Physics 3AB

Electricity and Magnetism Unit Test 2012

Name: Solutions

Mark: / 64

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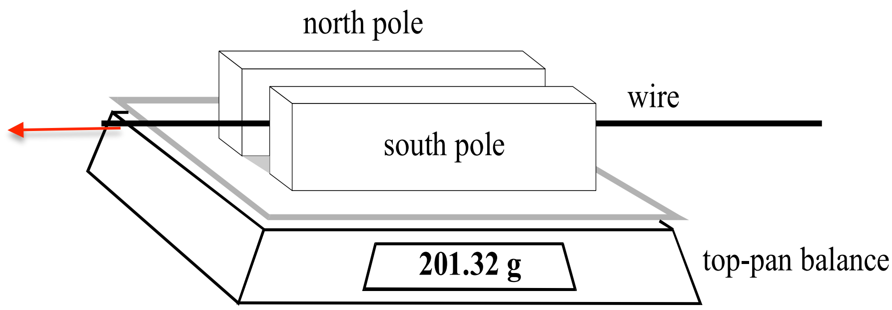
Notes to Students:

- 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.

1. The diagram below shows a magnet placed on a top-pan balance. A fixed, horizontal wire, through which a current can flow, passes centrally through the magnetic field, parallel to the pole pieces. With no current flowing, the balance records a mass of 201.32 g. When a current of 5.00 A flows, the reading on the balance is 202.86 g.



(a) Annotate the diagram to show the direction of current flow.
(1 mark)

(b) Explain why the reading on the balance increased when the current was switched on.
(4 marks)

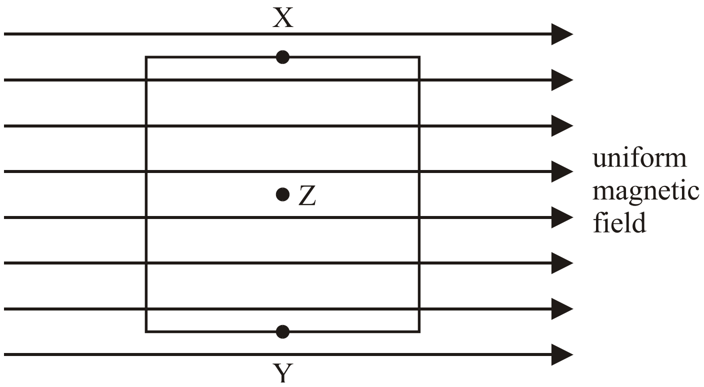
- The current flowing through the wire has a magnetic field associated with it.
- This magnetic field will interact with the external magnetic field due to the magnets.
- The external magnetic field will exert a force upwards on the wire.
- Due to Newton's 3rd Law, an equal an opposite force downwards will be exerted on the magnets (hence pushing down on the balance).

(c) If the length of the wire in the magnetic field is 60.0 mm, calculate the magnitude of the flux density of the magnetic field.
(4 marks)

$$\Delta m = 202.86 - 201.32$$
$$= 1.54\ g \quad (1)$$
$$F_g = F_B$$
$$mg = I\ell B \quad (1)$$
$$(0.00154)(9.80) = (5)(60 \times 10^{-3})(B) \quad (1)$$
$$B = 50.3\ mT \quad (1)$$

2. The diagram below shows a square coil with its plane parallel to a uniform magnetic field. Which one of the following would induce an emf in the coil? Circle your chosen response.

(1 mark)



(i) Movement of the coil slightly to the left.

(ii) Movement of the coil slightly to the right.

(iii) Rotation of the coil about an axis through XY.

(iv) Rotation of the coil about an axis perpendicular to the plane of the coil through Z.

3. A student wishes to charge his phone. The charger he uses has a transformer operating on 12.0 V. If there are 80 turns in the secondary coil, how many turns are present in the primary coil? Assume the mains voltage is 240 V.

(3 marks)

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} \quad (1)$$

$$\frac{N_P}{80} = \frac{240}{12} \quad (1)$$

$$N_P = 1600 \quad (1)$$

4. The transformer used in Q3, makes use of a laminated, soft iron core. Explain why the laminations are used.

[3]

- Eddy currents are induced in the soft iron core (because the magnetic flux through the soft iron core keeps changing in magnitude and direction, an emf proportional to the rate of change of flux is induced (Faraday's Law). In a bulk piece of metal the induced current is called an eddy current).
- Laminations reduce the amount of metal in which eddy currents can flow, thus reducing the magnitude of the eddy currents.
- This reduces the amount of energy lost due to resistive heating due to the current flow ($P=I^2R$).

5. A 90.0 km transmission line made from aluminium cable has an effective radius of 1.00 cm and a total resistance of 9.00 Ω. The line carries the electrical power from the 500 MW power station to a substation. Calculate the percentage power loss in the line when the power station is operating at 250 kV.

