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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.

Merit

TOTAL 19.

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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.

- force of gravity 9.8 ms^{-2} downwards.
- attractive force between negatively charged oil drop and positive plate - upwards.

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

$$F = mg$$

$$m = \frac{F}{g}$$

$$m = \frac{1.464 \times 10^{-6}}{9.8}$$

$$m = 1.4939 \dots \times 10^{-7}$$

$$m = 1.5 \times 10^{-7} \text{ kg}$$

$$F = Eq$$

$$F = 610 \times 24 \times 10^{-10}$$

$$F = 1.464 \times 10^{-6} \text{ N}$$

Needed to identify that E and F would both increase.

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- (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 plates were brought closer together, the same charged oil drop would move towards the positive plate as the negative charge on the oil drop would repel the negative plate and be attracted to the positive plate. However, the force of gravity would then cause it to sit in the middle of the two (float again) as voltage across the plates remains unchanged.

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

Compare:

$$F = Eq \quad a = \frac{F}{m}$$

- 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.

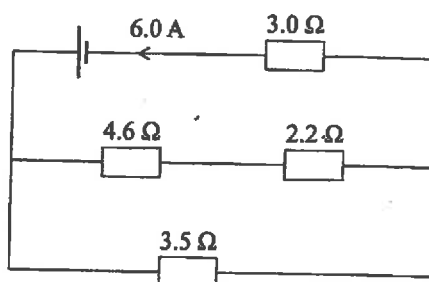
Electric force: The strength of the electric field for both the proton and the electron are the same. However because the electron is negatively charged and the proton positively charged, the electric force would have the same value but one + and one -.

Acceleration: Because the two particles have the same electric force (just one + and one -) ~~acceleration~~ F is almost the same. The mass of a proton is $1.67 \times 10^{-27} \text{ kg}$ and for an electron, $9.11 \times 10^{-31} \text{ kg}$. This will mean the electron has a greater acceleration towards the positive plate than the proton does towards the negative plate.

MS

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.



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

parallel

$$\frac{1}{R_T} = \frac{1}{3.5} + \frac{1}{6.8}$$

$$\frac{1}{R_T} = 0.43$$

$$R_T = 2.33 \Omega$$

series

$$R_T = 2.33 + 3.0$$

$$R_T = 5.33 \Omega$$

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

$$V = IR$$

$$V = 3 \times 3.5$$

$$V = 10.5 \text{ V}$$

Incorrectly assumed 1/2 the current went through the 3.5 ohm resistor

- (c) Express your answer to Question Two (b) to the correct number of significant figures. Give a reason for your choice of significant figures.

11 V Because 2 sf because this is the least number of significant figures we were given in the question so the most specific we can be in our answer.

Correctly rounded ans stated 2sf with a reason

- (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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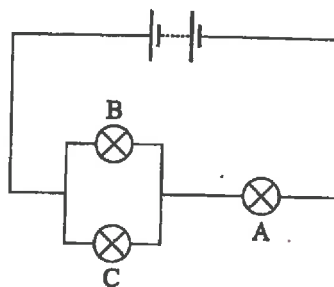
The amount of energy converted into heat is determined by the power output. This is determined by the voltage across the resistor. The voltage in a series circuit is split meaning the $4.6\ \Omega$ resistor will have a greater voltage meaning it will turn more energy into heat per second.

To gain e needed to state that the current was the same for both resistors as they are in series

MS

QUESTION THREE: LAMPS AND RESISTORS IN A DC CIRCUIT

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



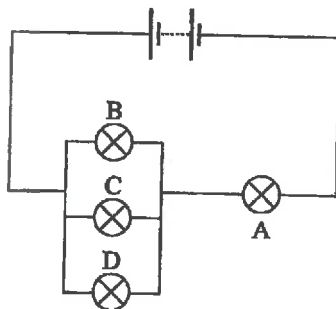
- (a) Lamp B blows.

State what happens to the brightness of lamp A.

~~increases~~ decreases.

