Physics 3AB

Electricity and Magnetism Test 2014

Mark: / 60

= %

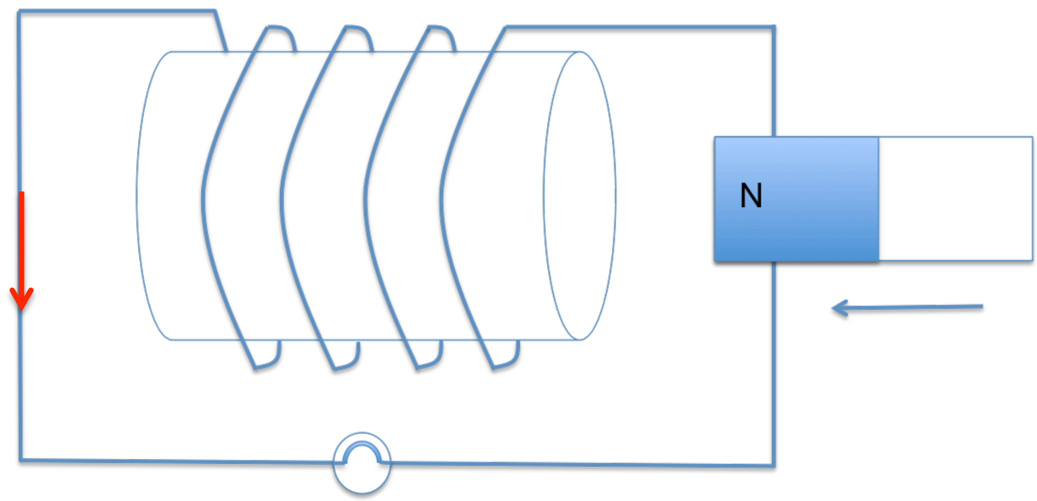
Name: SOLUTIONS

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(7 marks)**

A bar magnet is moved towards a solenoid (coil of wire), that is connected in a circuit with a light bulb, as shown in the diagram below. The solenoid has been wrapped around a cardboard tube.



(a) Explain why the light bulb lights up as the magnet moves towards the coil. (4 marks)

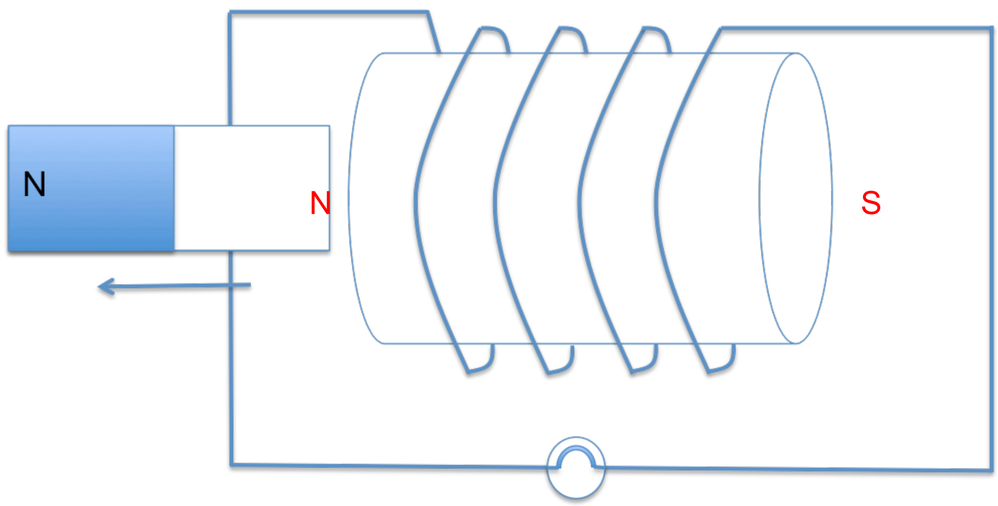
- As the magnet moves towards the coil, the magnetic flux through the coil increases/changes.
- According to Faraday's Law,
- A changing magnetic flux will induce an emf in the coil that is proportional to the rate of change of flux.
- This induced emf induces a current causing the light bulb to light up

(b) Add an arrow to the diagram to indicate the direction of the induced current in the coil, as the magnet approaches the coil as shown. (1 mark)

(c) State what happens to the bulb when the magnet is held stationary inside the coil. (1 mark)

- It is no longer lit.

