



**ALL SAINTS'
COLLEGE**

WACE PHYSICS Stage 3
Semester 2 Examination, 2010

Question/Answer Booklet

Student Number: In figures

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In words

SOLUTIONS

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Formulae and Constants Sheet

To be provided by the candidate

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters, mathaid

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course

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.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	14	14	54	54	30
Section Two: Problem-solving	8	8	90	90	50
Section Three: Comprehension	2	2	36	36	20
				180	100

Raw exam score: _____

Marks removed for inappropriate significant figures = _____

Marks removed for inappropriate units = _____

Total = _____

_____ %

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010*. Sitting this examination implies that you agree to abide by these rules.
2. Write answers in this Question/Answer Booklet.
3. You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.
4. Working or reasoning should be clearly shown when calculating or estimating answers. It is suggested that answers to calculations are given to 3 significant figures except when you are required to estimate. For estimation questions an appropriate number of significant figures must be stated.
5. Spare pages are included at the end of section 2 and section 3. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

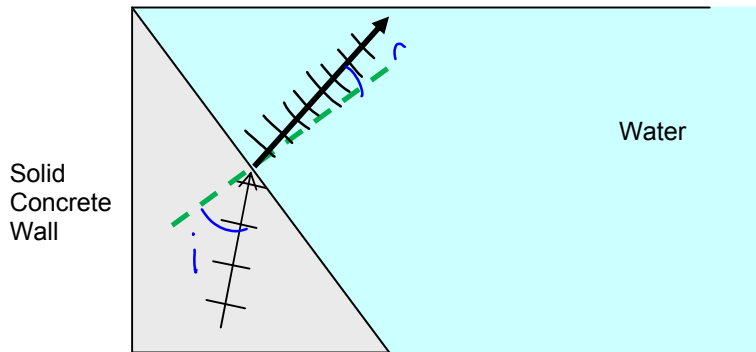
Section One: Short response

30% (54 Marks)

This section has **14** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 54 minutes.

Question 1

A sound wave travels through a solid concrete wall of a dam to meet a boundary with water.

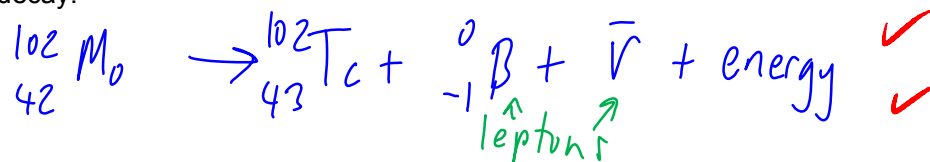


- a) Draw a possible path of the sound wave as it refracts into water. Indicate appropriate angles. (1)
towards normal 1/2 normal indicated 1/2
- b) The wave fronts in the solid concrete wall are shown on the diagram. Indicate the general pattern of wave fronts when the sound wave travels in the water. (1)
closer together
- c) Is it possible for total internal reflection to occur at this boundary? Explain briefly. (1)
No, can only happen when attempting to refract into a faster medium

Question 2

Molybdenum-102 undergoes **beta negative decay**.

- a. Write a balanced nuclear equation to show this. You must identify the leptons formed as part of this decay. (2)



- b. Explain, with reference to Protons and Neutrons within the nucleus, how the leptons are formed and emitted from the nucleus in this decay process. You must refer to the quarks that make up the hadrons involved. (2)

neutron (udd) decays to proton (uud) within the molybdenum nucleus.

down quark → up quark + W boson

W boson then decays to ${}_{-1}^0\beta + \bar{\nu}$

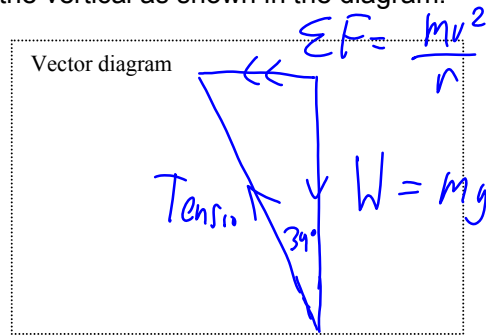
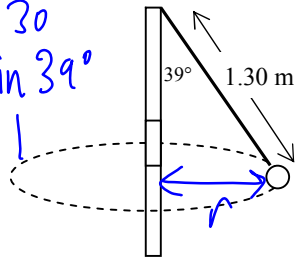
Question 3

During a game of totem tennis a ball of mass 60.0 g swings freely in a horizontal circular path. The string is 1.30 m long and is at an angle of 39° to the vertical as shown in the diagram.

$$\sin 39^\circ = \frac{r}{1.30}$$

$$r = 1.30 \times \sin 39^\circ$$

$$r = 0.8181$$



- a) Draw a vector diagram showing the forces acting on the ball and the sum of those forces in the space indicated above. (1)

- b) Calculate the net force (ΣF) acting on the ball (2)

$$\tan 39^\circ = \frac{\text{opp}}{\text{adj}} = \frac{\Sigma F}{mg}$$

$$\Sigma F = m \cdot g \cdot \tan 39^\circ$$

$$\Sigma F = 0.06 \times 9.8 \times \tan 39^\circ = 0.476 \text{ N}$$

- c) Demonstrate by calculation that the ball takes 2.02 seconds to make 1 revolution (3)

$$\tan 39^\circ = \frac{mv^2}{r} \times \frac{1}{mg} = \frac{v^2}{gr}$$

$$r = 0.8181 \text{ m}$$

$$v = \sqrt{g \cdot r \cdot \tan \theta}$$

$$v = \sqrt{9.8 \times 0.8181 \times \tan 39^\circ}$$

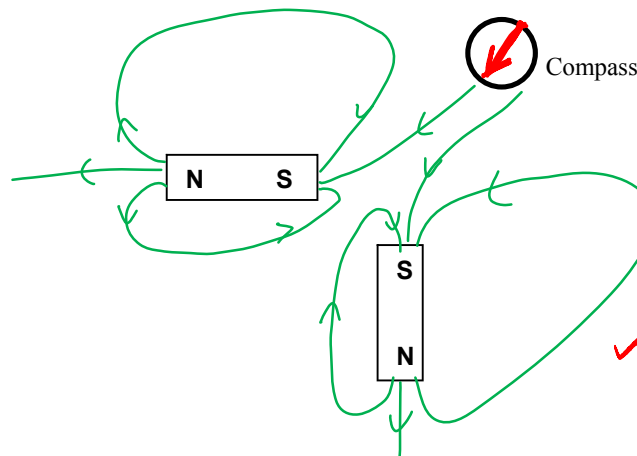
$$v = 2.548$$

$$v = \frac{2\pi r}{T}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi \times 0.8181}{2.548} = 2.02 \text{ s}$$

Question 4

Two identical magnets are fixed in position on a flat bench. A compass is placed near the magnets.

