PHYSICS
Year 12, 2012
Semester One Examination
SECTION A
Question/Answer Booklet

Name: *Solutions*

Teacher:

JAA \ MV

EXAMINERS USE ONLY	
Section A	
Section B	
Section C	
Total	

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes

Working time for paper: Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

TO BE PROVIDED BY THE SUPERVISOR

This Question/Answer Booklet comprising **12** pages

Data and Constants Sheet

TO BE PROVIDED BY THE CANDIDATE

Standard Items: Pens, pencils, eraser or correction fluid, ruler

Special Items: Drawing instruments, templates and calculators satisfying the conditions set by
                                  the Curriculum Council.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room.

It is your responsibility to ensure that you do not have any unauthorised notes or other items of a
non-personal nature in the examination room. If you have any unauthorised material with you
hand it to the supervisor BEFORE reading any further.

SECTION A : Short Answers
Marks Allotted: 54 marks out of 180 (30%). Attempt ALL **14** questions in this section.
Answers are to be written in the spaces provided.

QA1. [6 Marks]
A person is flying a kite in a brisk wind.

The kite is holding a steady (stationary)
 position as shown in the diagram.

The forces acting on the kite are resolved
into four parts.

The horizontal drag (D), the weight (W),
the vertical lift (L), and the force due to
tension in the string (T).

The mass of the kite is 408 g

The magnitude of the drag equals that of the lift, and
the magnitude of the lift is twice that of the weight.

Wind direction   C.O.M   D

W

T

RELATIVE
MAGNITUDE
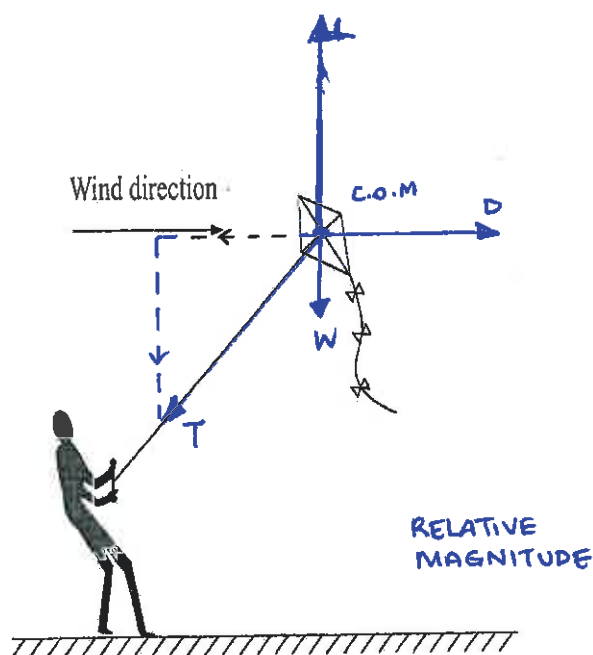
(2 marks)

1a)   Draw a free-body diagram to illustrate the forces acting on the kite (use the diagram above).

1b)   Carefully construct a scale diagram showing the vector addition of the forces, and hence
graphically determine the tension in the string.

NO CALCULATION REQUIRED !
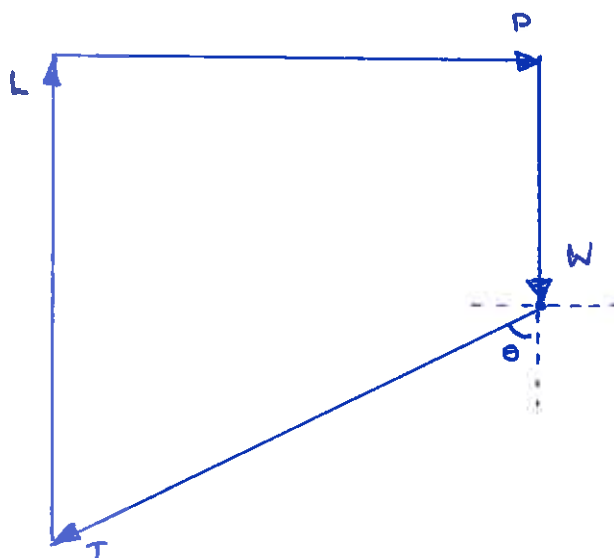
LET W = m.g = 0.408 × 9.8
          = 4.0 N

LET 1N ≡ 1cm SCALE

SINCE $\sum F = 0$

      T = 9 N (APPROX)

      θ = 60°

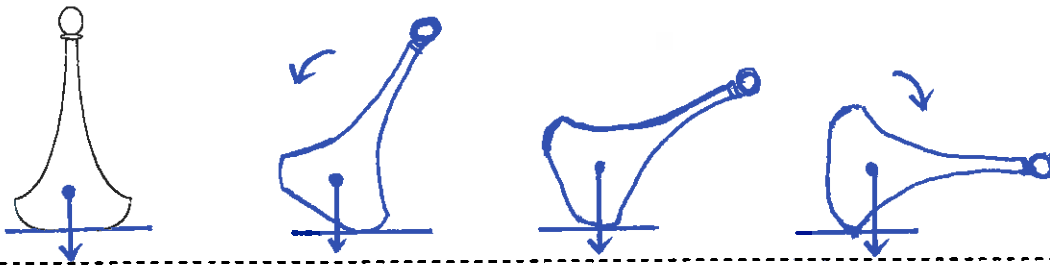∴   A TENSION OF 9N
    AT ~ 60° FROM VERTICAL

P

L

W

T

θ

· SCALE
· DIAGRAM
· MAGNITUDES
· DIRECTION

(4 marks)

QA2. [4 Marks]

Antique decanters used for serving drinks on sailing vessels were often shaped with a broad thick glass base? Explain, with the aid of diagrams, how this ensures their stability when the ship rolls.

• THE DECANTER REMAINS STABLE AS LONG AS ITS C.OM LIES WITHIN ITS BASE.

• THE LOW C.O.M AND THE WIDE BASE RESULTS IN TIPPING THE DECANTER ONTO ITS BASE (RESTORING TORQUE) WHEN TILTED, UNLESS THE ANGLE OF TILT / DEFLECTION IS EXCESSIVE. IT IS THUS HARD TO TOPPLE OVER

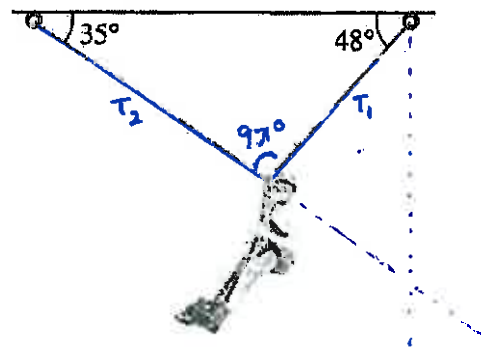• AND SPILL CONTENTS WHEN THE SHIP ROLLS. (i.e VERY STABLE FOR LARGE ANGLES OF TILT)   (4 marks)

QA3. [4 Marks]

In a rescue, a 73 kg policeman is suspended by two cables as shown.

Determine the tension in each cable.

(A vector diagram may be helpful)

USING SINE RULE!

THEN $\dfrac{F_W}{\sin 83°} = \dfrac{T_1}{\sin 55°} = \dfrac{T_2}{\sin 42°}$

$\therefore T_1 = \dfrac{F_W \cdot \sin 55°}{\sin 83°}$
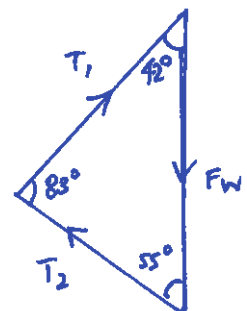
$= \dfrac{73 \times 9.8 \times \sin 55°}{\sin 83°}$

$\therefore T_1 = 590 \text{ N}$

$\therefore T_2 = \dfrac{F_W \cdot \sin 42°}{\sin 83°}$

$= \dfrac{73 \times 9.8 \times \sin 42°}{\sin 83°}$

$\therefore T_2 = 482 \text{ N}$

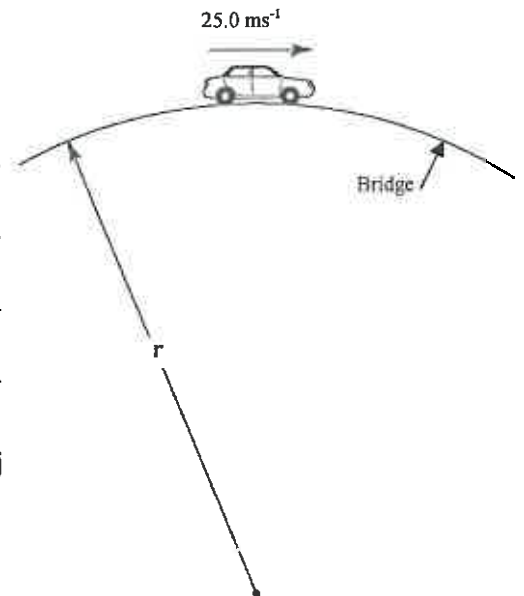   (4 marks)

QA4. [4 Marks]

A car of mass 935 kg is travelling at a constant speed of 25.0 ms^{-1} over a bridge. The bridge is shaped like an arc of a circle. At the top of the bridge the driver senses that the car is temporarily airborne at the instant he passes over the top of the curve.

