Physics ATAR - Year 12

Electricity and Magnetism
Unit Test
2019

Name: SOLUTIONS	Mark: / 56
	= %

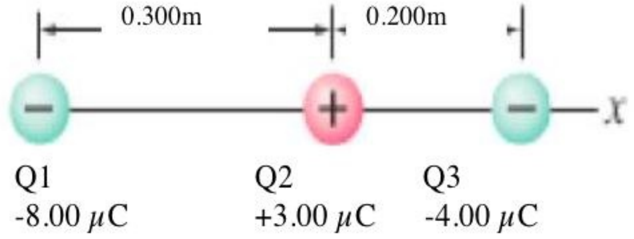
Time Allowed: 50 Minutes

Notes to Students:

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

Question 1 **(6 marks)**

Three charged particles are arranged in a line as shown in the diagram. Calculate the net electrostatic force on Q3 due to the other two charges.



$F_{Q1} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 \cdot q_3}{(r)^2}$ (1/2)

$= \frac{1}{4\pi(8.85\times10^{-12})} \cdot \frac{8.00\times10^{-6}(4.00\times10^{-6})}{(0.500)^2}$ (1/2)

= 1.15 N Right (1)

$F_{Q2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 \cdot q_2}{(r)^2}$ (1/2)

$= \frac{1}{4\pi(8.85\times10^{-12})} \cdot \frac{3.00\times10^{-6}(4.00\times10^{-6})}{(0.200)^2}$ (1/2)

= 2.70 N Left (1)

Must be quoted twice with correct notation To indicate charge and force.

$\Sigma F = F_{Q1} + F_{Q2}$ (1/2)

= +1.15 + (-2.70) (1/2)

= 1.55 N Left (1)

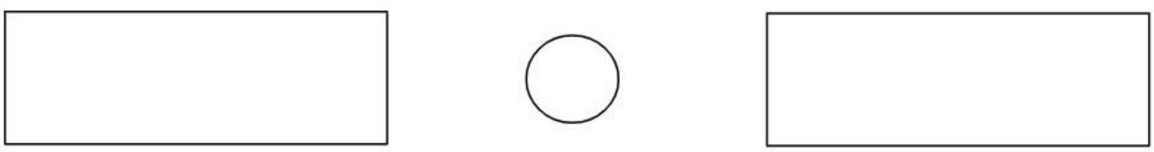
Question 2 **(3 marks)**

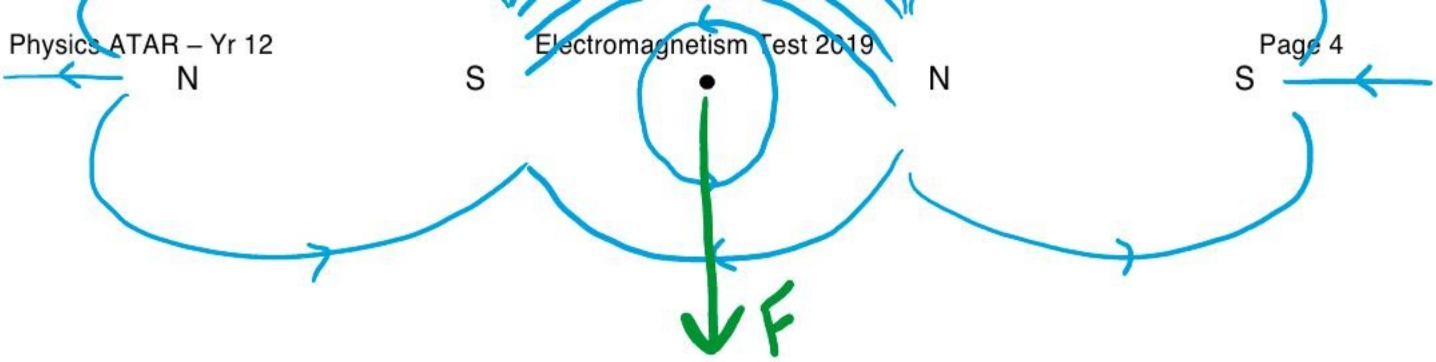
Sketch the net magnetic field of the current carrying conductor placed in between two permanent magnets below and indicate the direction of the force exerted on the conductor.

1 mark for direction of force

2 marks for field: Correct direction,
Symmetry about vertical and
horizontal axis.

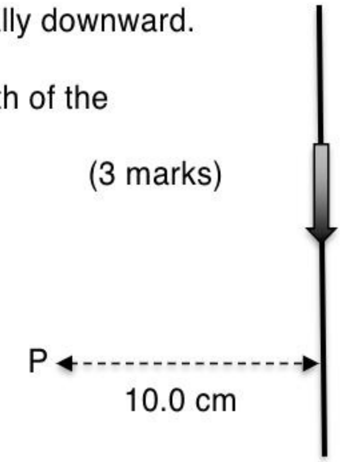
Small loop around conductor not necessary





Question 3 **(11 marks)**

An electric wire in the wall of a building carries a current of 25.0 A vertically downward.