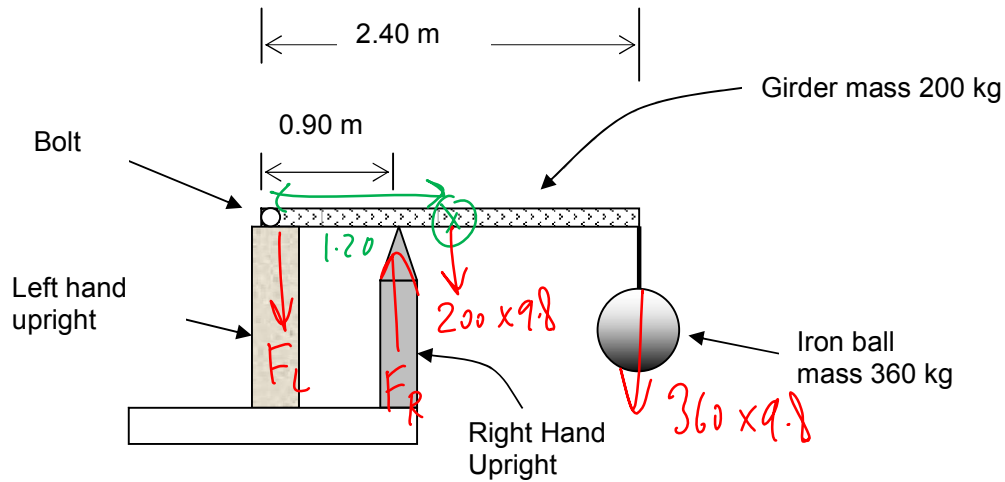


- a) Sketch the magnetic field in the region around the magnets. (1)

- b) Indicate the direction that the compass will point by placing an arrow in the circle. (1)

Question 5

An iron ball of mass 360 kg is suspended from the end of a rigid steel girder. The girder has a mass of 200 kg, a length of 2.40 m. It is securely attached to 2 uprights each of mass 200 kg. The reaction force from the Right Hand Upright acts in the vertical at 90.0 cm from the bolt.



Calculate the forces acting on the girder from both the left and right uprights and state whether each upright is in compression or tension.

Take moments about the bolt

(5)

$$\sum a_{\text{down}} = \sum c_{\text{up}}$$

$$0.9 \times F_R = (1.20 \times 200 \times 9.8) + (2.40 \times 360 \times 9.8)$$

$$F_R = 12021.333 = 1.20 \times 10^4 \text{ N up (Compression)}$$

$$\sum F_{\text{down}} = \sum F_{\text{up}}$$

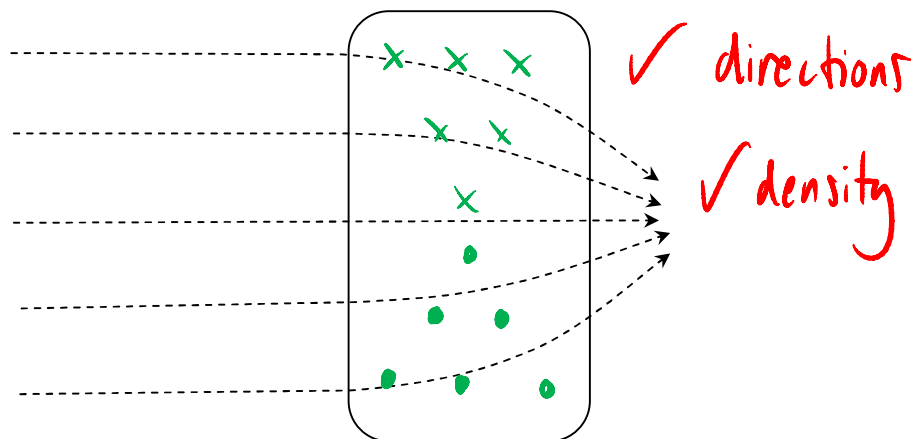
$$F_L + (200 \times 9.8) + (360 \times 9.8) = 12021.333$$

$$F_L = 6533.33 = 6.53 \times 10^3 \text{ N down (tension)}$$

Question 6

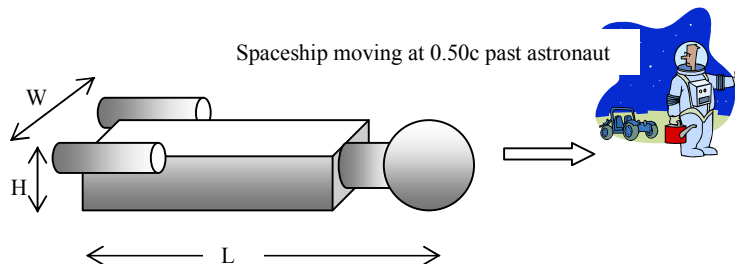
The diagram shows the path of electrons as they are deflected in a region of non uniform magnetic flux within the rectangle. Use magnetic field symbols to indicate the density and direction of the field that will cause these deflection paths. Place symbols in the rectangle.

(2)



Question 7

A spaceship travelling at 50% of the speed of light flies past an astronaut. The astronaut records its dimensions as L , W and H . A pilot on the spaceship records the dimensions as L_0 , W_0 and H_0



- (a) Which of the following options best describes the dimensions observed by the astronaut outside the spaceship compared to the measurements made by the passenger? (1)

- A. $L < L_0$, $W < W_0$, $H = H_0$
- B. $L > L_0$, $W = W_0$, $H = H_0$
- C. $L < L_0$, $W = W_0$, $H = H_0$**
- D. $L < L_0$, $W < W_0$, $H < H_0$

Answer C ✓

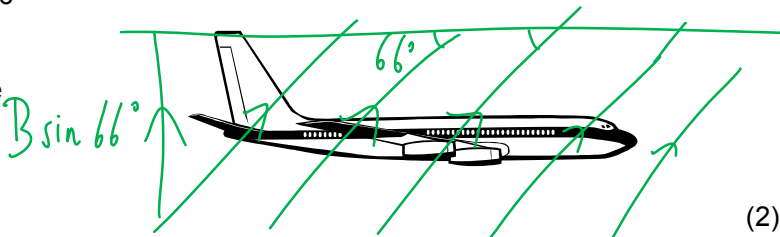
- (b) Explain your answer. (2)

According to Einstein's special relativity length contracts in the dimension of travel other dimensions not affected. ✓

Question 8

A jet airliner is flying due North above Perth where the Earth's magnetic field has a flux density of 4.90×10^{-5} T at an angle of dip of 66°

- a) Sketch the alignment of the Earth's field lines relative to the jet airliner on the diagram, indicating any angles and direction. (2)