4a) What is the centripetal force acting on the car at the top of the bridge?

THE REACTION IS ZERO (AIR BORNE)

$$\therefore F_c = \cancel{R}^0 + F_W$$

$$= M \cdot g$$

$$= 935 \times 9.8$$

$$= 9.16 \times 10^3 \, N \quad (DOWNWARDS)$$

(2 marks)

4b) What is the radius of the bridge?

SINCE $F_c = \dfrac{Mv^2}{r}$

$$r = \dfrac{Mv^2}{F_c}$$

$$= \dfrac{935 \times (25)^2}{9.16 \times 10^3}$$

$$\therefore r = 63.8 \, m$$

(2 marks)

QA5. [4 Marks]

Estimate the force of gravitational attraction that you experience towards your favourite Physics teacher when he is presenting a lesson from the front of the classroom. Compare this force to that towards a student sitting next to you. Show all the relevant detail of your estimation.

$M_T = 80 \, kg$ (TEACHER)

$M_S = 70 \, kg$ (STUDENT)

$M_X = 70 \, kg$ (SELF)

$S_T = 2 \to 10 \, m$ (SAY 5m)

$S_S = 0.50 \, m$

$$F_T = \dfrac{G \cdot m_X m_T}{(r_{XT})^2}$$

$$= \dfrac{6.67 \times 10^{-11} \times 70 \times 80}{(5)^2}$$

$$\therefore F_T = 1.4 \times 10^{-8} \, N \qquad \sim 10^{-8} \, N$$

$$F_S = \dfrac{6.67 \times 10^{-11} \times 70 \times 70}{(0.5)^2}$$

$$\therefore F_S = 1.3 \times 10^{-7} \, N \qquad \sim 10^{-7} \, N$$

YOU ARE APPROXIMATELY 10 TIMES MORE ATTRACTED (DISTRACTED!) BY THE STUDENT SITTING NEXT TO YOU THAN YOUR TEACHER.

(4 marks)

QA6. [2 Marks]

In which geographical direction are satellites launched? Explain why it is advantageous for satellites to be launched from the equator. (Hint: A diagram may assist your explanation.)
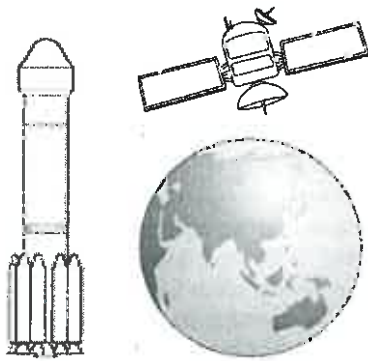
THE FORCE/ENERGY REQUIRED TO LAUNCH/ACCELERATE THE ROCKET/SATELLITE TO THE VELOCITY NEEDED TO MAINTAIN THE DESIRED ORBIT IS CONSIDERABLY REDUCED WHEN DIRECTED WEST → EAST TO MATCH EARTH'S ROTATION. TO TAKE ADVANTAGE OF THE VELOCITY OF ALL OBJECTS AT THE EARTH'S SURFACE, ESPECIALLY AT THE EQUATOR WHERE THE CIRCUMFERENCE IS GREATEST.
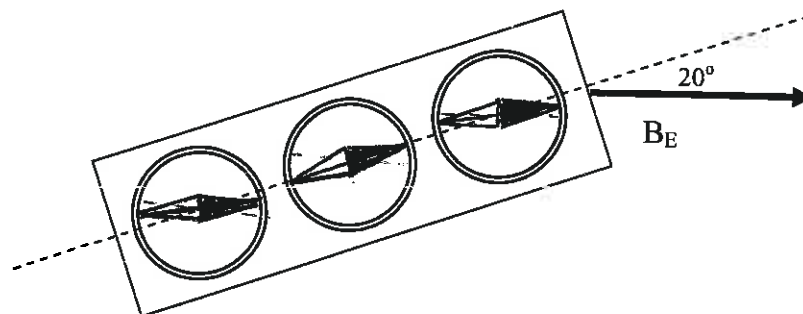
(2 marks)

QA7. [4 Marks]

Three compasses are placed on a card and aligned close together in Earth's magnetic field, B_E as shown.
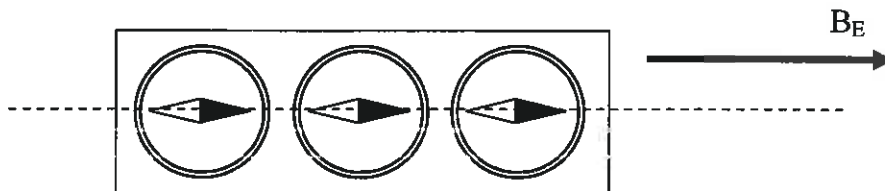
The card is then rotated so that the line joining the compasses makes an angle of 20° with the Earth's magnetic field.

(2 marks)

7a) Clearly indicate on the diagram, the directions of the three compass needles in this new position.

7b) Briefly justify your choice of directions.

THE COMPASSES ARE MAGNETS AND WILL EXERT A FORCE ON EACH OTHER SO THEY TEND TO ALIGN WITH EACH OTHER. THE CENTRAL COMPASS/MAGNET WILL BE MORE AFFECTED THAN THE OTHER TWO SINCE IT IS AFFECTED AT BOTH ENDS.

(2 marks)

QA8. [3 Marks]

A laboratory solenoid consists of 1050 turns. The length of such a solenoid is 16.3 cm with a radius of 2.25 cm. When it carries a current of 4.0 A it generates a magnetic field strength of 0.62 T.

Determine the magnetic flux passing through the coil well inside the solenoid.

SINCE $B = \frac{\phi}{A}$

$\phi = B.A \quad$ WHERE $A = \pi r^2$

$\qquad = 0.62 \times \pi \times (2.25 \times 10^{-2})^2$

$\therefore \quad \phi = 9.86 \times 10^{-4} \text{ wb}$

NOTE: NOT ALL DATA IS RELEVANT IN DETERMINING THE ANSWER

(3marks)

QA9. [4 Marks]

A wire carrying an electric current is placed between the poles of a horseshow magnet as shown.

The 6.35 cm long conductor carries a current of 4.8 A and the magnetic field between the poles of the magnet has a strength of 0.54 T.

9a) On the diagram, carefully illustrate the resulting magnetic field and the direction of the force experienced by the conductor.

(2marks)
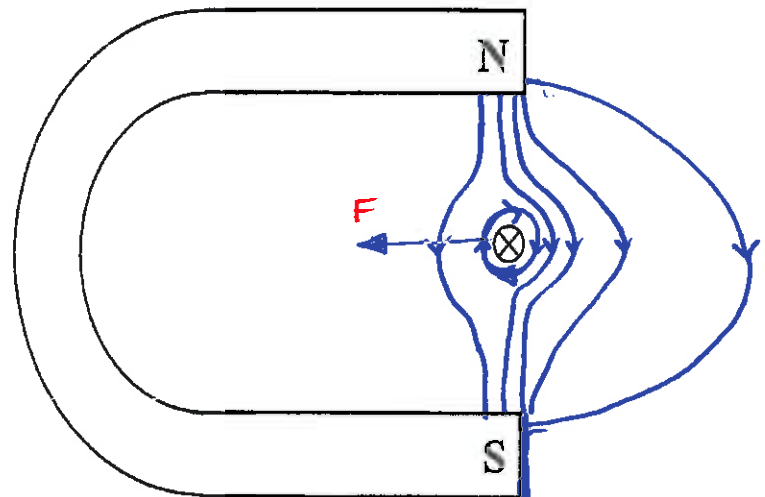
9b) Determine the magnitude of the force experienced by the conductor.

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

$\qquad = 0.54 \times 4.8 \times 6.35 \times 10^{-2} \times \sin 90°$

$\therefore F = 0.165 \text{ N}$

$\{ \quad = 0.16 \text{ N} \quad (2.S.F) \}$

(2 marks)

QA10. [5 Marks]

An aero-plane with a wingspan of 10.0 m is flying horizontally at a velocity of 200 m s^{-1}. In the region the plane is flying, the Earth's magnetic field is 2.0 x 10^{-4} T, at an angle of 60° to the horizontal.

10 a) label the diagram to show the polarity of the induced EMF on each wing tip.

