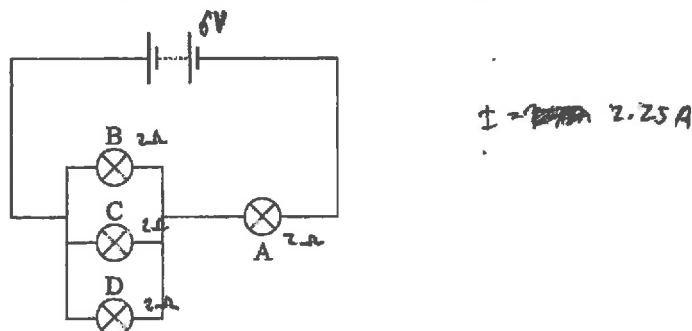
- (a) Lamp B blows.

State what happens to the brightness of lamp A.

Decrease.

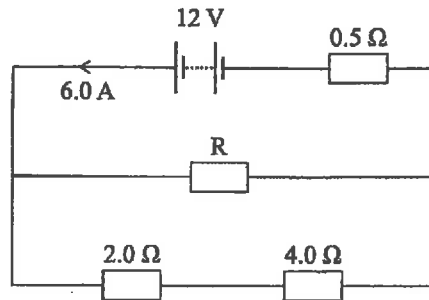
- (b) Stephen replaces lamp B with a new one.

Explain what would happen to the voltage across lamp B and the voltage across lamp A if another identical lamp, D, was added in parallel, as shown in the diagram below.



As an extra lamp is added in parallel, the resistance of the parallel section will decrease. This will cause the overall resistance of the circuit to decrease, resulting in an increase in current for the circuit. This will result in an increase in voltage for lamp A, as $V \propto I$ when R remains constant. For lamp B, the current across it would decrease, as there are now 3 lamps, ~~but~~ and the voltage would also decrease, so lamp B would become dimmer.

Stephen then takes a selection of resistors and connects them as shown in the diagram below.



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- (c) Calculate the voltage across the $0.5\ \Omega$ resistor.

$$V = IR = 6 \times 0.5 = 3\text{ V}$$

- (d) Calculate the resistance of resistor R.

Begin your answer by calculating the voltage across each branch.

$$V_T = V_{R1} + V_{R2}$$

$$V_T = 6 \times 0.5 + R_T \quad R_T = 0.5 + R_2 \quad \frac{1}{R_2} = \frac{1}{0.6} + \frac{1}{R}$$

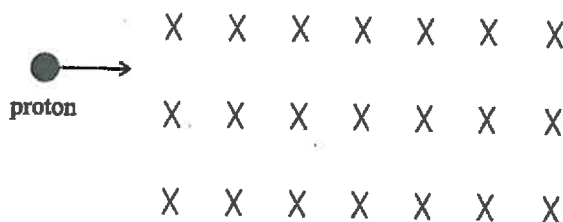
$$2 = 0.5 + \frac{1}{R_2} \quad \frac{1}{R_2} = 1.5 \quad 1.5 = \frac{1}{6} + \frac{1}{R}$$

$$R = 0.14\ \Omega$$

Correctly stated $1/1.5 = 1/6 + 1/R$ and the mathematical error in solving this was ignored.

QUESTION FOUR: ELECTROMAGNETISM

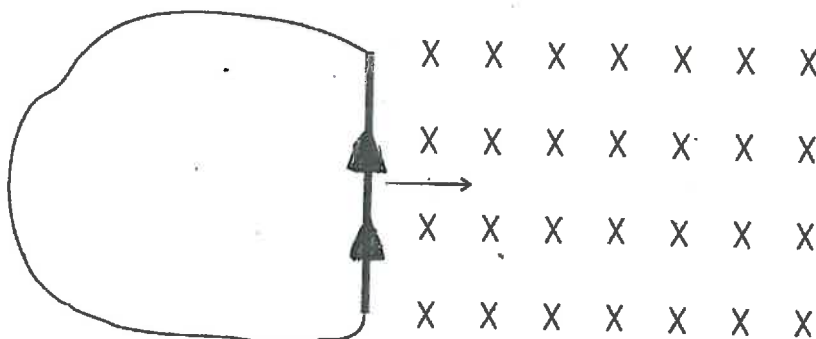
A proton of charge $+1.6 \times 10^{-19} \text{ C}$ moves at right angles across a magnetic field of strength 0.65 T . The constant speed of the proton (in the magnetic field) is $4.8 \times 10^3 \text{ m s}^{-1}$.



- (a) Calculate the size of the magnetic force on the proton while it is in the field.

$$F = Bqv \quad F = 0.65 \times 1.6 \times 10^{-19} \times 4.8 \times 10^3 \quad F = 4.99 \times 10^{-16} \text{ N}$$

A piece of conducting rod whose ends are connected by a wire as shown, is moved through a magnetic field that is directed into the page. The direction in which the rod is moved is indicated by an arrow.



- (b) On the diagram draw an arrow to show the direction of the induced current (conventional current) around the loop formed by the rod and wire.
- (c) Explain why there will be an induced current in the rod and wire due to movement of the rod across the magnetic field.

As the conducting rod is moved into the magnetic field, the charges are separated by their ^{electric} ~~attraction~~ ^{force} into the magnetic field. These ~~charges~~ ^{charges} ~~flow~~ ^{flow} causing a current to be induced.

For E needed to state the current flowed because of a complete circuit

- (d) In the situation above, the length of the rod is 0.40 m and the magnetic field strength is 0.85 T. The rod is moved with a speed of 4.6 m s^{-1} through the field. The combined resistance of the rod and wire is 0.68Ω .

By calculating the voltage induced, calculate the size of the force that must be applied to the rod to keep it moving at a steady speed through the magnetic field.

$$V = BLv = 0.85 \times 4.6 \times 0.4 = 1.564 \text{ V}, \quad V = IR, \quad I = \frac{V}{R}, \quad I = \frac{1.564}{0.68}$$
$$I = 2.3 \text{ A}, \quad F = BIL, \quad F = 0.85 \times 2.3 \times 0.4, \quad F = 0.782 \text{ N}$$

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