- b) Calculate the emf induced across the 60.0 metre wingspan if the jet has a speed of 900 km h^{-1} . (3)

$$V = \frac{900}{3.6} = 250 \text{ m/s} \quad B_v = B \cdot \sin 66^\circ = 4.90 \times 10^{-5} \times \sin 66^\circ \quad \checkmark$$

$$\text{emf} = B_v \cdot l \cdot v = 4.90 \times \sin 66^\circ \times 60 \times 250 \quad \checkmark$$

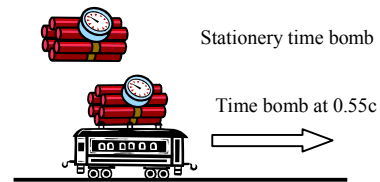
$$\text{emf} = 0.671 \text{ V} \quad \checkmark$$

- c) Would this source of emf be suitable to power the electrical systems on the jet? Explain. (1)

No, too low. Probable requirements 12V - 250V ✓

Question 9

A simple time bomb consists of an accurate timer clock that can detonate sticks of dynamite. A physicist and her assistants are able to observe a stationary time bomb and an identical time bomb on a model train that moves along a track at a constant 55% of the speed of light. As the train passes the stationary time bomb both clocks are triggered to start a short countdown.



a) From the frame of reference of the physics team explain which time bomb detonates first.

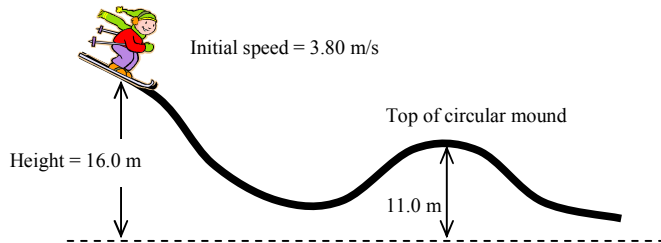
Stationary bomb. According to Einstein's special relativity time progresses at a slower rate on moving object. ✓ (2)

b) An imaginary observer on the moving train disagrees with the Physics team. Explain the order of explosions that the imaginary observer sees and then explain who is correct and why.

#1 train bomb #2 stationary bomb. ✓ (2)
 In frame of reference of train, the other bomb is moving and \therefore its time progresses more slowly.
 Both are correct. (example of simultaneity) ✓

Question 10

A 70 kg skier is on a frictionless slope. At a height of 16.0 m he has a speed of 3.80 m s^{-1} . He descends and then follows a circular path of radius 11.0 m whilst going over a mound.



Use the principle of conservation of mechanical energy to determine the **momentum** of the skier at the top of the circular mound.

$$\begin{aligned}
 TME_{\text{Top}} &= m \cdot g \cdot h_1 + \frac{1}{2} m v^2 = (70 \times 9.8 \times 16) + \left(\frac{1}{2} 70 \times 3.8^2\right) \\
 TME_{\text{Top}} &= 11481.4 \text{ J} = TME_{\text{mound}} \quad \checkmark \\
 11481.4 &= m \cdot g \cdot h_2 + \frac{1}{2} m v^2 = (70 \times 9.8 \times 11) + \left(\frac{1}{2} 70 \cdot v^2\right) \quad \checkmark \\
 \frac{1}{2} 70 \times v^2 &= 3935.4 \quad \checkmark \quad v = 10.6 \text{ m/s} \quad \checkmark \\
 \text{momentum } p &= m \cdot v = 70 \times 10.6 = 742 \text{ kg m s}^{-1} \text{ right} \quad \checkmark
 \end{aligned}$$

Question 11

An alpha particle enters a vacuum chamber at a speed of $1.20 \times 10^5 \text{ m s}^{-1}$. A uniform magnetic flux density of 54 mT is present as shown. 2 parallel charged plates are also present with a potential difference of 450 V across a gap of 6.00 cm. Determine the approximate path the alpha particle will take. You must refer to calculations to show how you arrived at your answer.

$$E = \frac{V_a}{a} = \frac{450}{0.06} = 7500 \text{ V m}^{-1}$$

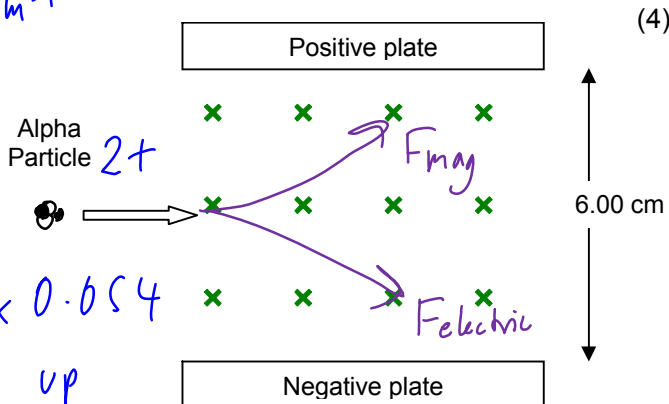
$$F_{\text{mag}} = q \cdot v \cdot B$$

$$F_{\text{mag}} = 2 \times 1.60 \times 10^{-19} \times 1.20 \times 10^5 \times 0.054$$

$$F_{\text{mag}} = 2.0736 \times 10^{-15} \text{ N up}$$

$$F_{\text{ele}} = E \times q = 7500 \times 3.20 \times 10^{-19} = 2.40 \times 10^{-15} \text{ N down}$$

$F_{\text{ele}} > F_{\text{mag}} \therefore$ alpha particle curves down
 $\left(V_{\text{filter}} = \frac{E}{B} = \frac{7500}{0.054} = 1.39 \times 10^5 \text{ m/s}, V < V_{\text{filter}} \right)$



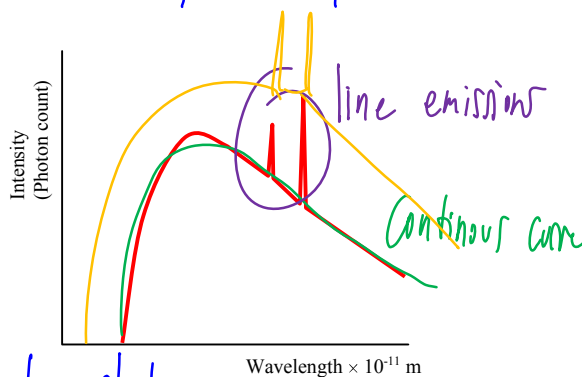
Question 12

The graph shows the X-ray spectrum from a machine with a supply voltage of 31.0 kV

- a) Identify the continuous portion of the spectrum from the graph and briefly explain how it is formed.

As high speed bombarding electrons are slowed down KE transforms to photons in a continuous range.