10 b) What is the magnitude of EMF induced across the wingtips of the aero-plane?
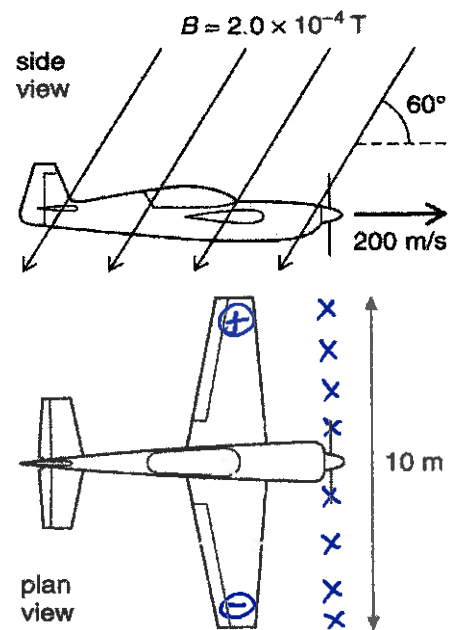
(USE VERTICAL COMPONENT OF MAGNETIC FIELD)

$$B_V = 2.0 \times 10^{-4} \times \sin 60°$$

$$\therefore B_V = 1.73 \times 10^{-4} T$$

$$\mathcal{E} = B_V \cdot v \cdot l$$
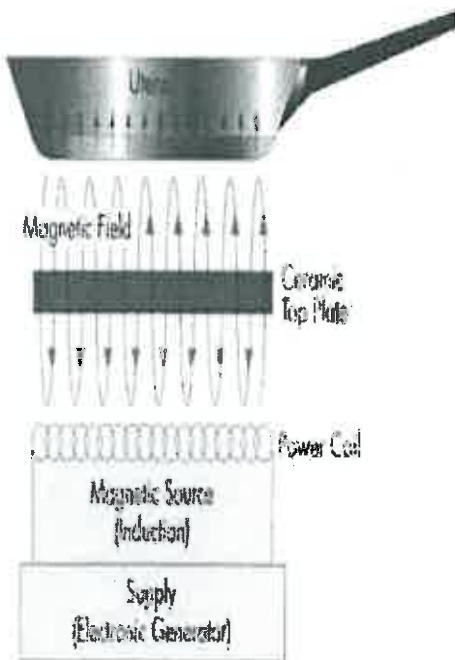
$$= 1.73 \times 10^{-4} \times 200 \times 10.0$$

$$\therefore \mathcal{E} = 0.346 V = 0.4 V \ (1SF)$$

ALTERNATIVELY: $\mathcal{E} = B \cdot v \cdot l \cdot \sin \theta$

$B = 2.0 \times 10^{-4} T$

side view

60°

200 m/s

10 m

plan view

(4 marks)

QA11. [3 Marks]

Carefully explain how an induction cooker produces the heat to cook the food.

• THE ALTERNATING POWER SUPPLY PRODUCES A CONSTANTLY CHANGING MAGNETIC FIELD

• THE CHANGING FIELD INDUCES AN EMF AND THEREBY EDDY CURRENTS IN THE BASE of THE COOKING UTENSIL

• DUE TO THE RESISTANCE OF THE COOKING UTENSIL, THE (EDDY) CURRENTS INCREASE THE AVERAGE KINETIC ENERGY, AND THEREBY THE TEMPERATURE

OR//

• SINCE $P_{LOSS} = I^2 R = HEAT$

Magnetic Field

Ceramic Top Plate

Power Coil

Magnetic Source (Induction)

Supply (Electronic Generator)

(3 marks)

QA12. [4 Marks]

A Physics teacher set up the equipment shown below to present an important demonstration.
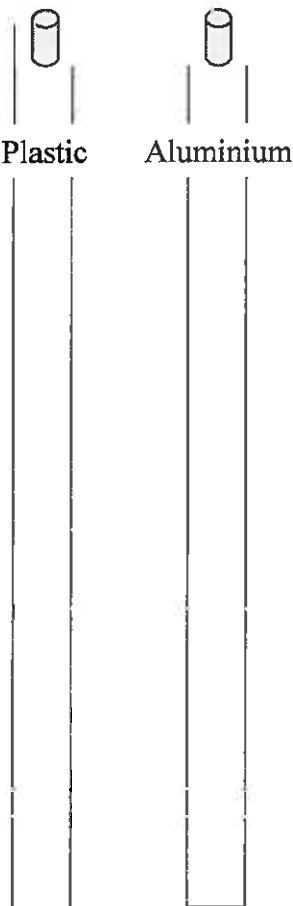
The time required for a cylindrical rare earth magnet to fall from the same height in both tubes was measured.

It was observed that the magnet falling through the plastic tube travelled much faster compared to falling through the aluminium tube.

Carefully explain this observation in terms of the Physics principles involved.

Plastic   Aluminium

- THE FALLING MAGNET INDUCED AN EMF AND THEREBY A CURRENT IN THE ALUMINIUM TUBE (ACCORDING FARADAY)
- THE CHANGING MAGNETIC FIELD OF THE FALLING MAGNET WILL BE OPPOSED BY THE MAGNETIC FIELD PRODUCED BY THE CURRENT INDUCED IN THE ALUMINIUM TUBE (ACCORDING TO LENZ'S LAW)
- THE INTERACTING MAGNETIC FIELDS RESULT IN A DECELERATING FORCE ON THE FALLING MAGNET DECREASING ITS SPEED.

(4 marks)

QA13. [3 Marks]

- PLASTIC IS NOT AFFECTED AS IT IS NOT A CONDUCTOR.

A transformer for a toy train set plugs into the 240 V mains supply and changes it to 12.0 V.

13a) Is this a step-up or step-down transformer ?

STEP - DOWN $(240 \rightarrow 12)$

(1 mark)

secondary leads

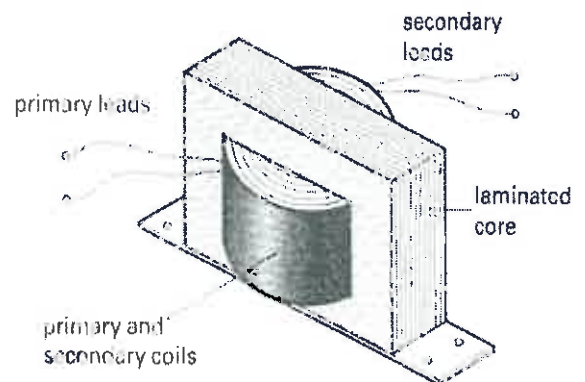primary leads

laminated core

primary and secondary coils

13 b) If the primary consists of 360 turns of wire, how many turns will the secondary have?

SINCE $N_P/N_S = V_P/V_S$

THEN $N_S = \dfrac{N_P \cdot V_S}{V_P}$

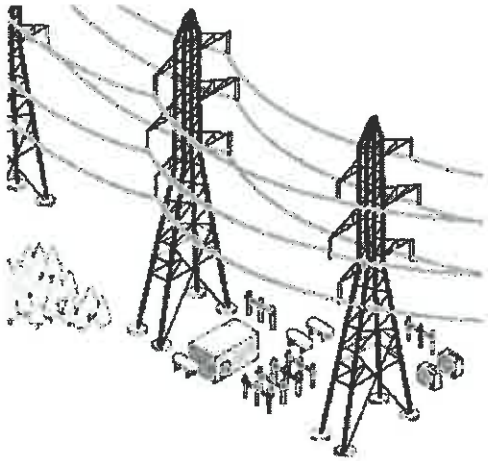$= \dfrac{360 \times 12}{240}$

$\therefore N_S = 18$ TURNS

(2 marks)

QA14. [4 Marks]

Briefly explain why our electrical energy is an AC supply that is transmitted at very high voltages between the power stations and the cities where it is used.

