Christ Church
Grammar School

Science Department
Year 12 2020

ATAR PHYSICS
UNIT 3: ELECTROMAGNETISM
TOPIC TEST 2020

Teacher: JRM HKR
(Please circle)

Time allowed for this paper **SOLUTIONS**

Working time for paper: 50 minutes.

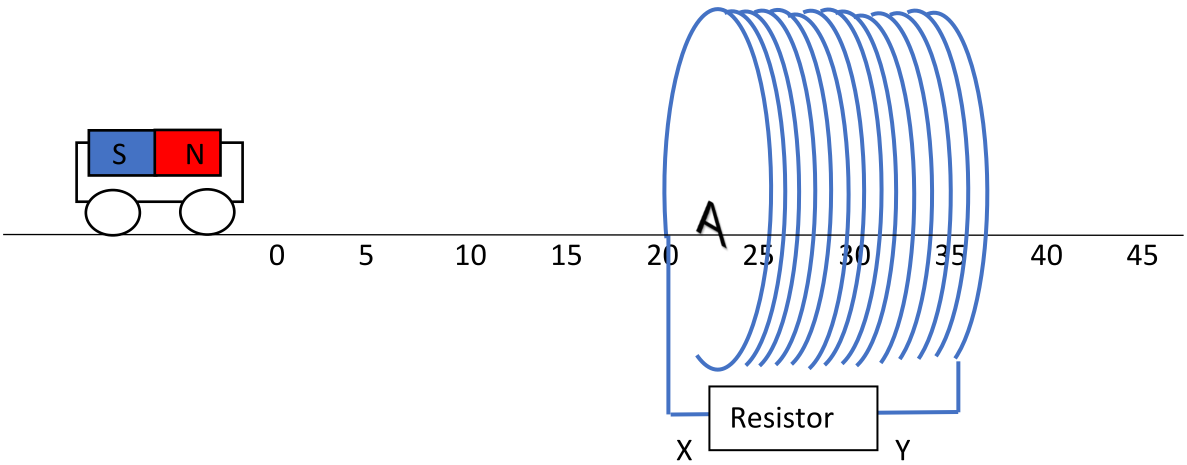
Instructions to candidates:

- You must include **all** working to be awarded full marks for a question. Answers should be expressed to 3 significant figures unless otherwise indicated.
- Marks may be deducted if diagrams are not drawn neatly with a ruler and to scale (if specified).
- Marks will be deducted for incorrect or absent units.
- **No** graphics calculators are permitted – scientific calculators only.

Mark:	/ 55
=	%

Question 1 **(10 marks)**

A 5.00 cm magnet on a motorised cart rolls at a constant speed into a 15.0 cm long solenoid of radius 3.00 cm and attached to a resistor. When the north pole enters the first coil, the magnetic field passing through the area bounded by the coil changes from 155 mT Right to 35.0 mT Left in a time period of 0.150 s. The coil is placed at 20 to 35 cm along the horizontal section of the track.



(a) State which direction the conventional current passes through the resistor when the north pole **enters** the coil and include a detailed explanation as to why this direction was chosen.

(4 marks)

Description	Marks
As the north pole enters the solenoid, the area bounded by the solenoid experiences a change in magnetic flux	1
From right to left which is a change in left.	1
Lenz's law states that the induced EMF must be in such a direction as to oppose that which induced it. (Hence change in right)	1
As per the right grip rule, conventional current must flow Y to X	1
Total	4