(4 marks)

$P = VI$ (0.5)

$500 \times 10^6 = (250 \times 10^3)(I)$ (0.5)

$I = 2000\,A$ (0.5)

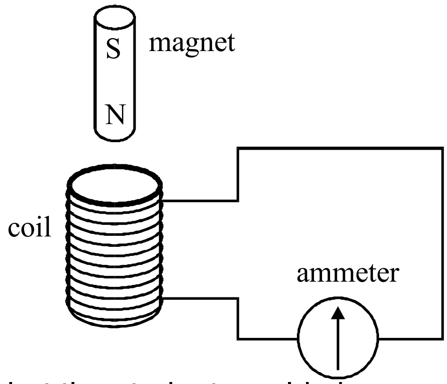
$P = I^2 R$ (0.5)

$= (2000)^2 (9)$ (0.5)

$= 36.0\ MJ$ (0.5)

(0.5) $\dfrac{36 \times 10^6}{500 \times 10^6} = 7.20\%$ (1)

6. A coil is connected to a centre zero ammeter, as shown below. A student drops a magnet so that it falls vertically and completely through the coil.



(a) Describe what the student would observe on the ammeter as the magnet falls through the coil.

(2 marks)

- The current would increase in one direction
- then decrease, passing through zero
- then increasing in the opposite direction
- then decreasing and returning to zero (1/2 mark each)

(b) Determine the direction of the induced current in the coil (when looking directly from above) as the magnet moves towards the coil.

(1 mark)

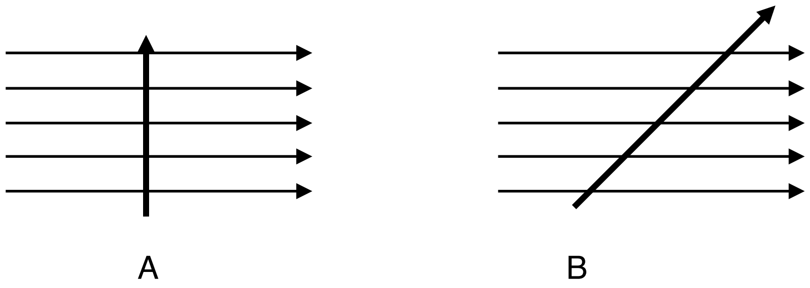
- Counter clockwise

(c) As the magnet exits the coil, would you expect it to be falling at a rate greater than, equal to or less than acceleration due to gravity. Explain your reasoning.

(4 marks)

- Less than acceleration due to gravity.
- As the magnet starts to exit the coil, the magnetic flux through the coil will start to decrease and an emf will be induced in the coil proportional to the rate of change of flux (Faraday's Law).
- The direction of the induced emf (and associated current and magnetic field) will be such as to oppose the change that caused it (Lenz's Law).
- The direction of the induced magnetic field will be such as to attract the magnet back towards the coil, hence the force is in the opposite direction to the motion (due to gravity) and the net acceleration of the magnet is less than that due to gravity.

7. The two wires below are in a uniform magnetic field of 0.400 T. Both wires are 0.500 m long and carry a current of 2.00 A.



(a) Calculate the size of the force on:

(5 marks)

(i) wire (A)

$F = I\ell B \sin\theta$ (1)

$= (2)(0.5)(0.4)(\sin 90)$ (1)

$= 0.400\,N$ (1)

(ii) wire (B) which is at 45° to the field.

$F = I\ell B \sin\theta$

$= (2)(0.5)(0.4)(\sin 45)$ (1)

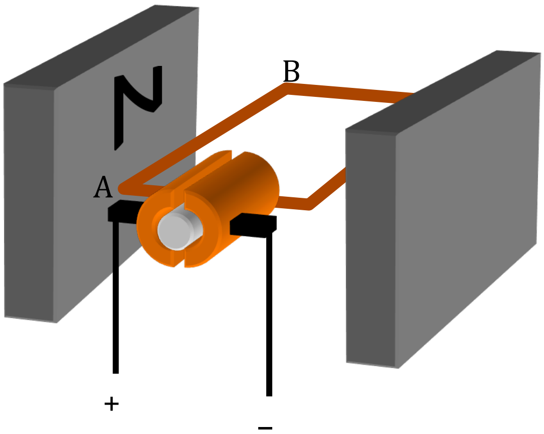
$= 2.83 \times 10^{-1}\,N$ (1)

(b) In which direction would the wires experience a force in the diagrams above?

(1 mark)

- Into the page

8. A simple d.c motor is shown in the diagram below. The armature is made of a rectangular coil of length 5.00 cm and width 2.00 cm and has 25 turns of wire. The magnet produces a uniform field with a magnetic flux density of 0.300 T. The coil carries a current of 2.20 A.



(a) Calculate the force exerted on side AB of the coil.

(4 marks)

$F = I\ell B$ (1)

$= (25)(2.2)(0.05)(0.3)$ (1)

$= 8.25 \times 10^{-1}\ N$ (1) $down$ (1)

(b) Determine the torque of the motor.