Many electrons are reduced in KE by varying amounts



- b) Identify the line emission portion of the spectrum and explain briefly how it is formed.

inner shell atomic electrons removed by collisions, Holes filled as atomic electrons from higher shells transition down \Rightarrow specific photon energies released

- c) Sketch on the graph, the general shape of the X-ray spectrum if the supply voltage is increased to 48.0 kV

higher, same spikes, λ_{min} lower

Question 13

Quark	Charge
Up	$+\frac{2}{3}e$
Down	$-\frac{1}{3}e$
Charmed	$+\frac{2}{3}e$
Strange	$-\frac{1}{3}e$
Top	$+\frac{2}{3}e$
Bottom	$-\frac{1}{3}e$

Hadron	Quarks
Proton	uud
Neutron	udd
Kaon-minus	$s\bar{u}$
Pi-plus (π^+)	$u\bar{d}$
Sigma-plus	uus
Lambda-zero	uds
Charmed Omega	ssc

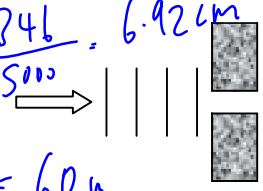
- a) Determine the charge (C) of the Charmed Omega: $5 + 5 + c = -\frac{1}{2} + -\frac{1}{2} + \frac{2}{3} = 0$ (1)
- b) Determine the charge (C) of the Pi-plus: $u + \bar{d} = \frac{2}{3} + \frac{1}{3} = e = +1.60 \times 10^{-19} C$ (1)
- c) Identify the Mesons from the information above: Kaon-minus, Pi-plus (1)
- d) Briefly explain the relevance of the **Colour Charge** of quarks in the composition of hadrons (1)
- all quarks have a colour charge red, blue or green
 all antiquarks have a colour charge cyan, yellow, magenta
 quarks combine such that colours add to give white
 in terms of colour addition model.

Question 14

A source of waves can be directed through air towards a 37 mm gap between 2 lead (Pb) blocks. The wave source can be any of the following four types.

- A. Monochromatic green light.
- B. Sound waves at a frequency of 5.0 kHz
- C. Radio at a frequency of 5.0 MHz
- D. X rays

$\lambda = \frac{v}{f} = \frac{346}{5000} = 6.92 \text{ cm}$
 $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5 \times 10^6} = 60 \text{ m}$



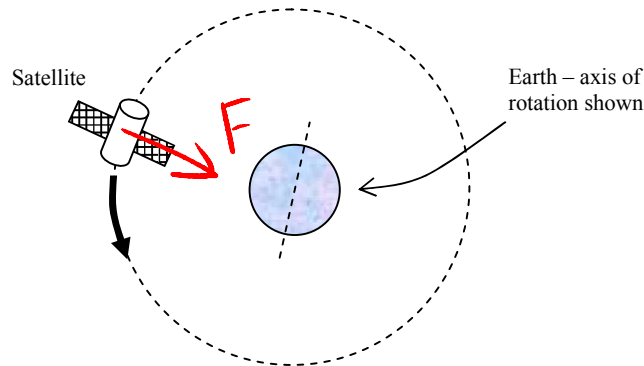
- a) List them in order from "most diffraction" to "least diffraction". (e.g. A D B C): C B A D (1)
- b) Explain briefly why you have selected this order. (1)
- longer wavelengths diffract more

End of Section One

This section has **eight (8)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 1 (13 marks)

A satellite provides information about receding glaciers at the Northern and Southern hemispheres on the Earth's surface. It must be able to view the Earth's entire surface over the course of a day. It has a mass of 1395 kg and makes one orbit every 4 hours.



- a) Explain why this orbit is suitable for the task of the satellite and also explain why a geostationary satellite would not be suitable.

Satellite sweeps North to South 6 times per day therefore can view entire surface including poles. ✓ (2)
 Geostationary fixed in one position over equator ✓
 so cannot view poles. ✓

- b) On the diagram above place **labelled** arrow(s) to show the direction of the force(s) acting on the satellite as it orbits the Earth. ✓ (1)

- c) Using equations on your formula and constant sheet derive the equation that expresses Kepler's third law, which states that r^3 is proportional to T^2 . (2)

$$\begin{aligned} \text{field strength} &= \text{centripetal acceleration} \\ g &= \frac{GM}{r^2} = \frac{v^2}{r} \quad \left(v = \frac{2\pi r}{T} \right) \quad \checkmark \\ \frac{GM}{r^2} &= \frac{4\pi^2 r}{T^2} \\ r^3 &= \frac{GM}{4\pi^2} \cdot T^2 \quad \checkmark \end{aligned}$$

d) Calculate the **altitude** that this satellite is orbiting above the Earth. ✓

$$T = 4 \times 60 \times 60 = 14,400 \text{ s} \quad M_e = 5.98 \times 10^{24} \text{ kg} \quad (4)$$

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

$$r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{4 \cdot \pi^2} \cdot (14,400)^2$$

$$r^3 = 2.095 \times 10^{21} \quad r = 12,795,620.25 \text{ m}$$

$$\text{alt} = r - r_e = 1.28 \times 10^7 - 6.37 \times 10^6$$

$$\text{altitude} = 6.43 \times 10^6 \text{ m}$$

The moon is a natural satellite that orbits the Earth. (Assume a circular orbit for this question)

e) Calculate the orbital speed of the Moon as it orbits the Earth.

$$\frac{v^2}{r} = \frac{GM}{r^2} \quad v = \sqrt{\frac{GM}{r}} \quad M_E = 5.98 \times 10^{24} \quad (3)$$

$$r = 3.84 \times 10^8$$

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{3.84 \times 10^8}}$$

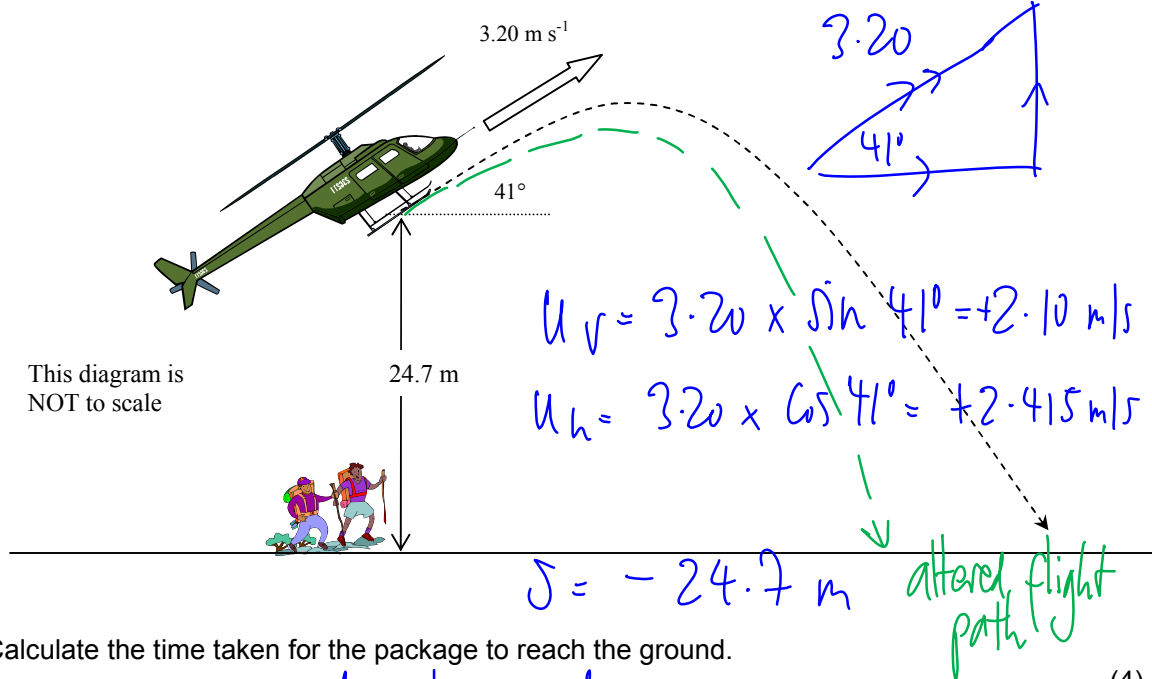
$$v = 1.02 \times 10^3 \text{ m s}^{-1}$$