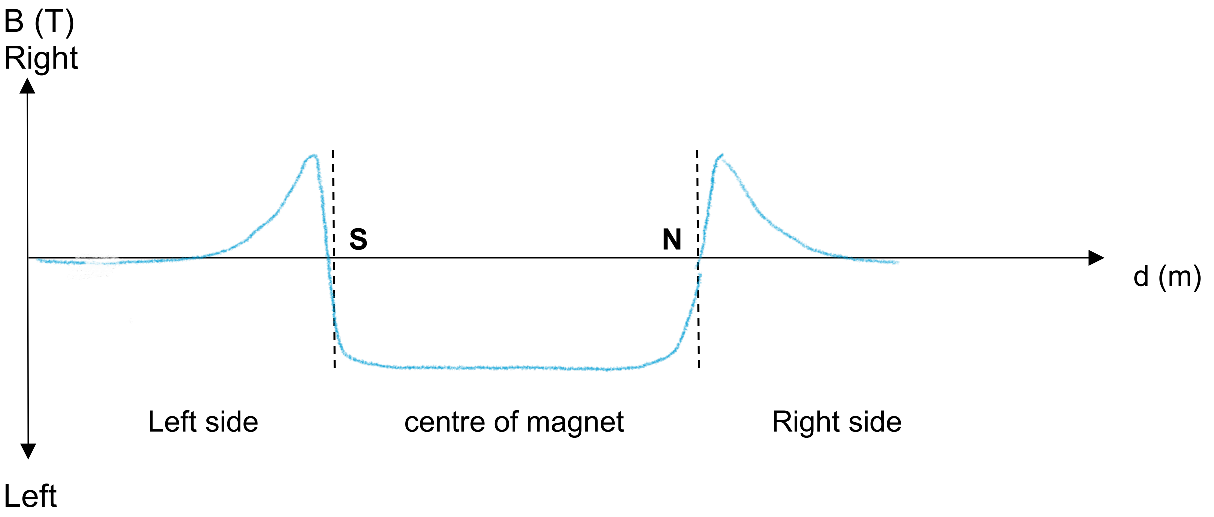
(b) Calculate the magnitude of the induced EMF across the first coil when the north pole enters the solenoid.

(3 marks)

Description	Marks
Emf = $\frac{-n\,\Delta\phi}{\Delta t} = \frac{-n\,\Delta B(A)}{\Delta t}$ let left = -	1
= $\frac{-1(-0.0355 - 0.155)(\pi 0.03^2)}{0.150}$	1
= 0.00358 V	1
Total	3

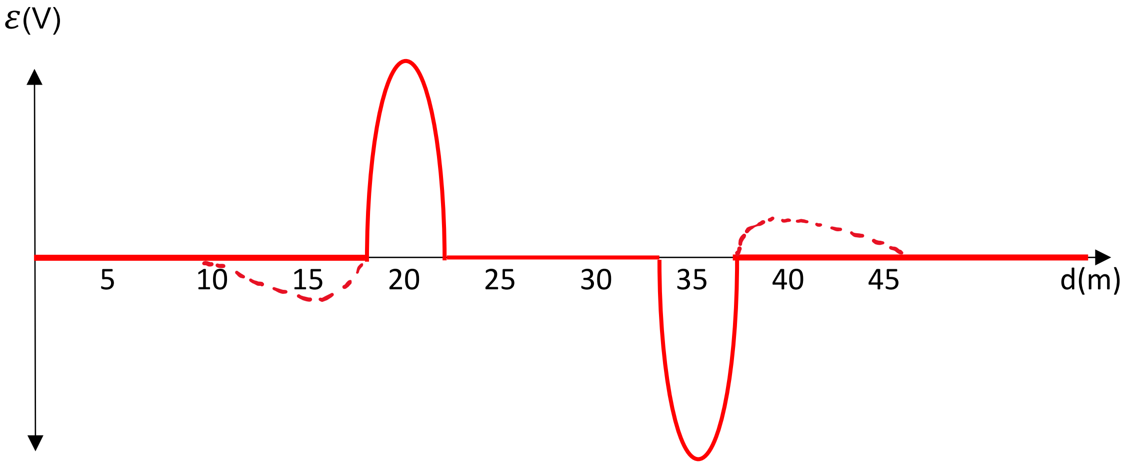
Question 1 continued

The graph below shows how the magnetic field strength changes along the dimensions of the magnet.



On the graph below sketch the induced EMF across the solenoid as the north face of the magnet rolls along the horizontal section of the track.