- ALTERNATING CURRENT ALLOWS FOR THE USE OF TRANSFORMERS ...
- ⇒ ALLOWS STEP UP TO HIGH VOLTAGES FOR TRANSMISSION
- ⇒ REDUCING TRANSMISSION CURRENT AND THUS LINE LOSS / POWER LOSS $(P_{LOSS} = I^2 R)$

- A.C IS ALSO "EASIER" TO GENERATE
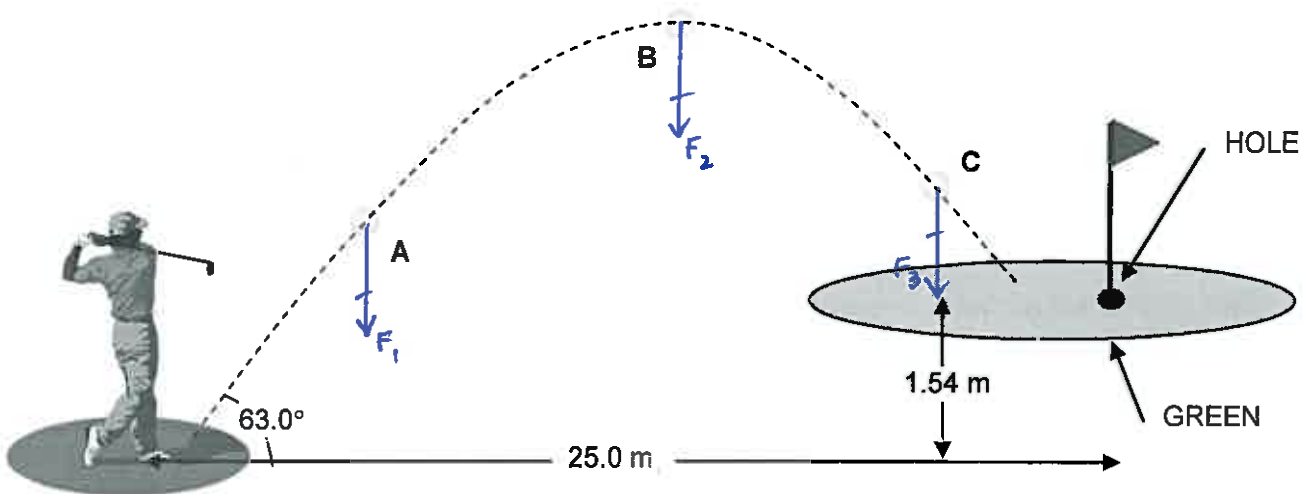
(4 marks)

End of Section A

SECTION B : Problem Solving

Marks Allotted: 90 marks out of 180 (50%). Attempt ALL **6 questions** in this section.
Answers are to be written in the spaces provided.

QB1. [16 Marks]

A golfer is approaching the green on the 18th hole in a round of golf as summarised in below.


The green is elevated 1.54 m above his position and the hole is located 25.0 m horizontally away.

Using a lofted club, he strikes the ball at an angle of 63° to the horizontal such that it is launched at 16.0 m s^{-1} and it flies directly toward the flag (hole).

1a) On the diagram above, carefully indicate with an arrow the relative net force on the ball at points A, B and C, as indicated. (Assume that air resistance is negligible)   (2marks)

1b) Ignoring the effects of air resistance, determine the time of flight of the ball, i.e. how long is the ball in the air during its flight?
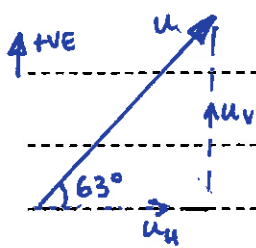
$u_v = V \sin 63° = 16.0 \times \sin 63° = 14.3 \ m\,s^{-1}$

$u_H = V \cos 63° = 16.0 \times \cos 63° = 7.26 \ m\,s^{-1}$

USING $S_v = u_v t + \frac{1}{2} g t^2$

$1.54 = (14.3 \times t) + (\frac{1}{2} (-9.8) t^2)$

FROM QUADRATIC EQUATION : $4.9t^2 - 14.3t + 1.54 = 0$

$t = 0.104 \ s$ OR $2.80 \ s$

$\therefore t = 2.80 \ s$

(4marks)

1c)   Ignoring the effects of air resistance, determine how far from the hole the ball will land.
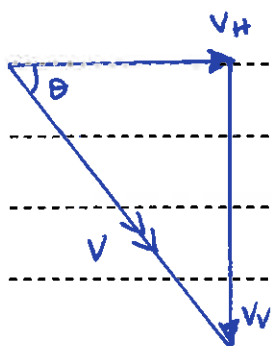
USING $S_H = v_H \cdot t$

$= 7.26 \times 2.80$

$\therefore S_H = 20.3 \, m$ FROM THE TEE

$\therefore S = 25.0 - 20.3$

$= 4.68 \, m$ FROM THE HOLE

(4marks)

1d)   Ignoring the effects of air resistance, determine the velocity of the ball when it hits the green.

V_H REMAINS CONSTANT ie $7.26 \, ms^{-1}$

$V_v^2 = u_v^2 + 2g S_v$

$= (14.3)^2 + (2 \times (-9.8) \times 1.54)$

$\therefore V_v = -13.2 \, ms^{-1}$

$\vec{V} = \vec{V_H} + \vec{V_v}$ $TAN \, \theta = V_v / V_H$

$V^2 = (7.3)^2 + (13.2)^2$ $= \dfrac{13.2}{7.26}$

$\therefore V = 15.0 \, ms^{-1}$ $\therefore \theta = 61.2°$

$\therefore V = 15.0 \, ms^{-1}$ AT $61.2°$ TO THE HORIZONTAL

(4marks)

1e)   Briefly describe how your answers to parts c) and d) would be different if the effects of air resistance are taken into account. (Hint: a simple sketch may assist your answer).

THE TIME OF FLIGHT WOULD BE LESS

THE RANGE WOULD BE LESS

(2marks)

QB2. [14 Marks]

A person bending forward to lift a load "with his back" rather than "with his knees" can be injured by the large forces exerted on the back muscles and vertebrae.

To consider the magnitude of the forces involved in such poor lifting practices, consider the following simplified schematic diagram for a person lifting a 25.0 kg load (L).
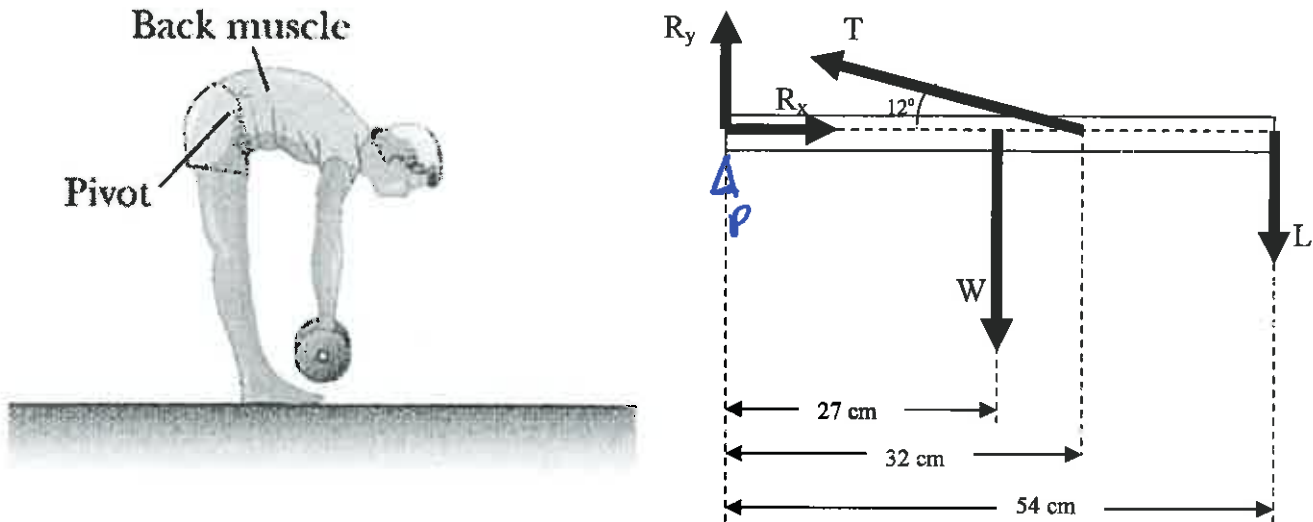
The spine and upper body are represented as a uniform horizontal rod of 41.5 kg (W) pivoted at the base of the spine. The erector spinalis muscle acts at an angle of 12° to maintain the position of the back.

5a) Determine the tension (T) in the erector spinalis muscle while in this position.

TAKING MOMENTS ABOUT P:

$\sum CWM = \sum ACM$

$\therefore (L.r_L) + (W.r_W) = T.r_T \sin\theta$

$\therefore T = \dfrac{(L.r_L) + (W.r_W)}{r_T . \sin 12°}$

$= \dfrac{(25 \times 9.8 \times 0.54) + (41.5 \times 9.8 \times 0.27)}{0.32 \times \sin 12°}$

$= \dfrac{132.3 + 109.8}{0.0665}$

$\therefore T = 3.64 \times 10^3 N$

(4 marks)

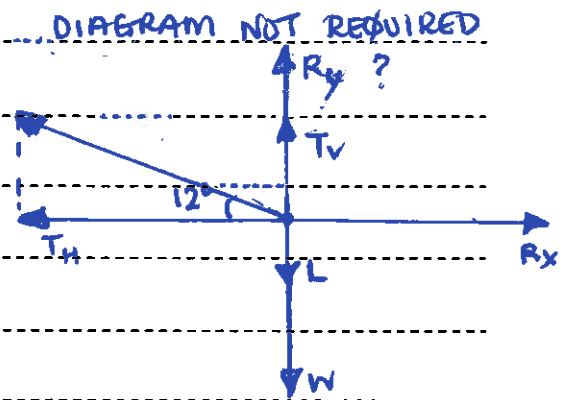5b) Determine the "compressional" force on the spine (R_x) while in this position.