The magnet is pulled out of the other side of the loop, as shown in the diagram below.

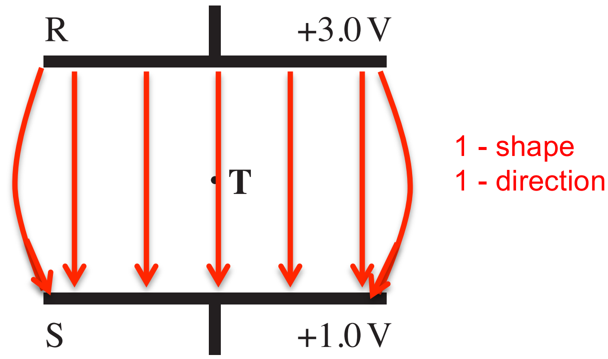


(d) Add labels to the diagram to show the north and south pole of the solenoid as the magnet moves away.

(1 mark)

Question 2 **(8 marks)**

R and S are two charged parallel plates, 0.600 m apart, as shown in the diagram below. They are at potentials of + 3.00 V and + 1.00 V respectively.



(a) On the diagram, sketch the electric field between R and S, showing its direction. Point T is mid-way between R and S.

(2 marks)

(b) Calculate the electric field strength at T.

(3 marks)

E = V / d (1)

E = 2 / 0.6 (1)

E = 3.33 Vm^{-1} (1)

An alpha particle (charge +2e) is placed next to plate R and is released from rest.

(c) Calculate the force on the alpha particle if it is placed at T.

(3 marks)

E = F / q (1)

3.33 = F / (2 x 1.6 x 10^{-19}) (1)

F = 3.33 x 2 x 1.6 x 10^{-19}

F = 1.07 x 10^{-18} N towards the bottom plate (1)

Question 3 **(11 marks)**

In the Large Hadron Collider (LHC) at CERN in Switzerland, protons are accelerated and made to collide in a tunnel that is 27.0 km in circumference.

For a particular experiment a proton completes 8 000 revolutions per second.

(a) Calculate the magnitude of the velocity of the proton.

(4 marks)

$T = 1 / f$ (0.5)

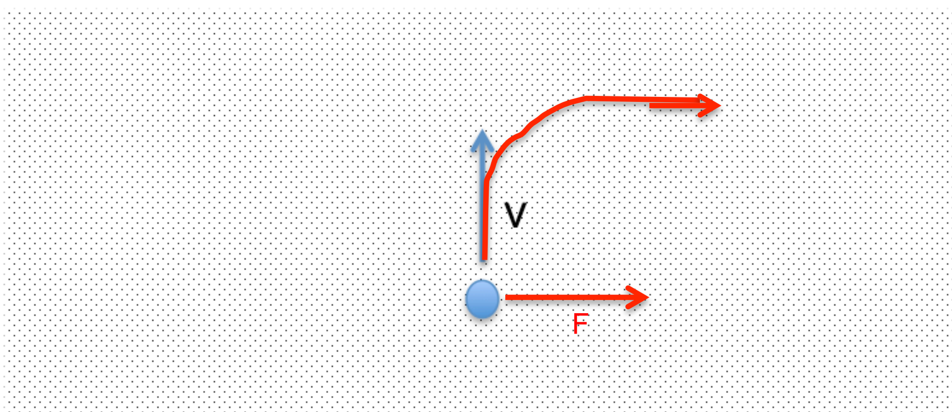
$T = 1 / 8000$

$T = 1.25 \times 10^{-4}$ s (1)

$s = vt$ (0.5)
$v = s / T$
$v = 27 \times 10^{3} / 1.25 \times 10^{-4}$ (1)

$v = 2.16 \times 10^{8}$ ms^{-1} (1)

The proton is made to travel in a circular path by the use of magnetic fields. The diagram below shows a proton travelling with velocity *v* in a magnetic field *B*, which is orientated out of the page.