(4 marks)

$\tau = rF$ (1)

$= 2 \times (0.01)(0.825)$ (1)

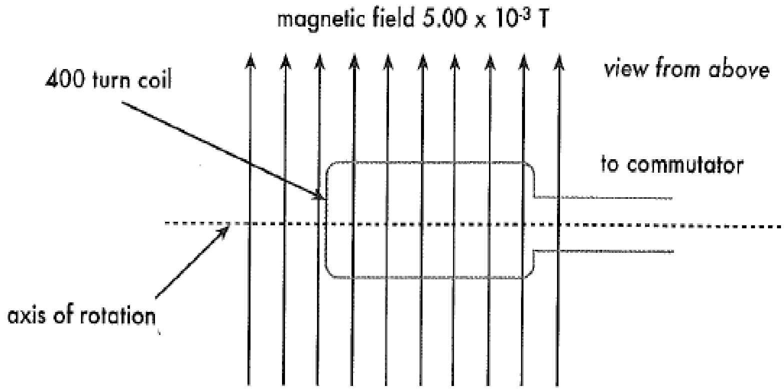
$= 1.65 \times 10^{-2}\ Nm$ (1) $anticlockwise$ (1)

(c) Explain what happens to the magnitude of the current flowing through the motor as it spins up to maximum speed.

(4 marks)

- The magnitude of the current flowing through the motor decreases.
- As the motor turns the magnetic flux through the motor changes and an emf will be induced in the coil proportional to the rate of change of flux (Faraday's Law).
- The direction of the induced emf (and associated current and magnetic field) will be such as to oppose the change that caused it (Lenz's Law) – i.e it will be trying to stop the motor from turning.
- The induced emf will be in the opposite direction to the applied emf (i.e it is a back emf) and therefore the net emf across the motor will be reduced and so will the current flowing.

9. The rotor of a generator has a coil of 400 turns and is rectangular in shape with dimensions 5.00 cm x 3.00 cm. It lies in a magnetic field of 5.00 mT and is rotated at a rate of 3.00 x 10^3 revolutions per minute.



(a) Determine the magnetic flux threading through the rotor when it is in the position shown in the diagram.

(1 mark)

- 0 Wb

(c) Calculate the magnitude of the average emf produced by the generator if it is rotated through 90°.

(4 marks)

$$3\times10^{3} rev/\min = 50 rev/s$$

$$\therefore time for 1 rev = 2\times10^{-2}\ s$$

$$\varepsilon = \frac{\Delta\phi}{\Delta t} \quad (1)$$

$$= \frac{(400)(5\times10^{-3})(0.05\times0.03)-(0)}{\left(\frac{2\times10^{-2}}{4}\right)} \quad (2)$$

$$= 0.600\ V \quad (1)$$

10. Two parallel plates are positioned 12.0 cm apart and connected to a 240 V power supply which creates an electric field between the plates.

(a) What is the strength of the electric field between the plates?

(3 marks)

$$E = \frac{V}{d} \quad (1)$$

$$= \frac{240}{0.12} \quad (1)$$

$$= 2000\ Vm^{-1} \quad (1)$$

(b) Determine the force on an electron placed at rest next to the negative plate.

(4 marks)

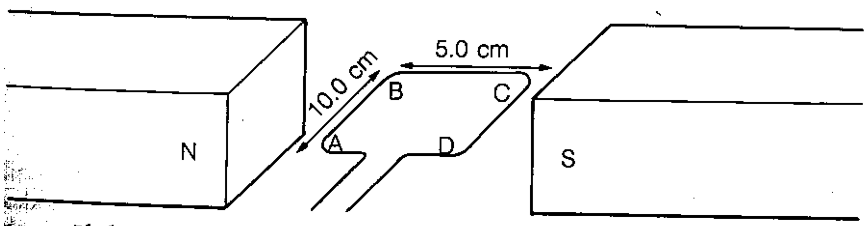
$$E = \frac{F}{q} \quad (1)$$

$$2000 = \frac{F}{1.6 \times 10^{-19}} \quad (1)$$

$$= 3.20 \times 10^{-16}\ N \quad \textit{towards the positive plate}$$

(1) (1)

11. A generator consists of 50 loops of copper wire which have a length of 10.0 cm and a width of 5.00 cm, as shown in the diagram below. The magnetic flux density in the region of the coil is 2.50 x 10^{-1} T. The coil is manually rotated at 150 Hz.



(a) Calculate the speed at which side AB is moving.

(3 marks)

$$v = 2\pi rf \quad (1)$$
$$= (2\pi)(0.025)(150) \quad (1)$$
$$= 23.6\, ms^{-1} \quad (1)$$

(b) If the coil is rotated anticlockwise, which end will be at the higher potential A or D?

(1 mark)

- A

(c) What will be the maximum emf generated?

(3 marks)

$$\varepsilon = v\ell B \quad (1)$$
$$= 2 \times (50)(23.6)(0.1)(0.25) \quad (1)$$
$$= 59.0\, V \quad (1)$$