(a) Calculate the magnetic field strength at Point P; 10.0 cm due South of the wire as shown in the diagram.

(3 marks)

$B = \frac{\mu_0}{2\pi} . \frac{I}{r}$ (1)

$= \frac{1.26 \times 10^{-6}}{2\pi} . \frac{25}{10 \times 10^{-2}}$ (1)

$= 5.01 \times 10^{-5}$ T (1)

Allow 5.00 if $\mu_0 = 4\pi$ is used as both values are given in the data sheet.

(b) If the magnitude of the field strength in (a) is the same magnitude of horizontal component of the Earths, state which direction a compass would point if placed at this point (in Perth).

(1 mark)

North West

(c) Describe and explain how the compass would change as it is moved away from the wall.

(3 marks)

- The compass needle would move more towards the north
- As the Westward magnetic field produced by the will decrease as B ∝ 1/r
- As the west component reduces the north component produced by the Earth will dominate the net magnetic field.

(d) Calculate the distance the compass would need to be from the wire in order for it to point 15.0 degrees from magnetic north. (If you could not do (a), use $B_{wire} = 4.50 \times 10^{-5}$ T)

(4 mark)

Tan θ = B_{wire} / B_{Earth}

$B_{wire} = B_{Earth} \tan 15$ (1/2)

$= 5.01 \times 10^{-5} \tan 15$ (1/2)

$= 1.34 \times 10^{-5}$ T (1)

$B = \frac{\mu_0}{2\pi} . \frac{I}{r}$ $r = \frac{\mu_0 I}{2\pi B}$ (1/2)

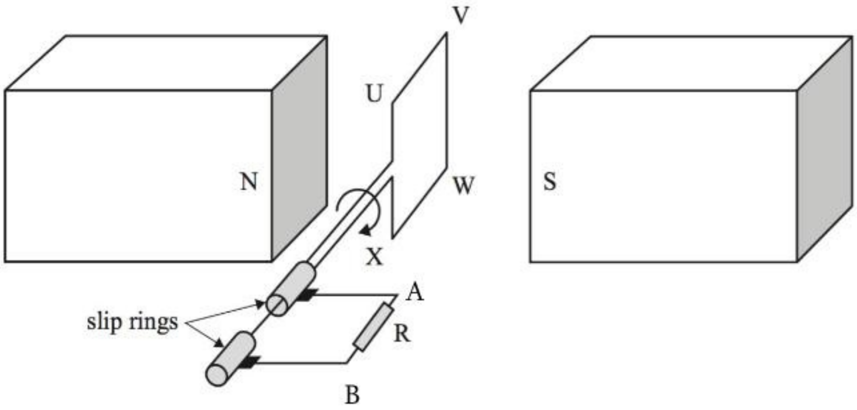
$= \frac{1.26\times10^{-6}}{2\pi} \cdot \frac{25}{1.34\times10^{-5}}$ (1/2)

$= 0.374$ m (1)

Allow 0.373 m $\mu_0 = 4\pi$ is used as both values are given in the data sheet.

Question 4 **(10 marks)**

Students construct a generator similar to the simplified diagram as shown. The armature contains 250 loops, has an area of 2.25 x10^{-2} m^2 and is contained within a magnetic field of 0.150 T. When the armature is rotating steadily, they observe that V_{RMS} is 12.0 V.



(a) Calculate the peak voltage ($\mathcal{E}_{max}$) of the generator.

(2 marks)

$\mathcal{E}_{max} = \sqrt{2}.\mathcal{E}_{RMS}$ (1/2)

$= \sqrt{2} \times 12$ (1/2)

$= 17.0$ V (1)

(b) Calculate the revolutions per minute (rpm) of the armature that would produce a V_{RMS} of 12.0 V.

(4 marks)

$\mathcal{E}_{max} = 2\pi BANf$ $\quad f = \frac{\mathcal{E}max}{2\pi BAN}$ (1)

$= \frac{17}{2\pi(0.150)(2.2\times10^{-2})(250)}$ (1)