f) If the moon was 65% of its current mass, explain how its orbital speed would be affected if it remained at the same distance from Earth.

Equation $v = \sqrt{\frac{GM}{r}}$ shows that only mass of the host body (Earth) affects speed. ✓
 \therefore Not affected. (1)

Question 2 (13 marks)

A helicopter is required to drop emergency equipment to a group of walkers stranded in rugged bushland. A package is released from the helicopter 24.7 m directly above the group. The helicopter is moving with a velocity of 3.20 m s^{-1} at an angle of 41° above the horizontal when the package is released. Ignore air resistance for calculations.



- a) Calculate the time taken for the package to reach the ground.

speed on arrival at ground

$$v^2 = u^2 + 2 \cdot a \cdot s$$

$$v^2 = 2.10^2 + (19.6 \times 24.7)$$

$$v^2 = 488.53$$

$$v = -22.1 \text{ m/s (down)}$$

$$v = u + at$$

$$t = \frac{v - u}{a} = \frac{-22.1 - 2.10}{-9.8}$$

$$t = 2.47 \text{ s}$$

alternatively $s = ut + \frac{1}{2}at^2$

$$-24.7 = 2.10t - 4.9t^2$$

$$-4.9t^2 + 2.10t + 24.7 = 0$$

→ general solution.

- b) Calculate the horizontal distance between the walkers and the place where the package lands. (3)

$$u_h = 3.20 \times \cos 41^\circ = 2.415 \text{ m/s} \quad \checkmark$$

$$u_h = 2.415 \quad t_f = 2.47 \text{ s} \quad \checkmark$$

$$s_{\text{range}} = u_h \times t_f = 2.415 \times 2.47 = 5.97 \text{ m} \quad \checkmark$$

- c) The helicopter continues in a straight line 41° above the horizontal at a constant 3.20 m s^{-1} . Calculate the distance between the helicopter and the package at the instant the package reaches the ground. (3)

Concept, horizontal component of velocity for helicopter and package are identical

\therefore helicopter stays above package as it falls

$$u_v \text{ helicopter} = 2.10 \text{ m/s constant}$$

$$\text{Change in height helicopter} = u_{\text{heli}} \times t_f = 2.10 \times 2.47 = 5.19 \text{ m up}$$

$$\begin{aligned} \text{distance b/w package + helicopter} &= 5.19 \text{ m} + 24.7 \text{ m} \\ &= 29.9 \text{ m} \quad (30.0 \text{ m}) \end{aligned}$$

If air resistance is taken into account then the flight path is altered.

- d) Sketch the altered flight path onto the diagram. *as above* \checkmark (1)

- e) Consider the time of flight when air resistance is taken into account, do you think it will be longer or shorter? Discuss the factors that affect this. (2)

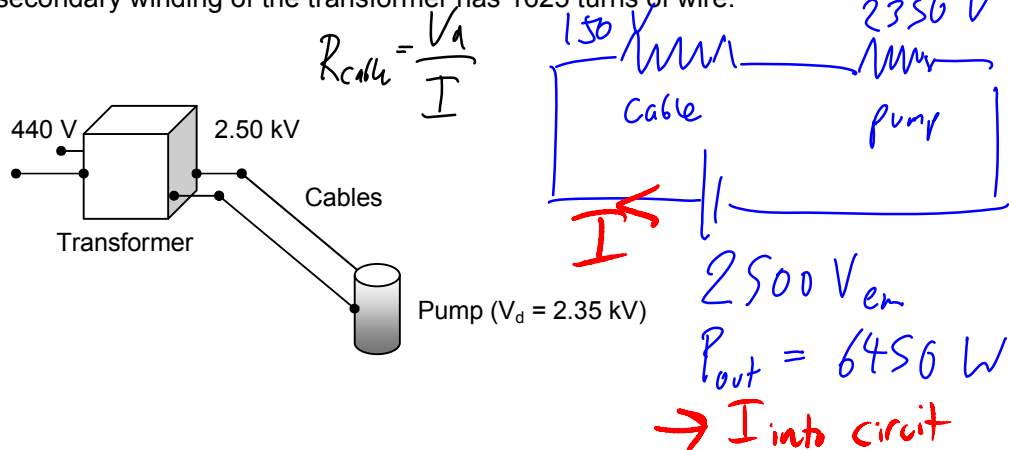
time up = shorter due to air resistance \checkmark

time down = increased as air resistance holds package up

(like a parachute)
larger component of motion travelling down \checkmark
 \therefore probably longer time

Question 3 (12 marks)

A mining company has a water pump with an operating voltage in the range 2.25 kV-2.50 kV. There is only a 440 V_{RMS} supply available. They use a transformer to step up the output emf to 2.50 kV_{RMS}. The secondary winding of the transformer has 1625 turns of wire.



- a) Calculate the number of turns required on the primary winding of the transformer. (2)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \frac{2,500}{440} = \frac{1625}{N_p}$$

$$N_p = \frac{1625 \times 440}{2500} = \underline{286}$$

The transformer has an electrical power output of 6.45 kW. The underground pump is connected by 1.40 km of cables to the surface. The potential difference across the pump is 2.35 kV.

- b) Calculate the total resistance of the cables. (3)

$$P_{out} = V_{out} \times I_{out} \quad I_{out} = \frac{P_{out}}{V_{out}} = \frac{6450}{2500}$$

$$I_{out} = 2.58 \text{ A} \quad \checkmark$$

$$V_{cable} = 2500 - 2350$$

$$V_{cable} = 150 \text{ V} \quad \checkmark$$

$$R_{cable} = \frac{V_{cable}}{I_{in}} = \frac{150}{2.58} = \underline{58.1 \Omega} \quad \checkmark$$

c) Calculate how much electrical power is transformed to heat in the cables.