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

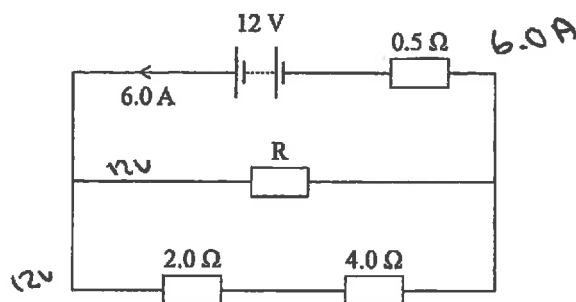
Explain what would happen to the voltage across lamp B and the voltage across lamp A if another identical lamp, D, was added in parallel, as shown in the diagram below.



Voltage in a parallel circuit is the same across all branches assuming the bulbs are identical. This means that all 3 bulbs, B, C and D will have the same voltage and therefore the same brightness. The voltage across lamp B would remain the same along with the voltage across lamp A.

Failed to realise that adding another bulb changes the resistance of the circuit which then affects V and I for components.

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



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

$$V = IR$$

$$V = 6 \times 0.5$$

$$V = 3\text{ V}$$

- (d) Calculate the resistance of resistor R.

Begin your answer by calculating the voltage across each branch.

Voltage & series splits up

$0.5\ \Omega$ resistor $\rightarrow 3\text{ V}$

Resistor R $\rightarrow 9\text{ V}$

$$V = IR$$

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

$$R = \frac{9}{6}$$

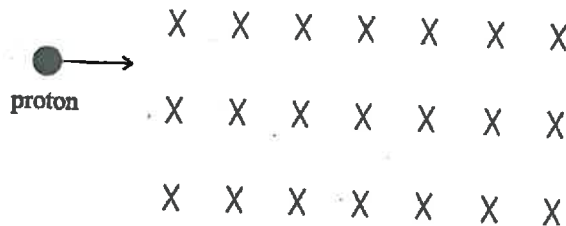
$$R = 1.5\ \Omega$$

For a higher grade needed to find the current in R and then R.

At

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.

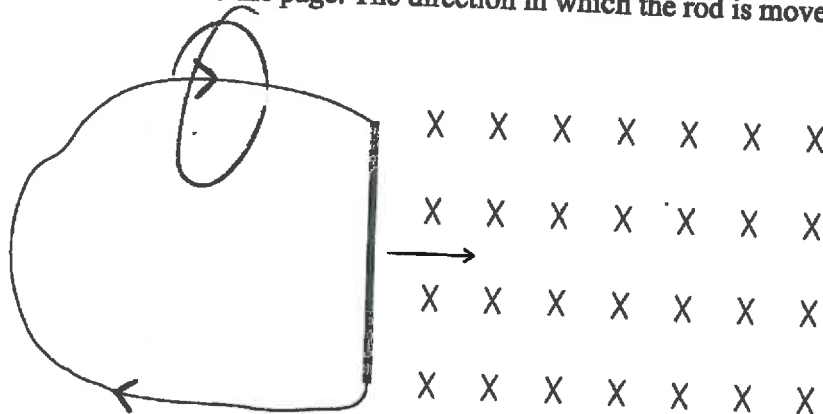
$$F = Bqv$$

$$F = 0.65 \times (1.6 \times 10^{-19}) \times (4.8 \times 10^3)$$

$$F = 4.992 \times 10^{-16}$$

$$F = 5.0 \times 10^{-16} \text{ NC}^{-1}$$

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.

There will be an induced current in the rod and wire because when it moves through the magnetic field, it moves at right angles and cuts across the magnetic field. This allows an ~~induced~~ current to be induced in the rod and wire.

For a higher grade needed to discuss the force on the electrons in the wire

- (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 0.68 Ω .

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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.

$$V = BLv$$

$$V = 0.85 \times 4.6 \times 0.4$$

$$V = 1.564 \text{ V}$$

$$V = IR$$

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

$$I = \frac{1.564}{0.68}$$

$$I = 2.3 \text{ A}$$

$$F = BIL$$

$$F = 0.85 \times 2.3 \times 0.4$$

$$F = 0.782 \text{ N}$$

e

MS