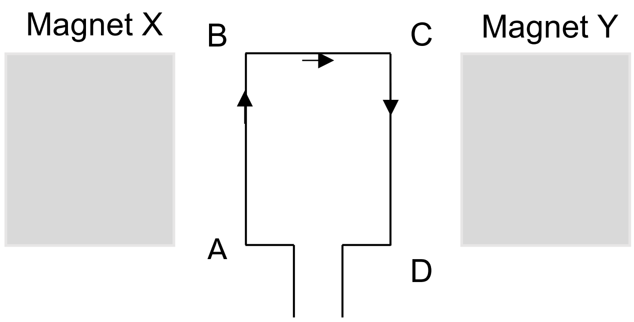
(3 marks)



Description	Marks
Two EMF peaks that are opposite to each other	1
Zero EMF at start and mid-point and end.	1
Amplitudes and width (time interval) are equal for both peaks	1
Total	3
Allow dotted lines to indicate the growing strength of mag field away from the pole of the magnet. But not necessary for full marks.	

Question 2 0 **(6 marks)**

The diagram below shows the structure of a simple DC Motor. A rectangular coil (ABCD) consisting a single loop is sitting in a magnetic field created by the poles of two bar magnets (X and Y).



(a) As shown by the arrows on the coil, at a particular instant in time, conventional current flows from A to D. At this instant, side AB experiences a force out of the page and side CD experiences a force into the page. In the spaces provided below, write down the polarity (North or South) of Magnets X and Y that would create these forces.

(1 mark)

MAGNET X: SOUTH MAGNET Y: NORTH

The dimensions of the coil are AB = CD = 20.0 cm; BC = AD = 10.0 cm.
The current flowing is equal to 1.50 A and the strength of the magnetic field is 0.400 T.

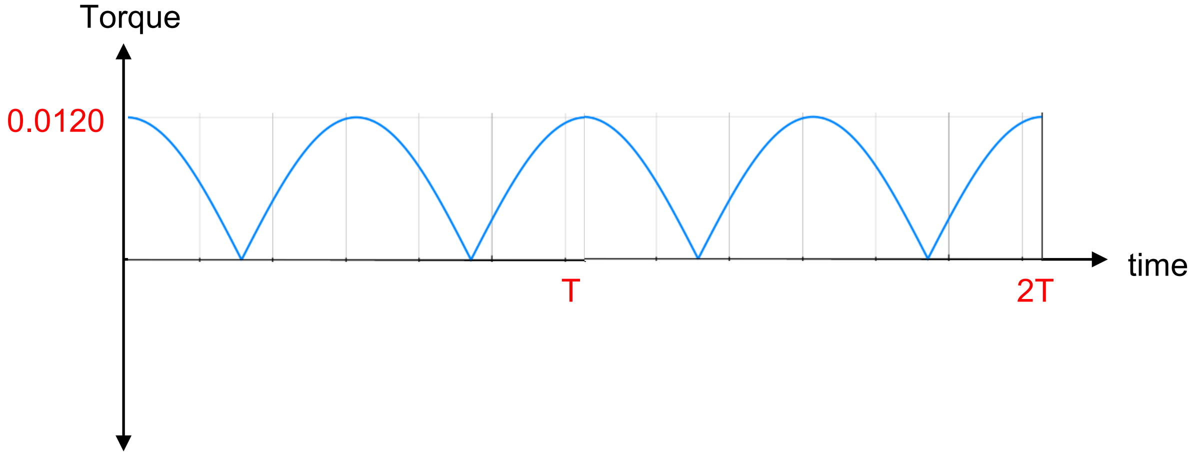
(b) Calculate the magnitude of the torque acting on the coil when it is in the position shown in the diagram.