(2)

$$P_{\text{cable}} = I^2 R = 2.58^2 \times 58.1$$

$$P_{\text{cable}} = 387 \text{ W}$$

alternative

$$P = \frac{V_n^2}{R} = \frac{150^2}{58.1} = 387 \text{ W}$$

$$P = V_n \times I = 150 \times 2.58$$

$$P = 387 \text{ W}$$

d) The transformer is 94.5% efficient. Calculate the current on the primary side of the transformer.

(3)

$$P_{\text{out}} = 6450 \text{ W}$$

$$\frac{P_{\text{out}}}{P_{\text{in}}} = 0.945$$

$$P_{\text{in}} = \frac{6450}{0.945} = 6825.39 \text{ W}$$

$$P_{\text{in}} = I_{\text{in}} \times V_d$$

$$6825.39 = I_{\text{in}} \times 440$$

$$I_{\text{in}} = \frac{6825.39}{440} = 15.5 \text{ A}$$

e) Explain why it is more efficient to transfer electricity to the pump at a high voltage of 2.50 kV rather than 440 V.

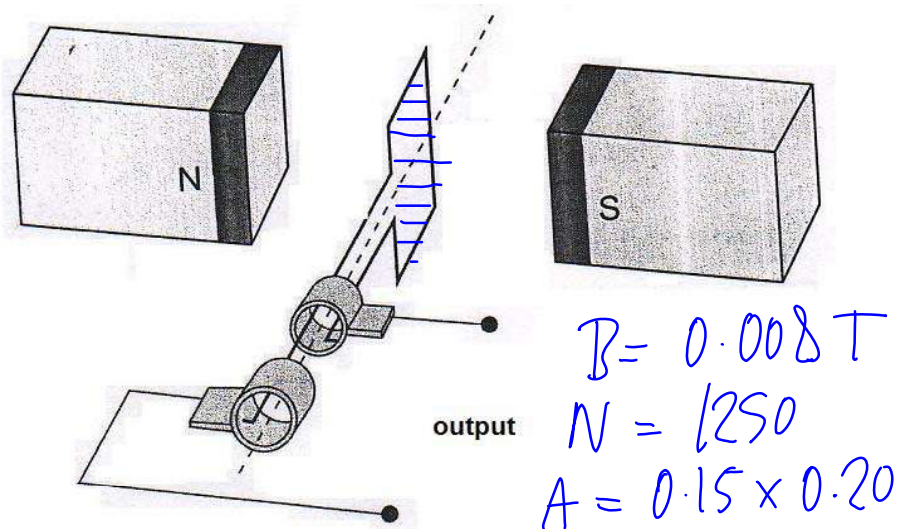
(2)

High output voltage means less current for a given power. $P_{\text{out}} = V \times I$

If R_{cable} fixed and $P_{\text{loss}} = I^2 R$
the low I means less power \rightarrow heat

Question 4 (13 marks)

The figure below shows an AC generator consisting of a rectangular coil which has dimensions of $15.0\text{ cm} \times 20.0\text{ cm}$ and 1250 turns of copper wire. The magnetic flux density between the poles is 8.00 mT . The coil is turned at a uniform rate.



- a) Calculate the maximum flux enclosed by the coil.

(2)

$$\Phi = B \cdot A$$
$$\Phi = 0.008 \times (0.15 \times 0.20) \quad \checkmark$$
$$\Phi = 2.40 \times 10^{-4}\text{ Wb} \quad \checkmark$$

- b) Referring to Lenz's law, explain how induced emf is achieved from such a generator and why the output is a sine or cosine shape rather than being constant.

(3)

As flux within coil changes as coil rotates, then by Lenz's law emf is induced that will establish a current and therefore magnetic field that will oppose the change. Rate of change of flux is not linear, rather it follows a sine/cosine shape.

- c) The coil is rotated at 900 rpm. Calculate the magnitude of the average induced emf in the coil using the 1/4 turn method. (3)

$$emf = -N \frac{\Delta \Phi}{\Delta t} = -\frac{NBA}{T_{1/4}} \quad (3)$$

$N = 1250$
 $B = 0.008$ ✓
 $A = 0.03$
 $f = \frac{900}{60} = 15 \text{ Hz}$
 $T = \frac{1}{f} = \frac{1}{15}$ $T_{1/4} = \frac{1}{4 \times 15} = 0.01667 \text{ s}$

$$emf = \frac{1250 \times 0.008 \times 0.03}{0.01667} \quad \checkmark$$

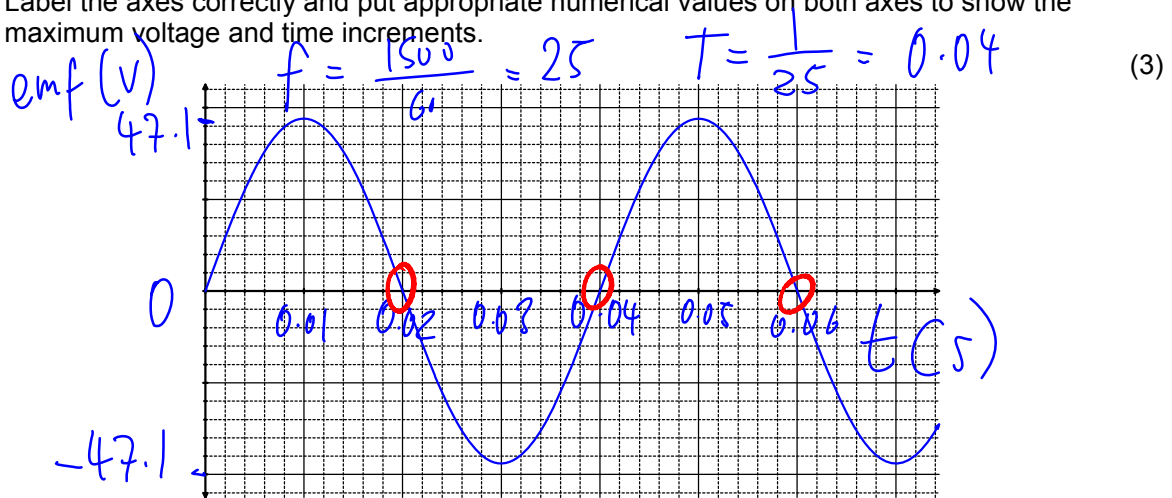
$$emf = 18.0 \text{ V} \quad \checkmark$$

- d) Explain why the value that you calculated is not exactly the same as the true RMS voltage of 20.0 V. (1)

This equations assumes a uniform rate of change of flux - in fact sinusoidal. (1)

When the coil is rotated at 1500 rpm the output changes to 33.3 V_{RMS}. A voltage curve is shown on the graph below.

