Physics ATAR
Year 12

Electricity and Magnetism
Unit Test
2016

Name: SOLUTIONS

Mark: /58

= %

Time Allowed: 50.0 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 **(4 marks)**

A small plane with a wingspan of 10.0 m is flying east towards Perth at 250 kmh^{-1} where the magnetic field is 5.50 μT at 66.0˚ above the horizontal.

(a) Calculate the potential difference that will be generated along the length of the wings.

(3 marks)

$\varepsilon = Blv$ 1

$\varepsilon = 5.50\times10^{-6}\times \sin 66 \times10\times \frac{250}{3.6}$ 1

$\varepsilon = 3.49 \times 10^{-3}\ V$ 1

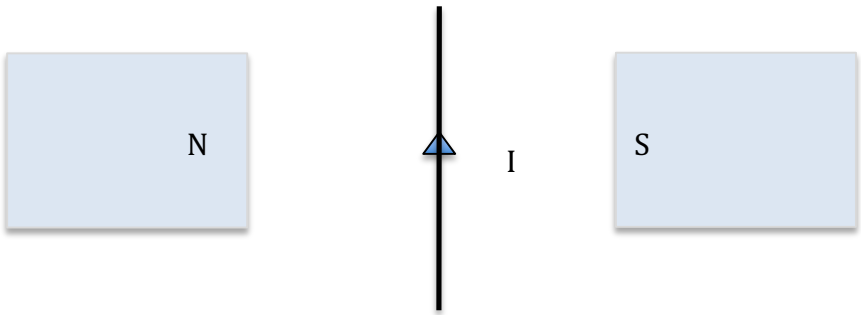
(b) State which end of the wing (north or south) will be positive.

(1 mark)

South end of wing

Question 2 **(3 marks)**

A wire that has a current of 5.00 A passing along it, is suspended at right angles to a magnetic field of 15.0 mT as shown below.



Calculate the length of the wire within the field if the magnitude of the force it experiences is 3.60 x 10^{-3} N.

$F = BIl$ 1

$l = \frac{F}{BI}$

$l = \frac{3.60 \times 10^{-3}}{15.0 \times10^{-3}\times 5.00}$ 1

$l = 4.80 \times10^{-2}\ m$ 1

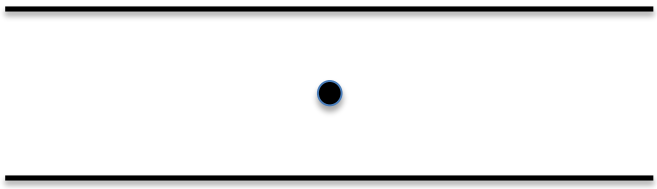
Question 3 **(5 marks)**

A student measures the time it takes a cylindrical magnet and a piece of iron of the same shape to fall through a suspended aluminium tube of 2.00 m length. He notes that the magnet took longer to fall through the tube. Explain why this happened.

- The aluminium tube experiences a changing magnetic field through it as the magnet falls
- Faraday's Law states an emf proportional to the rate of change of magnetic flux will be produced in the tube.
- Lenz's Law states that the resulting current will produce a magnetic field which will oppose the change in flux that created it.
- Thus the opposing magnetic field creates a repulsive force slowing down the rate at which the magnet falls under the action of gravity through the aluminium tube so net acceleration is less.
- The iron cylinder will fall through the tube as normal due to gravity

Question 4 **(5 marks)**

An oil drop with a charge of -12.5 nC and a mass of 2.30 mg is suspended mid way between two parallel, horizontal plates 1.00 cm apart. The diagram below shows a side view of the droplet between the two plates.



(a) Explain why the oil drop is suspended between the two plates.

(2 marks)

The oil drop is suspended because the two forces acting on it, the electrical force (F_E) upward and the weight force (W) downward, are in balance.

(b) Calculate the magnitude of the electric field strength that exists between the two plates.

(3 marks)

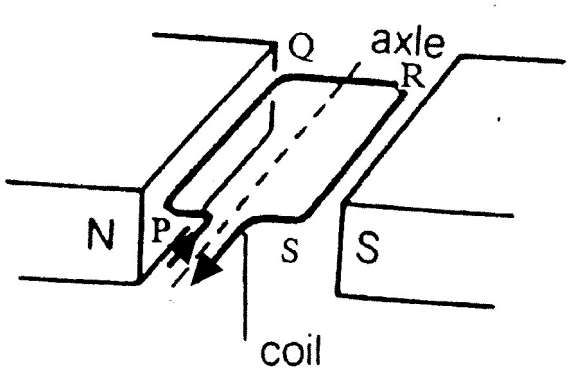
$F_E = W$ so $qE = mg$ 1

$$E = \frac{2.30 \times 10^{-6} \times 9.8}{12.5 \times 10^{-9}}$$ 1

$E = 1.80 \times 10^3\ NC^{-1}$ 1

Question 5 **(20 marks)**

A simple DC electric motor has a rectangular coil PQRS (as shown in the diagram below). PQ = RS = 6.00 cm and QR = PS = 4.00 cm. The motor has 50.0 turns and a resistance of 7.50 Ω and is connected to a 24.0 V DC supply. The magnetic field is 5.00 x 10^{-1} T and can be assumed to be radial. The arrows show the direction of flow of conventional current.