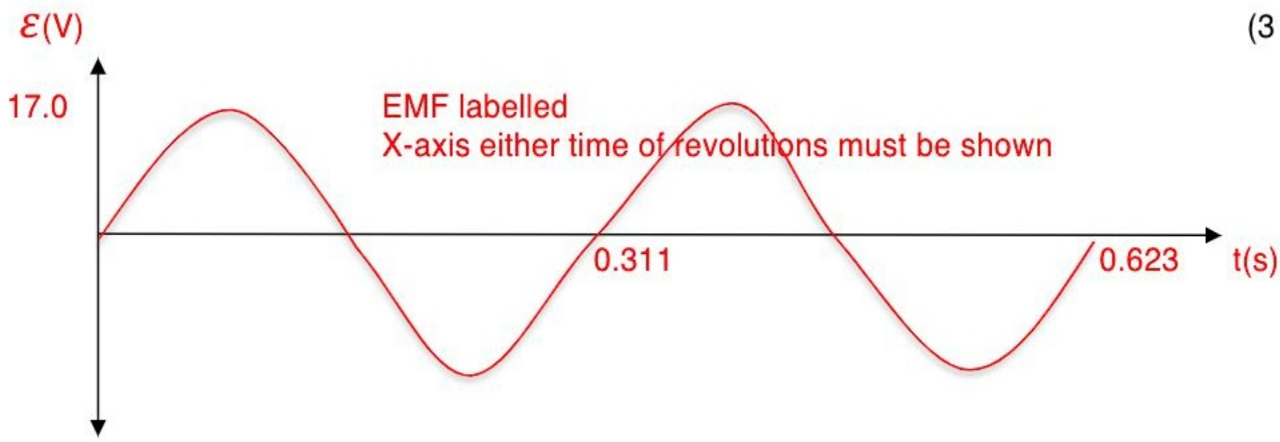
$= 3.21$ Hz (1)

x60

$= 193$ rpm (1)

(c) Sketch a labelled graph of $\mathcal{E}$ on the axis below for 2 revolutions beginning from the original orientation shown in the diagram.

(3 marks)



-17.0

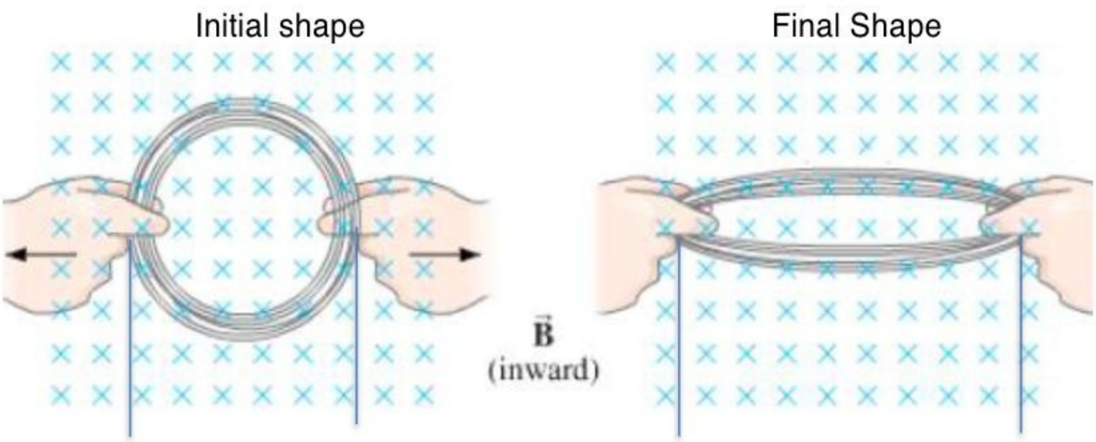
(d) Assuming the slip ring closest to the armature is contact with side length XW only, circle the direction of conventional current through the resistor R as currently shown in the diagram.

(1 mark)

A to B B to A zero.

Question 5 **(8 marks)**

Consider a circular loop of 100 wires with an initial radius of 7.00 cm in an external magnetic field of 90.0 mT. The loop is pulled outwards such that the area of the loop is reduced to ¼ of its original area in a time of 155 ms.



(a) Calculate the magnitude of the average induced EMF as the loop is pulled outwards.

(4 marks)

$$\text{Emf} = \frac{-n\,\Delta\phi}{\Delta t} = \frac{-n\,B\Delta A}{\Delta t} \qquad (1)$$

$$= \frac{-100(0.090)(1/4\pi(0.07^2) - \pi(0.07^2))}{155 \times 10^{-3}} \qquad (2)$$

$$= 0.670 \text{ V} \qquad (1)$$

*Students must show Δ = final - initial to receive full marks.
If ¾ A is shown with no prior working or mathematical logic, maximum 3 marks.

(b) State and explain the direction of induced current in the loop as it is being pulled outwards.

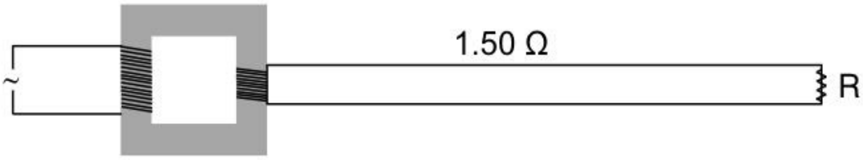
(4 marks)

- As the coil is pulled outwards, the area bounded by the magnetic field reduces / Area perpendicular to the field decreases.
- Which creates a change in magnetic flux directed out of the page
- According the Lenz's Law, the direction of the induced emf will be in such a way as to oppose the change in magnetic flux that created it

- The induced current will then need to circulate clockwise (as per right grip rule).