- e) Label the axes correctly and put appropriate numerical values on both axes to show the maximum voltage and time increments. (3)



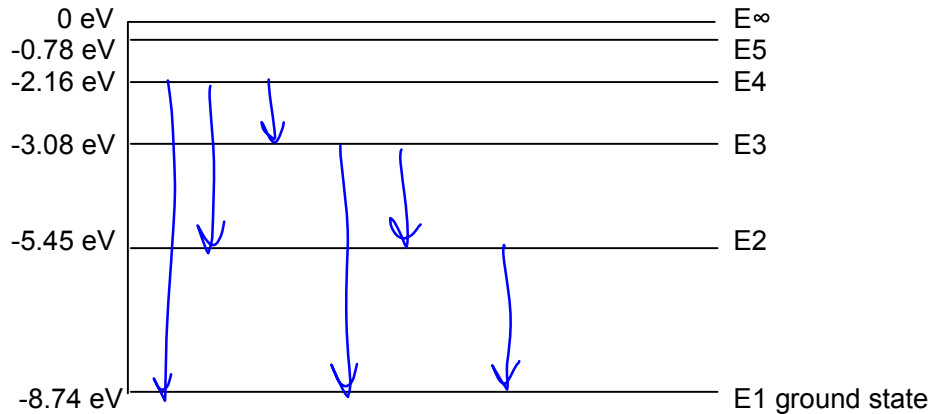
- f) Indicate three times on the graph when the flux enclosed by the coil is a maximum value. Circle these times. (1)

$$V_{max} = V_{RMS} \times \sqrt{2} = 33.3 \times \sqrt{2} = 47.1 \text{ V}$$

0, 0.02 s, 0.04 s, 0.06 s

Question 5 (13 marks)

The diagram below details some of the energy levels for a metallic vapour that surrounds a star



- a) What is the minimum energy (joules) required to ionise this atom.

$$8.74 \text{ eV} = 8.74 \times 1.60 \times 10^{-19} = 1.3984 \times 10^{-18} \text{ J} \quad (1)$$

default is from ground state

- b) Whilst in the ground state the atom absorbs a 6.58 eV photon. How many lines in the emission spectrum would be possible as the atom de-excites? Indicate them on the diagram. (1)

$$-8.74 + 6.58 = -2.16$$

as above

Number of lines = 6

- c) Calculate the shortest photon wavelength (nm) possible in the emission spectrum you have just identified.

$$\lambda_{\text{short}} = \frac{hc}{E_{\text{high}}} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6.58 \times 1.60 \times 10^{-19}} = 1.889 \times 10^{-7} \text{ m} = 189 \text{ nm} \quad (3)$$

- d) For the wavelength you calculated in part c) state which area of the electromagnetic spectrum this belongs to. (Remember that the Curriculum Council F&C sheet is a rough guide only). (1)

ultraviolet

A **single** atom in the ground state is bombarded by **one** electron with a kinetic energy of 6.02 eV.

- e) Detail in the table below the possible photon energies observable on de-excitation and the possible bombarding electron energies after passing through the atom.

$$-8.74 + 6.02 = -2.72 \quad \therefore E3 = \text{max excitation} \quad (3)$$

Possible photon energies on de-excitation (eV)	Possible bombarding electron energy after passing through the atom (eV)
$8.74 - 3.08 = 5.66 \text{ eV}$	0.36 eV
$8.74 - 5.45 = 3.29 \text{ eV}$	2.73 eV
$5.45 - 3.08 = 2.37 \text{ eV}$ (intermediate)	6.02 eV (misses)

- f) Explain how analysis of a line absorption spectrum of light coming from space is useful to determine the composition of stars and gas clouds in distant galaxies.

The line absorption spectrum is unique for each element. As a continuous spectrum passes through gas clouds or outer atmosphere of stars an absorption spectrum is formed. This can be matched to elements.

- g) The line absorption spectrum is also useful to determine the recessional speed of a galaxy. Explain the fundamental principles of this technique.

When the source of light is moving away from an observer the wavelength viewed is longer. This is the doppler effect also known as 'Redshift'. The amount of redshift can be used to determine relative speed.

Question 6 (13 marks)

A simple flute can be made from a steel pipe open at both ends. A mouthpiece at the top of the flute acts as a vibrating source. When the flute is played overtones are present in the note heard giving the sound a rich quality.




a) Explain what is meant by the phrase 'overtones are present in the note heard'

A 'single' note from the flute is comprised of the fundamental and harmonics which occur simultaneously. This gives the note an identifiable quality / timbre. (2)

b) Explain how standing waves can form within the pipe.

Sound waves reflect from both ends, the reflected wave train interferes with the incoming wave and provides the conditions for a standing wave to form - 2 waves, opposite directions, same speed and frequency interact via superposition. (2)

c) If the fundamental resonant frequency of the open pipe is 1225 Hz and the speed of sound in the pipe is 343 m s^{-1} , calculate the length of the pipe. (3)



$$\lambda = 2L$$
$$L = \frac{\lambda}{2}$$
$$v = f \cdot \lambda$$
$$343 = 1225 \times \lambda$$
$$\lambda = \frac{343}{1225} = 0.28$$
$$L = \frac{\lambda}{2} = \frac{0.28}{2} = 0.140 \text{ m}$$

- d) If one end of the pipe is closed explain what happens to the fundamental frequency of the pipe. (1)

Becomes lower $\lambda = 4L$ ($= 0.56 \text{ m}$) ✓

$$f = \frac{v}{\lambda} = \frac{343}{0.56} = 612.5 \text{ Hz}$$

- e) Calculate the frequency of the second overtone in a closed pipe of length 14.0 cm (3)