SINCE $R_x = -T_H$

THEN $R_x = T.\cos 12°$

$= 3.64 \times 10^3 . \cos 12°$

$\therefore R_x = 3.56 \times 10^5$ N

(COMPRESSIONAL FORCE ON SPINE)

DIAGRAM NOT REQUIRED

(3 marks)

5c) Determine the magnitude and direction of the vertical component (R_y) of the reaction on the base of the spine while in this position. Comment on this value.

$\sum$ VERTICAL FORCES $= 0$ $\therefore R_y + T_v + L + W = 0$

$\therefore -R_y = T_v + L + W$ WHERE $T_v = T.\sin 12°$

$\therefore -R_y = (3.64 \times 10^3 \times \sin 12°) + (-25 \times 9.8) + (-41.5 \times 9.8)$

$= 757 - 245 - 407$

$\therefore R_y = -105$ N

ie $R_y = 105$ N DOWNWARDS (VERY SMALL COMPARED TO R_x)

(3 marks)

5d) Describe and carefully explain the recommended way to lift heavy objects.

" TRY TO MAINTAIN A STRAIGHT BACK , BEND KNEES AND KEEP THE LOAD AS CLOSE AS POSSIBLE."

• BY KEEPING A STRAIGHT BACK/BEND KNEES, THE LOAD PRODUCES MINIMAL TORQUE SINCE THE DISTANCE TO PIVOT (FEET) IS MINIMAL.

• THE REDUCED TORQUE REQUIRES LESS COUNTER BALANCE/RESTORING TORQUE FROM THE BACK MUSCLES (ALSO CLOSER NOW) AND SO LESS FORCE IS REQUIRED AND LESS TENSION/STRAIN AND LESS RISK OF DAMAGE TO SURROUNDING TISSUE.
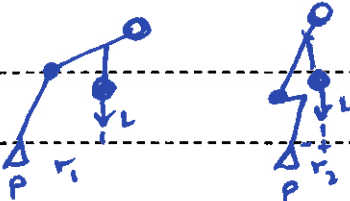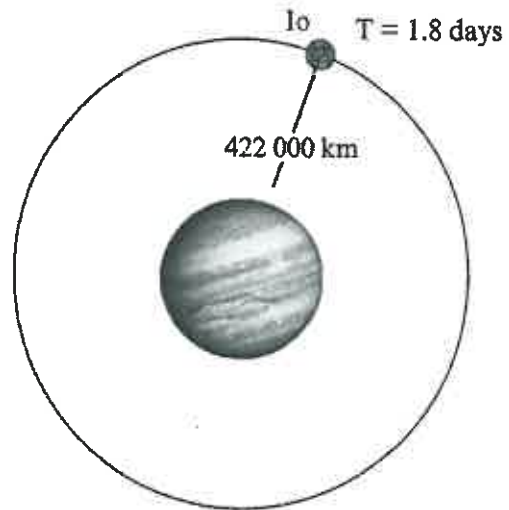

(4 marks)

QB3. [16 Marks]

Io, the fifth of Jupiter's moons was first discovered by Galileo and Marius in 1610.

A spacecraft approaches Io;
when it is 9.00×10^6 m away,
the crew determines that Io has
a radius of 1.80×10^6 m.

The spacecraft eventually lands on Io.

To determine the mass of Io,
a crew member drops a stone
from a rocky ledge of height 19.0 m
and finds that it takes 4.60 s to fall
to the ground.

Io $T = 1.8$ days

422 000 km

3a) Determine the acceleration of the falling stone due to the gravitational attraction of Io "near"
its surface.

$$\text{SINCE } s = \cancel{ut} + \tfrac{1}{2}gt^2$$

$$g = {}^{2s}/_{t^2}$$

$$= \frac{2 \times 19.0}{(4.60)^2}$$

$$\therefore g = 1.8 \text{ ms}^{-2}$$

(3 marks)

3b) Calculate the mass of the moon Io.

$$\text{SINCE } F_W = F_G$$

$$\cancel{m}g = \frac{G \cancel{m} M_I}{r^2}$$

$$\therefore M_I = \frac{g \cdot r^2}{G}$$

$$\therefore M_I = \frac{1.80 \times (1.8 \times 10^6)^2}{6.67 \times 10^{-11}}$$

$$\therefore M_I = 8.74 \times 10^{22} \text{ kg}$$

(3 marks)

3c) Io has an orbital radius of 422 000 km with a period of 1.80 Earth days.
    Determine the mass of Jupiter.

$$\text{SINCE} \quad F_c = F_G \quad \text{AND} \quad v = \frac{2\pi r}{T}$$

$$\text{THEN} \quad \frac{\cancel{M} v^2}{r} = \frac{G \cdot \cancel{M} \cdot M_J}{r^2}$$

$$\therefore \quad m_J = \frac{v^2 r}{G}$$

$$= \frac{4\pi^2 r^3}{T \cdot G}$$

$$= \frac{4\pi^2 \times (422 \times 10^6)^3}{(1.8 \times 24 \times 60 \times 60)^2 \times 6.67 \times 10^{-11}}$$

$$\therefore \quad m_J = 1.84 \times 10^{27} \text{ kg}$$

(4 marks)

3d) The spacecraft needs to remain in a "fixed" obit in order to observe a massive storm on the
    surface of Jupiter. It is known that the period of Jupiter's rotation is equal to 10.2 Earth hours.
    Determine the altitude required for the spacecraft to orbit directly over the same position.

$$\text{FROM ABOVE!} \quad \frac{v^2}{r_o} = \frac{G \cdot M_J}{r^2}$$

$$\therefore \quad r_o = \frac{G \cdot M_J}{v^2}$$

$$= \frac{G \cdot M_J \cdot T^2}{4\pi^2 r^2}$$

$$\therefore \quad r_o^3 = \frac{G \cdot M_J \cdot T^2}{4\pi^2}$$

$$= \frac{6.67 \times 10^{-11} \times 1.84 \times 10^{27} (10.2 \times 60 \times 60)^2}{4\pi^2}$$

$$\therefore \quad r_o^3 = 4.03 \times 10^{24}$$

$$\therefore \quad r_o = 1.61 \times 10^8 \text{ m}$$
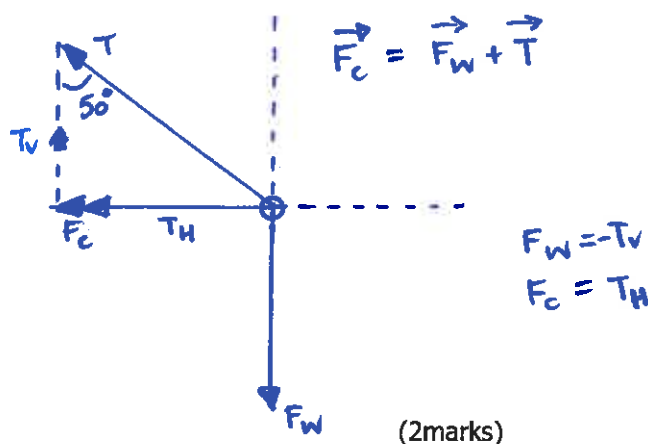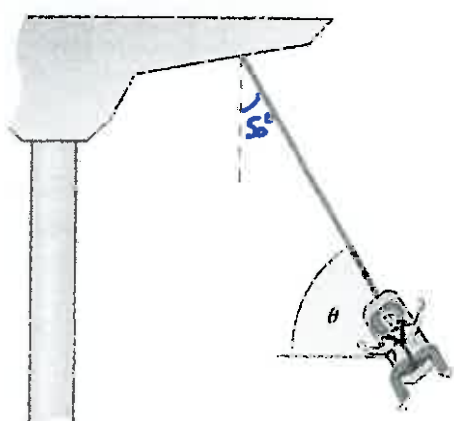
$$\text{SINCE ALTITUDE} = r_o - r_J$$

$$= 1.61 \times 10^8 - 7.00 \times 10^7$$

$$\therefore \text{ALTITUDE} = 9.10 \times 10^7 = 9.10 \times 10^4 \text{ km}$$

(5 marks)

QB4. [13 Marks]

A popular side show ride consists of a carousel with chairs suspended from light chains around its circumference (as seen in the diagram). Assume that the circular path is only horizontal.

(2marks)

Once the carousel is turning at full speed the chain typically makes an angle of 50° with the vertical. You can assume that for this example the combined mass of the chair and passenger is 115 kg and that the radius of revolution is 15.2 m.