(3 marks)

Description	Marks
τ = 2r F F = BIL = 2rBIL = BAIn	1
= 4.00(0.20 x 0.10)(1.50)(1)	1
= 0.0120 Nm	1
Total	3

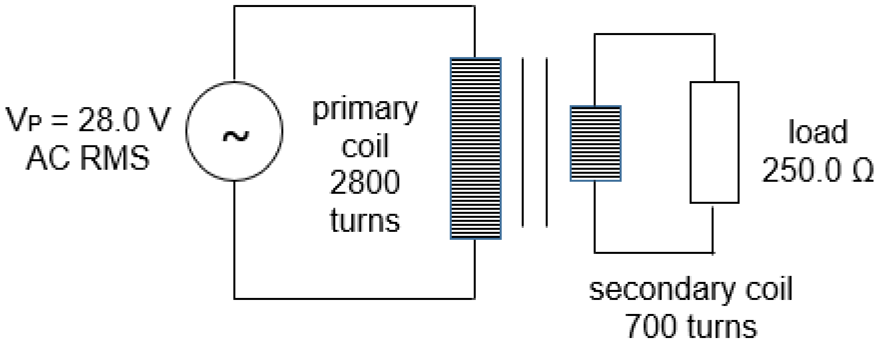
(c) On the set of axes below, sketch the torque curve of this simple DC motor over the course of two full rotations. Assume that a commutator is present in the motor and the coil starts in the position shown in the diagram above.

(2 marks)



Question 3 **(9 marks)**

A transformer has an input voltage of 28.0 V RMS AC. For the questions that follow, assume the transformer is 100% efficient.



(a) Calculate the output voltage for this transformer.

(2 marks)

Description	Marks
$\frac{V_P}{V_S} = \frac{N_P}{N_S};\ V_S = \frac{V_P\, N_S}{N_P} = \frac{28\ \times 700}{2800}$	1
= 7.00 V	1
Total	2

(b) Calculate the current flowing through the load in the secondary circuit.

(2 marks)

Description	Marks
$V_S = I_S\, R_S;\ \therefore\ I_S = \frac{V_S}{R_S} = \frac{7.00}{250}$	1
$= 2.80\ \times\ 10^{-2}$ A	1
Total	2

(c) Hence, calculate the power generated in the primary coil of this transformer.

(2 marks)

Description	Marks
$P_P = P_S = V_S\, I_S = 7.00\ \times\ 2.80\ \times\ 10^{-2}$	1
$= 0.196$ W	1
Total	2

(d) In reality, transformers are not 100% efficient; they experience energy losses through a combination of factors. State one type of energy loss experienced in a transformer and describe how it is reduced via its design.

(3 marks)

Description	Marks
Resistance in the current-carrying primary and secondary coils. OR	1
Causes heat losses as per $P = I^2R$	1
The coil carrying the highest current is thicker to reduce resistance and heat loss.	1
OR	
Eddy currents in the iron cores produced by the changing magnetic flux.	1
Causes heat losses as per $P = I^2R$	1
The iron cores are laminated reducing the bulk mass of iron and eddy currents that can be formed.	1
OR	
Stray flux losses / leakage	1
Not all magnetic field in the primary coil is linked / passes into the secondary coil	1
Soft iron is used to link primary coil to secondary coil.	1
OR	
Hysteresis Losses	1
Energy is required to demagnetise/demagnetise or change the direction of the magnetic field	1
Soft iron is used that requires less energy to change the direction than hard iron	1
Total	3

Question 4 **(12 marks)**

A group of students conducted an investigation measuring the force between two parallel current-carrying wires. Diagram 1 below shows conducting wires with current flowing through them. During the investigation, the students kept 'r' constant at a value of 5.00 cm and the values of I_1 and I_2 were kept at 5.00 A.

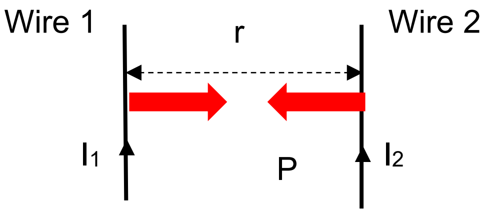
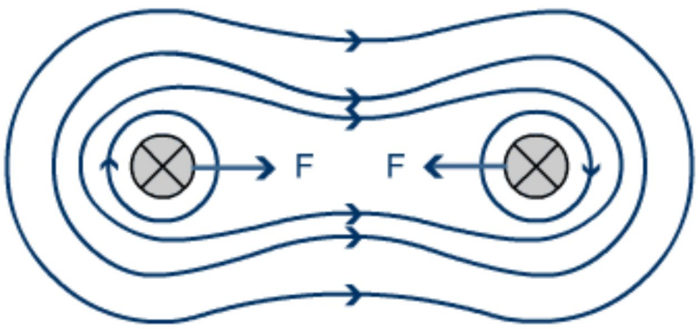


Diagram 1.