(b) Add an arrow to the diagram to show the force on the proton in the instant shown.

(1 mark)

(c) Sketch the path of the proton as it continues through the magnetic field.

(2 marks)

1 – circular path / curve
1 – arrow showing direction to right

(d) Calculate the magnetic field strength of the LHC for this experiment.
(4 marks)

$F = qvB$ (1)

$F_c = mv^2 / r$ (1)

Circumference = $2\pi r$

$r = C / 2\pi = 27 \times 10^3 / 2\pi = 4297$ m (0.5)

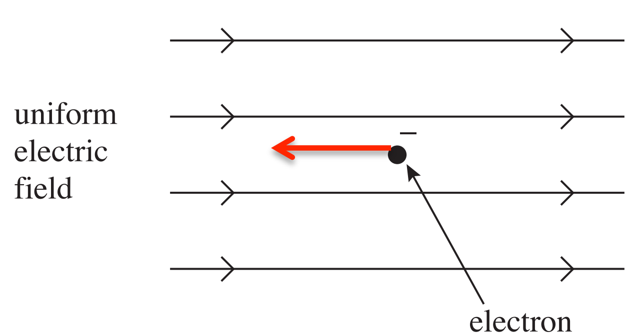
$B = mv / qr$ (0.5)

$B = (1.67 \times 10^{-27} \times 2.16 \times 10^8) / (4297 \times 1.6 \times 10^{-19})$

$B = 5.25 \times 10^{-4}$ T (1)

Question 4 **(1 mark)**

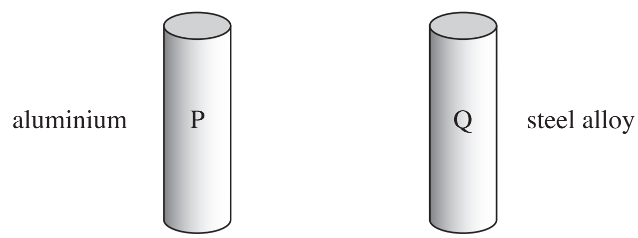
The diagram below shows an electron at a point in a uniform electric field at an instant when it is stationary.



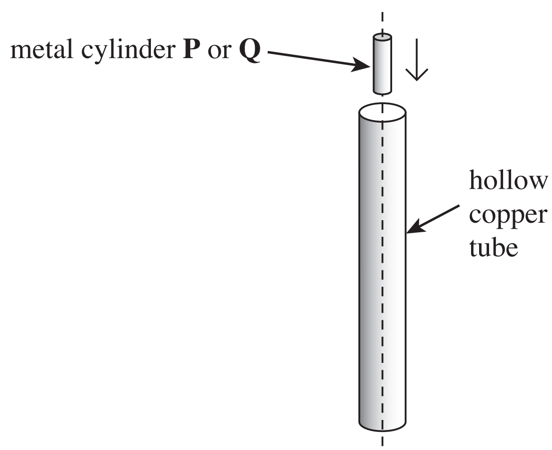
Draw an arrow on the diagram to show the direction of the electrostatic force that acts on the stationary electron.

Question 5 **(8 marks)**

The diagram below shows two small, solid metal cylinders, P and Q. P is made from aluminium. Q is made from a steel alloy.



The steel cylinder Q is a strong permanent magnet. P and Q are released separately from the top of a long, vertical copper tube so that they pass down the centre of the tube, as shown in the next diagram.



The time taken for Q to pass through the tube is much longer than that taken by P.

(a) Explain why you would expect an emf to be induced in the tube as Q passes through it.