(a) A split ring commutator is used in the motor (but is not shown). Explain the purpose of the split ring commutator.

(2 marks)

- The split ring commutator is there to make the current flowing through each side of the coil to change direction as the coil rotates
- So the resulting torque will turn the motor only in one direction (anticockwise for coil shown)

(b) Calculate the current to operate the motor.

(2 marks)

V=IR 1/2

I = 24.0/7.50 1/2

I = 3.20 A 1

(c) Calculate the force acting from one length of wire from side RS.

(3 marks)

$F = BIl$ 1

$F = 0.50 \times 0.06 \times 3.20$ 1

$F = 9.60 \times 10^{-2}\ N\ up$ 1

-1 if no direction given

(d) Calculate the initial torque of the motor.

(3 marks)

$\tau = 2Fr \times N$ 1

$\tau = 2 \times 9.60 \times 10^{-2} \times 0.02 \times 50$ 1

$\tau = 0.192\ Nm$ anticlockwise 1

-1 if no direction

(e) Explain why the torque of a motor decreases as the motor speeds up.

(5 marks)

- As the motor turns, the magnetic flux through the coil changes and there is an emf induced in the coil proportional to the rate of change of flux (Faraday's Law).
- Lenz's Law states that this emf will act in the opposite direction to the applied emf and oppose the change in flux that create it.
- This back emf increases as the speed increases because the rate at which the flux is changing has increased. (Faraday's Law)
- The net emf then decreases ($emf_{app} - emf_{back}$) and so the current in the coil decreases.
- Torque is proportional to the current and hence the torque must also decreases (τ = NAIB).

(f) Describe what changes are necessary to convert the motor into an AC generator.

(2 marks)

- The split ring commutator must be replaced with slip rings
- There must be an external source of energy rotating the coil

(g) Assuming the motor was converted into an AC generator, and was then rotated rotated at 25.0 Hz, determine the peak emf generated in the coil.

(3 marks)

$\varepsilon_{max} = -2\pi NBAf$ 1

$\varepsilon_{max} = -2\pi \times 50 \times 0.5 \times 0.04 \times 0.06 \times 25$ 1

$\varepsilon_{max} = 9.42\ V$ 1

Question 6 **(10 marks)**

A transformer connected to 240 V (rms) AC mains supply is used to provide 12.0 V to operate a laptop computer.

(a) Calculate the current to operate the laptop computer if the effective resistance of the laptop is 8.00 Ω.

(3 marks)

$V = IR$ 1

$12.0/8 = I$ 1

$I = 1.50\ A$ 1

(b) Calculate the power rating of the laptop.

(3 marks)

$P = V \times I$ 1

$P = 12.0 \times 1.50$ 1

$P = 18.0\ W$ 1

(b) The transformer has 100 turns in the secondary coil and is 80.0% efficient. Calculate the number of turns required in the primary coil to effectively operate the laptop computer.

(4 marks)

Input at 100% would produce 18.0/0.8 = 22.5 W 1

$P_P = V_P \times I_P$ 22.5 = 240 x I_P I_P = 22.5/240 = 0.09375 A 1

$\frac{N_P}{100} = \frac{I_S}{I_P}$ 1/2

$N_P = \frac{1.50 \times 100}{0.09375}$ 1/2

$N_P = 1600\ turns$ 1

Question 7 **(11 marks)**

An electrical distribution system is a mix of step up and step down transformers. The electricity that exits from a 322 MW generator is stepped up to 325000 V from 15800 V before entering a 60.0 km long high voltage power line, then stepped down in substations and transformers closer to the consumer.

(a) Explain the purpose of stepping up the voltage on leaving the power station

(4 marks)

- A flow of current through power lines creates resistive heating
- The amount of resistive heating and resulting power loss is due to the current (as $P_{loss} = I^2R$)
- For a constant value of power, stepping up the voltage decreases the current as P = VI
- So there will be less power loss in the high voltage power line

(b) Calculate the current in the high voltage power lines from stepping up the voltage from 15800 V to 325000 V assuming the step up transformer is 100% efficient.

(3 marks)

$\boldsymbol{P_P = V_S I_S}$ 1

$322\ MW = 325000 \times I$ 1

$I = 9.91 \times 10^2\ A$ 1

(c) Calculate the power loss in the distribution lines if they have a resistance of $2.00 \times 10^{-3}\ \Omega$ per kilometre.

(4 marks)

$R_{total} = 2.00 \times 10^{-3} \times 60.0 = 1.20 \times 10^{-1}\ \Omega$ 1

$P_{loss} = I^2 R_{total}$ 1

$P_{loss} = (9.91 \times 10^2)^2 \times 1.20 \times 10^{-1}$ 1

$P_{loss} = 1.18 \times 10^5\ W$ 1

End of Test