Diagram 2 below illustrates this experiment from a bottom-up view.

Diagram 2.



(a) On diagram 2, draw the net magnetic field around the two wires.

(2 marks)

Description	Marks
Overall shape. Symmetric about vertical and horizontal axis. Denser field outside compared to between wires	1
Arrows pointing in correct direction	1
Total	2

(b) On Diagram 1, draw vectors representing the forces that each conductor would experience due to the currents I_1 and I_2.

(1 marks)

(c) Calculate the magnetic field strength at Point P which is 2.00 cm from wire 2.

(4 marks)

Description	Marks
$B = \frac{\mu_o}{2\pi}\frac{I}{r}$ $\quad \Sigma B = B_1 + B_2$ convention out of page = +	1
$= \left(\frac{-\mu_o}{2\pi}\frac{I_1}{r_1}\right) + \left(\frac{\mu_o}{2\pi}\frac{I_2}{r_2}\right)$	1
$= \left(\frac{-4\pi\times10^{-7}}{2\pi}\cdot\frac{5}{0.03}\right) + \left(\frac{4\pi\times10^{-7}}{2\pi}\cdot\frac{5}{0.02}\right)$	1
$= 1.67 \times 10^{-5}$ T out of page (allow "up" from diagram 2)	1
Total	4

Question 4 continued.

The resultant force on each conductor was then measured with very sensitive force probes. The equation for calculating the *resultant force* acting between the two parallel current-carrying wires in this investigation is given by the formula below:

$$\frac{\mathbf{F}}{\mathbf{L}} = \frac{\boldsymbol{\mu_0}\ \mathbf{I^2}}{\mathbf{2\pi r}}$$

(d) Show the derivation of the *resultant force* equation.

(3 marks)

Description	Marks
$B = \frac{\mu_0}{2\pi}\frac{I}{r}$ and F = BIL	1
F = $\frac{\mu_0}{2\pi}\frac{I_1}{r}.I_2\,L$ given $I_1 = I_2$	1
$\frac{F}{\Delta L} = \frac{\mu_0\ I^2}{2\pi r}$	1
Total	3

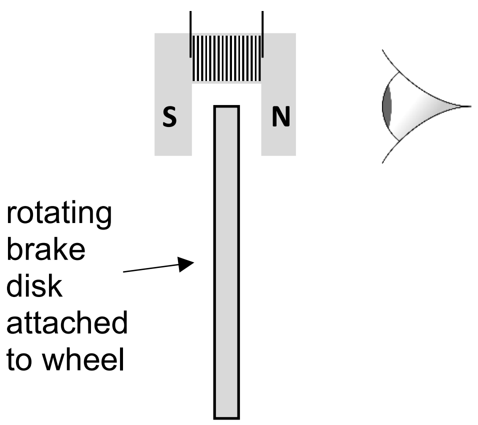
(e) Calculate magnitude of the force acting on a 10.0 cm length of wire.

(2 marks)