Question 6 **(9 marks)**

The diagram of a simple 'ideal' transformer below has 48 windings on the primary and 32 on the secondary. A resistor 'R' is connected to the secondary loop by a set of transmission wires with a total resistance of 1.50 Ω.



(a) The input power is 1.90 W_{rms}, determine the average power output by secondary coil. (1 mark)

1.90 W

(b) If the input voltage is 12.0 V AC, calculate the current that flows in the secondary coil. (4 marks)

$\frac{Np}{Ns} = \frac{Vp}{Vs} = \frac{48}{32}$ = 1.5x (1)

$V_s = \frac{32}{48}.12$ (1/2)

= 8.00 V (1/2)

$P_S = I_S V_S$ $I_S = P_S/V_S$ (1/2)

= 1.90 / 8.00 (12)

= 0.238 A (1)

Note: If student uses ratio of $\frac{Is}{Ip}$, full working of $P_p = P_s$ must be shown

(c) Calculate the voltage across the resistor. (4 marks)

$V_{drop} = I_S R_{wires}$ (1/2)

= (0.238)(1.5) (1/2)

= 0.357 V (1)

$V_{resistor} = V_S - V_{drop}$ (1/2)

= 8.00 – 0.357 (1/2)

= 7.64 V (1)

$P_L = I^2R$

= $0.238^2(1.50)$

$P_R = P_T - P_L$

= 1.90 – 0.085

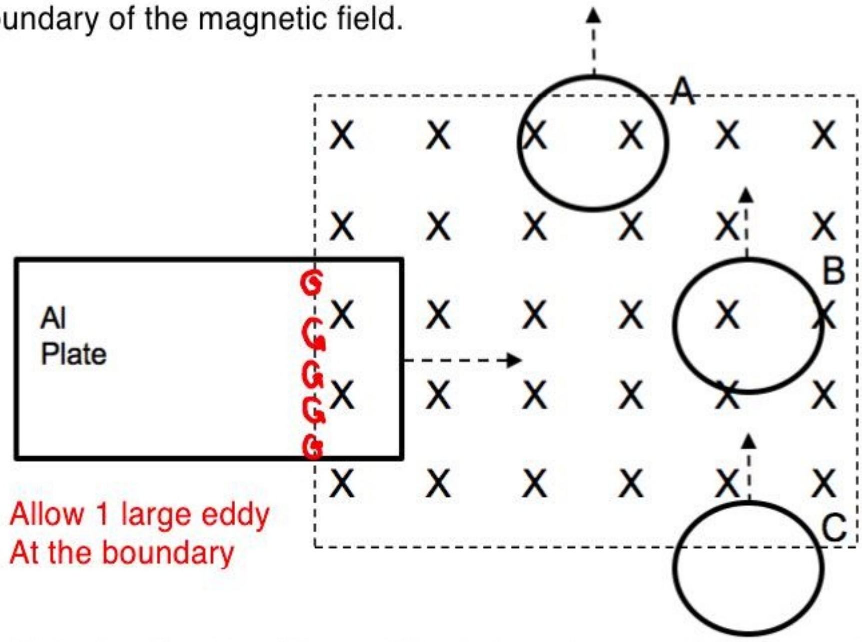
V = P/I

= 1.815 / 0.238

= 0.0850 W = 1.815 W = 7.63 V

Question 7 **(9 marks)**

Consider the following electrically conducting items travelling relative to a magnetic field shown below. The dashed arrows represent their direction of travel and the dashed boarder represents the boundary of the magnetic field.



(a) State the direction, if any of the induced conventional current for rings A, B and C. (3 marks)

A: Clockwise B: None C: Anticlockwise

(b) On the aluminium plate, draw the eddy currents that are produced at this instant in time. (1 mark)

(c) Explain your answer to the direction of ring C. (3 marks)

- As the coil is enters the field, the area bounded by the coil experiences a change in magnetic flux directed into the page
- According the Lenz's Law, the direction of the induced emf will be in such a way as to oppose the change in magnetic flux that created it, hence out of the page
- The induced current will then need to circulate anti clockwise (as per right grip rule)

(d) If the aluminium plate was lifted vertically out of the page, state and explain the effect this would have on the induced conventional current. (2 marks)

- There would be no induced EMF / induced current
- As the perpendicular area of the plate to the magnetic field experiences no change, hence no change in magnetic flux.

(if student mentions no change in flux but does not explain why, maximum 1.5 marks)

(if student mentions “area does not change” instead of perpendicular area, maximum 1.5 marks)

END OF TEST