4a) In the space provided above, carefully sketch and label a Vector diagram to show all relevant forces acting on the passenger (and the relationship between them).

4b) The passengers "feel" as if they are being pushed outwards. Is this due to a "centrifugal force"? Carefully explain why the chains suspending the chairs are leaning outwards.

NOT DUE TO A CENTRIFUGAL FORCE ! FORCE IS CENTRIPETAL.

THE INERTIA OF THE PASSENGER IS TANGENTIAL TO THE CIRCULAR PATH

AT ALL TIMES. THE CENTRIPETAL FORCE PREVENTS THE PASSENGERS

FROM TRAVELLING IN A STRAIGHT LINE. FROM THEIR (INERTIAL) FRAME OF REFERENCE

THEY "FEEL" PUSHED OUT BUT ARE ACTUALLY PULLED IN.   (2marks)

4c) Determine the tension in the light chain suspending the chair (plus passenger).

$$\text{SINCE } \sin\theta = \frac{opp}{hyp} = \frac{T_V}{T} = \frac{F_W}{T}$$

$$\text{THEN } T = \frac{F_W}{\sin 40°}$$

$$= \frac{115 \times 9.8}{\sin 40°}$$

$$\therefore T = 1.75 \times 10^3 \text{ N}$$

(3marks)

4d)   Estimate the acceleration (in g's) experienced by the passenger.

SINCE $F_c = m.a_c$ AND $F_c = T_H = \dfrac{F_W}{TAN\,\theta}$

THEN $\dfrac{m.g}{TAN\,40°} = m.a_c$

∴ $a_c = \dfrac{1}{TAN\,40°} \times g$

∴ $a_c = 1.19$ g's $\left(11.7\ ms^{-2}\right)$

<div align="right">(3marks)</div>

4e)   Determine the frequency of revolution necessary for this ride. (IN RPM)

SINCE $a_c = \dfrac{v^2}{r}$ AND $v = \dfrac{2\pi r}{T}$ $\left(AND\ f = \dfrac{1}{T}\right)$

THEN $a_c = \dfrac{4\pi^2 r}{T^2} = 4\pi^2 r f^2$

∴ $f^2 = \dfrac{a_c}{4\pi^2 r}$

$= \dfrac{11.7}{4\pi^2 (15.2)}$

∴ $f = 0.139$ Hz (REVOLUTIONS PER SECOND)

∴ $f = 8.38$ rpm

<div align="right">(4marks)</div>

QB5. [15 Marks]

The schematic diagram below shows an electric motor that produces is magnetic field from field coils either side of the armature coil. It is called a series wound motor because the field coils X and Y are wired in series with the armature coil. One advantage of this type of motor is that it works on either AC or DC electrical supplies.

- The armature coil of the motor has 150 turns.

- Side PQ is 5.0 cm long and side QR is 4.0 cm long.

- A 12 V supply provides a current of 0.75 A. and generates a 0.095 T magnetic field across the armature coil.
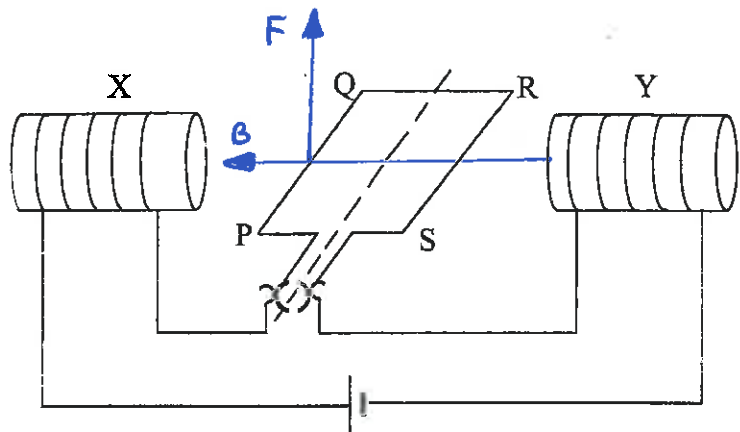
(2 marks)

5a) i) Draw one arrow on the diagram to show the direction of the magnetic field (label B)

   ii) Draw one arrow on the diagram to show the direction of the force of side PQ (label F)
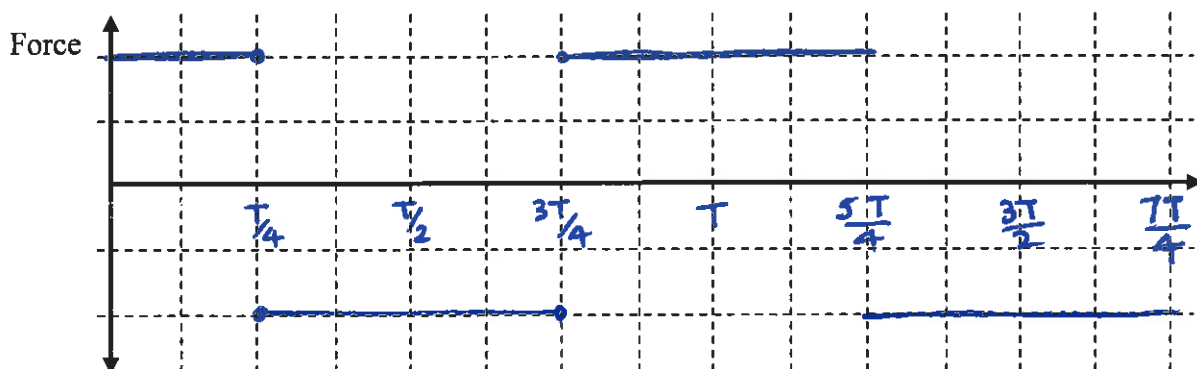
5b) Calculate the force on the side RS of the armature.

USING $F = N.B.I.\ell \sin\theta$

$\qquad = 150 \times (0.095) \times 0.75 \times 5.0 \times 10^{-2}$

$\qquad F_{RS} = 0.53 \text{ N} \quad \text{DOWNWARDS}$

(3 marks)

5c) Sketch the graph of the Force on the side PQ versus time for this simple motor.

(2 marks)

5d) Determine the torque produced when the plane of the armature coil at an angle of 30° to the magnetic field.

USING $\tau = N.B.I.A \cos\theta$ (OR $\tau = 2 \times F.r$)

$\qquad = 150 \times 0.095 \times 0.75 \times (5.0 \times 10^{-2} \times 4.0 \times 10^{-2}) \cos 30°$

$\qquad \therefore \tau = 0.0185 \, N\,m$ CLOCKWISE

ALTERNATIVELY:

$\qquad \tau = 2 \times F \times r \times \cos\theta$

$\qquad = 2 \times 0.53 \times \left(\dfrac{0.04}{2}\right) \times \cos 30°$

$\qquad \therefore \tau = 0.0185 \, N\,m$ CLOCKWISE

(3 marks)

5e) Describe and explain two practical ways in which the motor can be modified to produce a greater torque.

FROM $\tau = N.B.I.A \cos\theta$ • MORE FIELD COILS   • AREA OF ARMATURE

INCREASE N, B, I, A • MORE TURNS ON ARMATURE

$\qquad$ • ADD IRON CORE

(ANY TWO)   • USE CURVED POLES

(2 marks)

5f) Using either or both of the diagrams below as part of your answer, explain why this motor will turn in the same direction, regardless of the type of electrical supply.
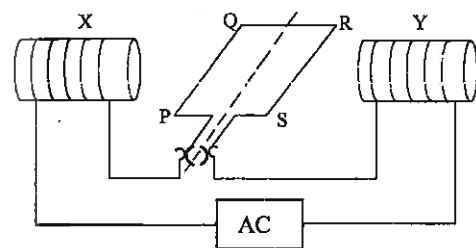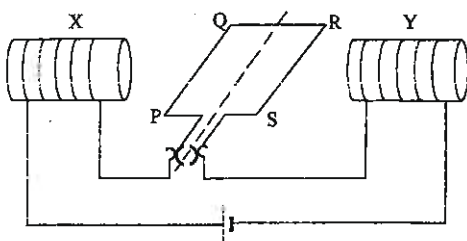
• THE FIELD COILS ARE IN SERIES WITH ARMATURE COILS SO THAT WHEN THE CURRENT REVERSES IN ONE, IT REVERSES IN THE OTHER

• THUS WHEN THE DIRECTION OF B CHANGES, THE DIRECTION OF THE FORCE ON EACH SIDE OF COIL STAYS THE SAME

• THEREFORE THE COILS WILL ALWAYS ROTATE IN THE SAME DIRECTION

(DIAGRAMS SHOULD ILLUSTRATE SOMETHING RELEVANT)

(3 marks)

QB6. [14 Marks]

The diagram represents a simple generator.