(3 marks)

- The falling magnet means there is a changing magnetic flux through an area of the tube.
- As the tube is a metal conductor,
- The rate of change of flux is directly proportional to the emf induced in the tube (Faraday's Law)

(b) State the consequences of this induced emf, and hence explain why Q takes longer than P to pass through the tube.

(5 marks)

- The induced emf will make (eddy) currents flow in the tube, the direction of these will be such as to oppose the change that caused them (Lenz's Law)
- These eddy currents create a magnetic field that interacts with the field of Q
- Exerting a force that acts in the opposite direction to the velocity
- Making the net force on Q less / making the acceleration of Q less / applying a retarding force to Q
- P is not a magnet so is only affected by acceleration due to gravity.

Question 6 **(16 marks)**

An electric motor is made using 300 turns of copper wire on a square coil, of length 7.50 cm, that is connected to a power supply, and placed inside a uniform magnetic field.

(a) If the power supply used is a battery pack, made up of four cells, describe the current that will flow in the wire.

(1 mark)

Direct current (DC)

To ensure that the motor continues to spin in one direction, an extra piece of equipment is added to the set up.

(b) State the name of the added component.

(1 mark)

Split ring commutator

The current in the coil is measured when the motor is turned on, and is found to be 1.56 A.

(c) Describe and explain how the current through the coil will change as the motor begins to turn.

(5 marks)

- Current will decrease.
- As the motor turns the magnetic flux through the coil will change.
- An emf proportional to the rate of change of flux is induced in the coil (Faraday's Law)
- The induced emf will be in a direction so as to appose the change that induced it (Lenz's Law)
- This 'back emf' will reduce the net emf across the coil, reducing the current.

(d) Referring to your answer to part (c), describe and explain how the torque will change as the motor begins to turn.

(3 marks)

- Torque will decrease
- Force is directly proportional to current ($F = ILB$) so force will decrease
- and torque is directly proportional to force ($\tau = Fr$) so will decrease.

(e) Calculate the magnitude of the force on one side of the coil when the motor is turned on, if the magnetic flux density is 4.35 mT.

(3 marks)

$F = ILB$ (1)

$F = 1.56 \times 0.075 \times 4.35 \times 10^{-3}$ (0.5)

$F = 5.09 \times 10^{-4}$ N for one length of wire (0.5)

$F = 0.153$ N (1)

(f) Calculate the magnitude of the net torque on the coil when the motor is turned on.

(3 marks)

$\tau_{total} = 2Fr$ (1)

$\tau_{total} = 2[0.153 \times (0.075/2)]$ (1)

$\tau_{total} = 1.15 \times 10^{-2}$ Nm (1)

Question 7 **(5 marks)**

The Earth's magnetic field is not constant.

(a) At which point/points on the Earth's surface would the magnetic field strength be:

(2 marks)

(i) The strongest

- the poles

(ii) Parallel to the surface of the Earth

- the equator

In Perth, the magnetic field strength of the Earth is approximately 5.50×10^{-5} T at 66.0° above the horizontal.

In carrying out some building work a steel girder of length 20.0 m is moved into position by a crane.

The girder is held at a fixed height, with a fixed North-South orientation and moved towards the South, at a velocity of 0.665 ms^{-1}.

(b) Determine the emf induced in the girder.

(3 marks)

$\varepsilon = vLB\sin\theta$ (1)

$\varepsilon = 0.665 \times 20 \times 5.5 \times 10^{-5} \sin 66$ (1)

$\varepsilon = 6.68 \times 10^{-4}$ V (1)

Question 8 **(4 marks)**

In the transmission of electricity from a power stations to consumer, a transformer is used to change a voltage of 3.40 kV produced at a power station to a voltage of 1.53 MV across the transmission lines.

Determine the turns ratio of this transformer, and state what type of transformer is used.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$ (1)

(1) $1.53 \times 10^6 / 3.40 \times 10^3 = 450$

(1) 1 : 450 (must have ratio around the correct way)

Step-up transformer (1)

END OF TEST