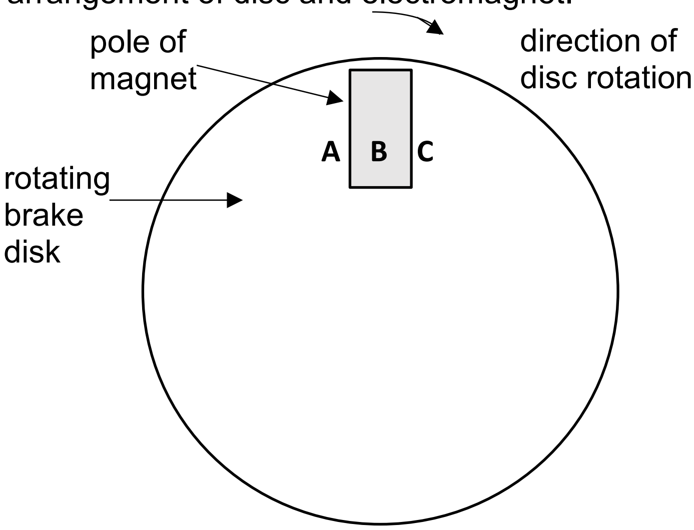
Description	Marks
$\frac{F}{\Delta L} = \frac{\mu_0\ I^2}{2\pi r}$, $F = \frac{\mu_0\ I^2 L}{2\pi r} = \frac{4\pi\times10^{-7}\ 5^2(0.1)}{2\pi(0.05)}$	1
$= 1.00\ \text{x}10^{-5}$ N	1
Total	2

Question 5 **(10 marks)**

Eddy currents can be used to apply ‘magnetic braking’ to a vehicle like a train. Like conventional ‘friction brakes’, the wheels of the train have a ‘brake disc’ attached to them that rotates with the wheel as the train is moving. Around the top of the disc, but without touching it, is an iron core electromagnet. When the brakes are applied, the electromagnet is switched on and the train is decelerated. The figures below show the arrangement of disc and electromagnet.



FRONT VIEW



SIDE VIEW (viewed from right)

(a) Referring to the ‘SIDE VIEW’ diagram, state the direction, if any, of the induced eddy currents generated at points A, B and C by the rotating disc and electromagnet.

(3 marks)

A: ACW B: NONE C: CW

(b) Explain how the movement of the disc causes the braking effect.

(4 marks)

Description	Marks
As the disc rotates into/out of the magnet, regions of the disc experience a change in magnetic flux	1
Lenz’s Law states that the direction of this induced EMF will be in such a direction as to oppose the change in magnetic flux that created it.	1
Hence, the magnetic field produced by the induced eddy currents will produce an opposing magnetic field OR The magnetic field of the induced eddy currents interact with the external magnetic field of the electromagnet to produce a retarding force	1
This opposing magnetic field opposes the motion of the disc and decelerates the train	1
Total	3

(c) Explain the effect, if any, of the speed of the train on the strength of the magnetic brake. (3 marks)

Description	Marks
Faraday's law states that magnitude of the induced emf is proportional to the rate of change of magnetic flux with respect to time	1
Hence, as the train/disc travels faster/slower there is a greater/lesser rate of change of magnetic flux with respect to time	1
This increases/decreases the magnitude of the magnetic force and hence, the braking effect.	1
Total	3

Question 6 **(3 marks)**

Two positively charged point charges of magnitude (in Coulombs) q_1 and q_2 are separated by a distance d and experience an electrostatic force F.
The charge sizes are changed to $2q_1$ and $3q_2$ and the distance is reduced to $0.50d$. Calculate an expression for the electrostatic force between these two charges in terms of F.

Description	Marks
$F = \frac{k\,(2q_1)\,(-3q_2)}{(0.5d)^2} = \frac{-6\,k\,q_1\,q_2}{0.25\,d^2}$	1
$= \frac{-24\,k\,q_1\,q_2}{d^2}$	1
$= 24F$	1
Total	3

Question 7 **(5 marks)**

A power station generates electric power at a rate of 2.00 x 10^2 MW. The power is transmitted along a 40.0 km long transmission line to a transformer at voltage of 220 kV. The line has a resistance rating of 0.15 Ω km^{-1}. Calculate the voltage delivered to the primary coil of the transformer at the end of this transmission line. Show working.

Description	Marks
$I_T = \frac{P_T}{V_T} = \frac{200 \times 10^6}{220 \times 10^3}$	1
$I_T = 909$ A	1
$R_T = 40 \times 0.15 = 6.00\ \Omega$	1
$V_{DROP} = 909 \times 6 = 5454$ V	1
$V_{DELIVERED} = 220 \times 10^3 - 5.45 \times 10^3$ = 215 kV	1
Total	5

END OF TEST