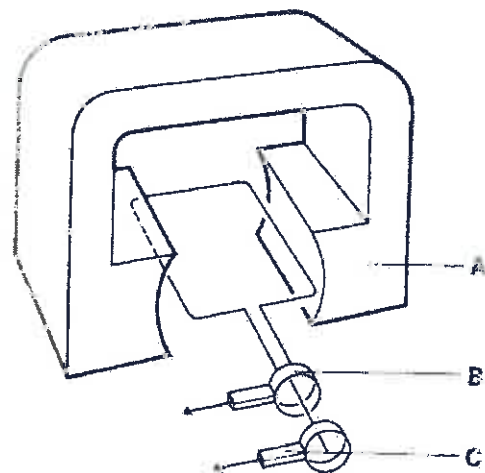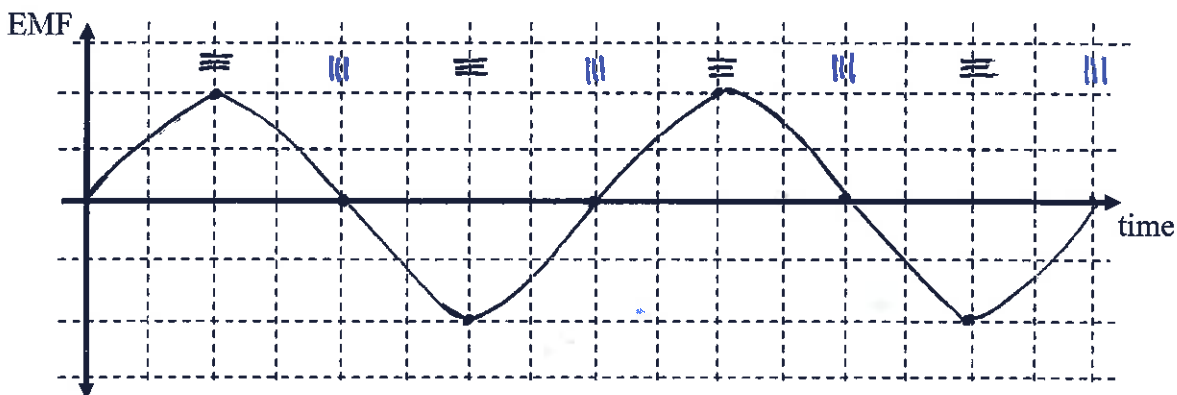6a) Is this an A.C or D.C generator?

A.C GENERATOR
(1 mark)

6b) What is the component labelled B ?

SLIP - RING COMMUTATOR
(1 mark)

6c) Carefully construct a graph of the EMF versus time for two rotations of the coil for this generator commencing in a vertical position.

(3marks)

6d) Carefully describe and explain two practical improvements that can be made to the simple model generator shown that will increase the EMF that is generated.

SINCE $\varepsilon = - \dfrac{NBA}{\Delta t}$ AND $\varepsilon = -4fNBA$

$\varepsilon \propto N$ $\equiv$ MORE TURNS

$\varepsilon \propto B$ $\equiv$ STRONGER MAGNETS , INCLUDE SOFT IRON CORE

$\varepsilon \propto A$ $\equiv$ LARGER AREA OF COIL

$\varepsilon \propto f$ $\equiv$ SPIN COIL FASTER

(2marks)

Now consider an A.C generator consisting of 400 turns of square coil of length 4.50 cm is spinning at 50 Hz. The magnetic field strength of the magnet is 0.50 T and the coil's resistance of 15 Ω.

6d) Determine the **average** induced EMF generated.

USING $\varepsilon_{AV} = -\dfrac{NBA}{\Delta t}$ (WHERE $\Delta t = \frac{T}{4}$ OR $4f$)

THEN $\varepsilon_{AV} = -NBA\,4f$

$= 400 \times 0.50 \times (4.5 \times 10^{-2})^2 \times 4 \times 50$

$\therefore \varepsilon_{AV} = 81$ V

(3 marks)

6e) Determine the **peak** value of the induced EMF generated.

$\varepsilon_{AV} = 81$ V $\equiv$ RMS

$\varepsilon_{MAX} = 81 \times \sqrt{2}$

$\therefore \varepsilon_{PEAK} = 115$ V

(2 marks)

6f) Determine the (average) current generated.

USING $V = IR$

$I_{AV} = \dfrac{\varepsilon_{AV}}{R}$

$= \dfrac{81}{15}$

$\therefore I_{AV} = 5.4$ A

(2 marks)

SECTION C : Comprehension and Interpretation

Marks Allotted: 36 marks out of 180 (20%). Attempt BOTH questions in this section.
Candidates are reminded of the need for clear and concise presentation of answers.
Diagrams, equations and/or numerical results should be included where appropriate.

QC1 [16 marks]

Experimental Analysis and Interpretation

The apparatus shown below is used to investigate the period of rotation of a conical pendulum.

The ball is set revolving and the motor
is adjusted to give a stable orbit with the
pendulum making an angle of 60° with
the vertical.
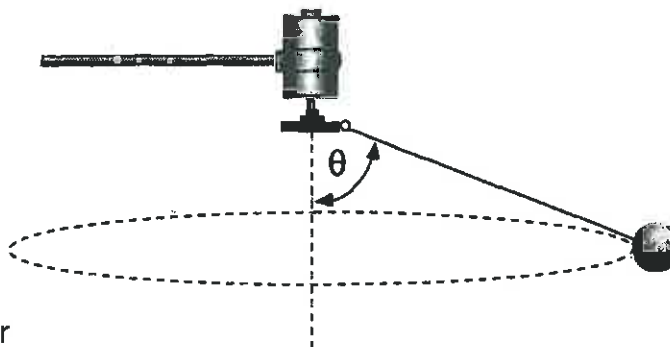
The time taken for the ball to complete
10 revolutions is taken with a stopwatch
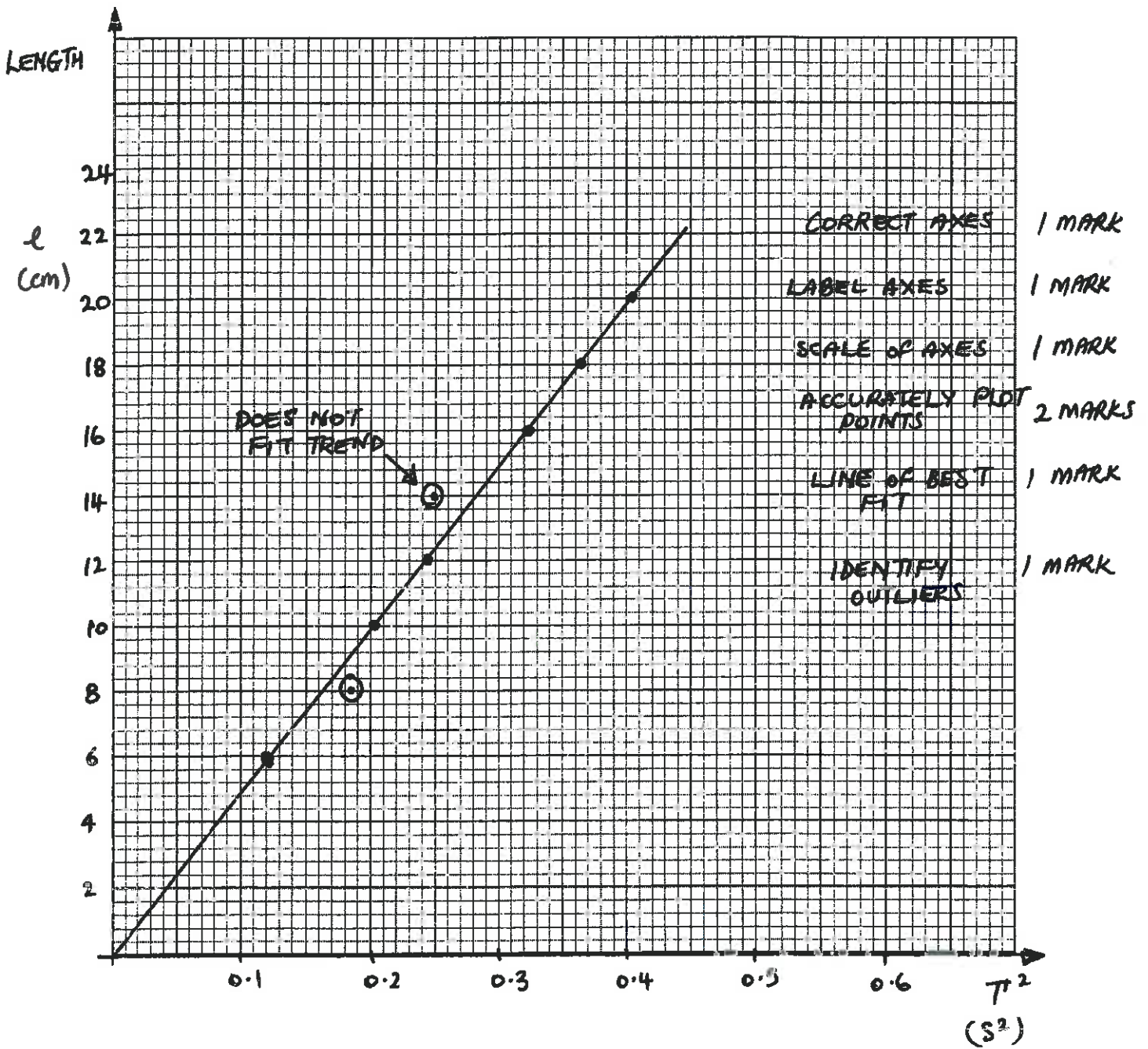and the period of revolution calculated.

This technique is repeated using a number
of strings of successively greater length.

The results are tabulated below.

Length ℓ (cm)	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
Period T (s)	0.348	0.432	0.449	0.492	0.500	0.568	0.602	0.635
T^2 (s^2)	0.121	0.187	0.201	0.242	0.250	0.323	0.362	0.403
↗ ↗ $\quad$ 1 MARK $\quad$ UNITS $\quad$ 1 MARK		1 MARK CORRECT VALUES $\quad$ 1 MARK SIGNIFICANT FIGURES						

When period T is graphed against length of pendulum ℓ, a curve results suggesting a relationship of
the form $\ell = kT^2$ where 'k' is a constant.

1a) You are to plot a second graph - **not** ℓ **against T** - which will test this relationship.
Modify the data as necessary, recording the required values in the vacant row of the table.
Include the heading and units. $\hspace{2cm}$ (4marks)

1b) Plot the points and clearly identify any which do not fit the trend. $\hspace{1cm}$ (7marks)
Draw a line of best fit through the others.

Graph of LENGTH ℓ (cm) versus T^2 (s^2), with marking annotations:

- CORRECT AXES — 1 MARK
- LABEL AXES — 1 MARK
- SCALE of AXES — 1 MARK
- ACCURATELY PLOT POINTS — 2 MARKS
- LINE OF BEST FIT — 1 MARK
- IDENTIFY OUTLIERS — 1 MARK
- DOES NOT FIT TREND
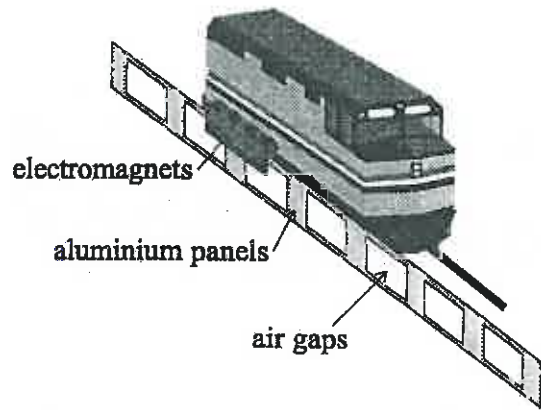
1c) From the gradient of the graph determine the value of the constant 'k' expressed in SI units.

$$K = \text{GRADIENT} = \frac{\Delta \ell}{\Delta T^2}$$ 1 MARK

$$= \frac{(20 - 0)}{(0.403 - 0)}$$ 1 MARK

$$= 49.6 \ cm\,s^{-2}$$ 1 MARK

$$\therefore k = 0.496 \ m\,s^{-2}$$ 1 MARK SI UNITS

1 MARK SIG. FIGS

(5marks)

Paragraph 5

Test models have, so far, given encouraging results but fullsoized operational trains pose some challenges to designers. Firstly, passengers would need to be shielded from the large magnetic fields of approximately two tesla. Without shielding passengers with metal shoes would stick to the floor! The shields can be built from iron which essentiallycontain the magnetic fields. Secondly, the noise made by switching magnets on and off will create acoustic waves in the middle range of human human hearing making soundproofing essential. Finally, the cooling of the magnets would need to be addressed. At this stage water is favoured. However, the fast moving air created by the locomotive may be utilised for this purpose.

Questions

1. Paragraph 3 states *"a conductor is made to move through a changing magnetic field and a magnetic force is created that pushes the original magnet away"*. Carefully explain how this may be achieved.

- LENZ'S LAW MAY BE USED TO EXPLAIN THE FORCE. (BUT MORE DETAIL REQUIRED)

- WHEN A CONDUCTOR MOVES THROUGH A CHANGING MAGNETIC FIELD, A CURRENT (INDUCED) WILL FLOW IN SUCH A WAY TO CREATE A MAGNETIC FIELD THAT OPPOSES THE CHANGE IN FLUX INDUCING THE CURRENT.

- THIS RESULTS IN A FORCE PUSHING THE CONDUCTOR AWAY.

- THE FORCE IS DERIVED FROM THE INTERACTION OF THE TWO FIELDS.

(4marks)

2. Why would the force propelling the train be reversed if the electromagnets were switched on before the centre of the aluminium plates had passed.   (paragraph 4)

• AS THE ALUMINIUM ENTERS THE FIELD IT WILL EXPERIENCE AN OPPOSING FORCE (IN ACCORDANCE WITH LENZ'S LAW), AND THIS WILL RESULT IN THE RETARDING OF THE ALUMINUM INTO THE FIELD.

• THE CHANGING FIELD => EMF => CURRENT (INDUCED) => MAGNETIC FIELD (OPPOSING) => FORCE

• FORCE OF REPULSION BACKWARDS RATHER THAN FORWARDS
            (ARRESTING)   (PROPELLING)

(4marks)

3. Carefully explain why people would "*stick to the floor*" if they were not shielded from the magnetic fields.(paragraph 5)

THE CHANGING MAGNETIC FIELDS DRIVING THE TRAIN WILL INDUCE A MAGNETIC FIELD IN STEEL SHOES (CONDUCTORS)
THEIR SHOES, DEVELOPING MAGNETIC FIELDS WILL RESULT IN ATTRACTING MAGNETIC MATERIALS (SUCH AS THE FLOOR)

EMF => EDDY CURRENTS => MAGNETIC FIELDS => FORCE

(ALIGNMENT OF DOMAINS IN METAL OBJECTS => RE-INFORCE FIELD => FORCE

(4marks)

4. Why does iron "*contain*" the magnetic fields enabling the passengers to be shielded from the magnetic fields? (paragraph 5)

SINCE IT IS A MAGNETIC MATERIAL, IRON HAS A HIGH PERMEABILITY. IT WILL CAUSE MAGNETIC FIELDS TO BE ATTRACTED TO IT AND INTENSIFY THE STRENGTH OF THE FIELD WITHIN IT. THE SURROUNDING AREAS OF AIR WILL HAVE A GREATLY REDUCED (PERMEABILITY) FIELD STRENGTH AS A RESULT.

AIR ONLY
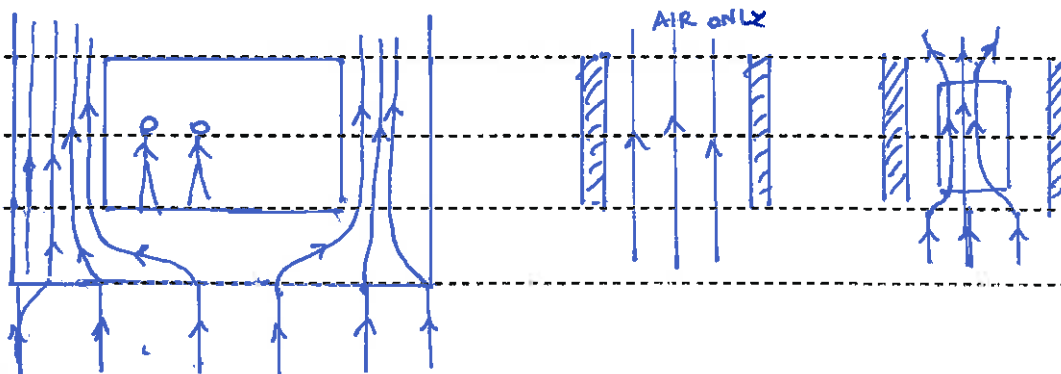
(4marks)

5. Calculate the current that would need to be induced in an aluminium conductor of resistance 0.15 Ω and length of 0.65 m if it travels at 500 kmh⁻¹ perpendicular to a 2.0 T field.

$$EMF = B \cdot v \cdot \ell = I \cdot R$$

$$\therefore I = \frac{B \cdot v \cdot \ell}{R}$$

$$= \frac{2.0 \times \frac{500\,000}{60 \times 60} \times 0.65}{0.15}$$

$$\therefore I = 1.20 \times 10^3 \, A \qquad (VERY \; HIGH\,!)$$

(4marks)