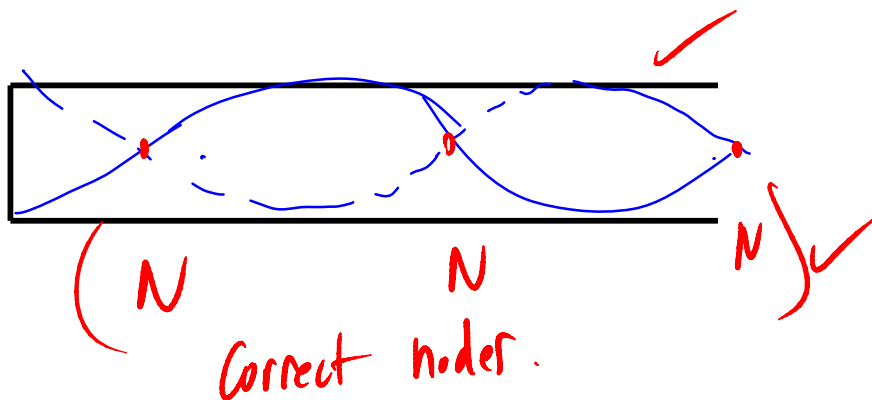
Second overtone = f_5 ($f_1 \rightarrow f_3 \rightarrow f_5$) ✓

$$f_5 = f_1 \times 5 = 612.5 \times 5$$

$$f_5 = 3062.5 \text{ Hz} \quad (= 3.06 \times 10^3 \text{ Hz})$$

$$f_5 = \frac{nv}{4L} = \frac{5 \times 343}{4 \times 0.14}$$

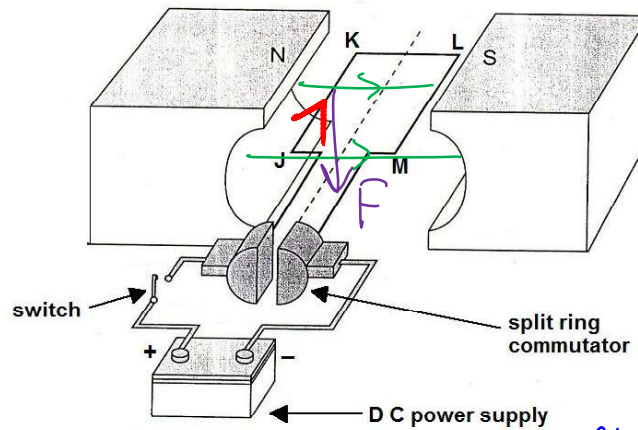
- f) Sketch the pressure variation wave envelope for the second overtone in the closed pipe. (2)



Question 7 (7 marks)

The figure below represents a DC motor whose coil is initially stationary.

- JK = LM = 14.0 cm KL = JM = 9.00 cm
- The coil has 120 turns of wire
- The magnetic flux density between the poles = 58.0 mT
- The current in the coil is 0.76 A when the motor is switched on.



a) In which direction will the coil turn when the switch is closed? anticlockwise (1)

b) Calculate the force acting on side JK of the coil when the switch is closed. (2)

$$F = B \cdot I \cdot l \cdot n$$

$$F = 0.058 \times 0.76 \times 0.14 \times 125$$

$$F = 0.771 \text{ N down}$$

c) Calculate the maximum torque that this motor can produce. (2)

$$\tau_{\text{max}} = BANlI = 0.058 \times (0.14 \times 0.09) \times 125 \times 0.76$$

$$\tau_{\text{max}} = 6.94 \times 10^{-2} \text{ Nm acw}$$

d) Explain why the torque is not constant. (2)

line of action of force is constant
 lever arm is constant but angle b/w them changes

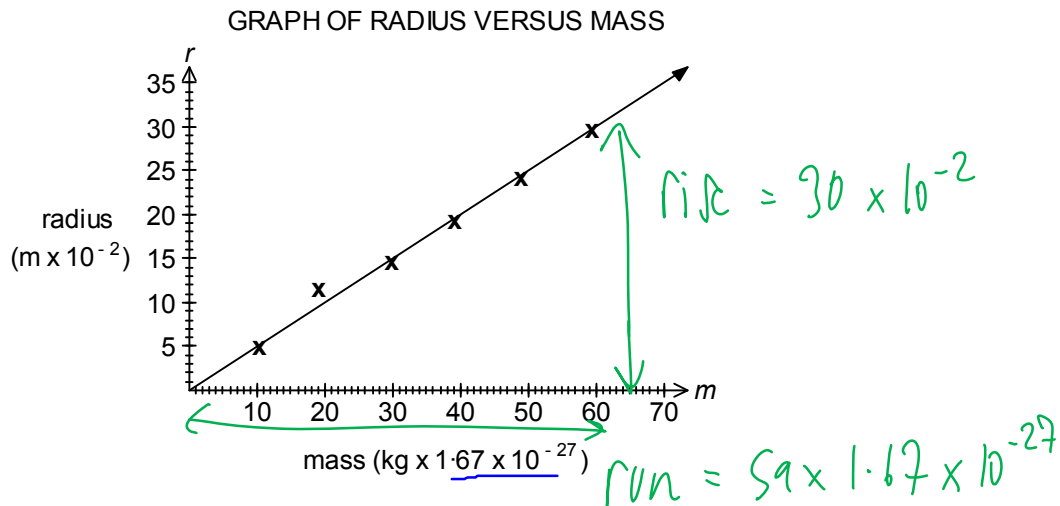
$$\tau = r \cdot F \cdot \sin \theta$$

Question 8 (6 marks)

A mass spectrometer is used to measure the amount of isotopes in a sample of an element. In an experiment to confirm the magnetic flux density used to deflect ions the following data is noted.

- Nature of ions: all singly charged and positive
- Mass of ions: all masses known
- Speed of ions: all travelling at $2.00 \times 10^5 \text{ m s}^{-1}$

The results were graphed with the radius of the curved path on the vertical axis ($\times 10^{-2} \text{ m}$) and mass of ions ($\times 1.67 \times 10^{-27} \text{ kg}$) on the horizontal axis. The graph appears below.



The data follows a $y = a.x$ format for the expression $r = \frac{m.v}{B.q}$ where a is the gradient.

a) The gradient of the line of best fit corresponds to: (Circle the correct response)

A $m \text{ (kg)}$

B $\frac{v}{B.q}$

C $\frac{B.q}{v}$

D $\frac{m}{B.q}$

(1)

b) From the graph obtain a value for the gradient of the line of best fit.

$$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{30 \times 10^{-2}}{59 \times 1.67 \times 10^{-27}} = 3.04 \times 10^{24} \text{ m kg}^{-1}$$

c) From the gradient of the line of best fit obtained, calculate the magnetic flux density B in this experiment.

$$3.04 \times 10^{24} = \frac{v}{B.q} \quad B = \frac{v}{3.04 \times 10^{24} \times q}$$

$$B = \frac{2.00 \times 10^5}{3.04 \times 10^{24} \times 1.60 \times 10^{-19}} = 0.411 \text{ T}$$

Section Three: Comprehension 20% (36 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided. Suggested working time for this section is 36 minutes.

Question 1 (17)

Mass on string (g)	Tension	Time for 20 revolutions (s)	Period	Speed v (m s^{-1})	v^2 ($\text{m}^2 \text{s}^{-2}$)
200	1.93	14.3	0.715	5.27	27.8
250	2.45	12.7	0.635	5.94	35.2
300	2.94	11.6	0.580	6.50	42.2
350	3.43	10.8	0.540	6.98	48.7
400	3.92	10.1	0.505	7.47	55.7
450	4.41	9.50	0.475	7.94	63.0

✓✓

✓

✓

✓

For this experiment it can be assumed that:

$$F_{\text{centripetal}} = \frac{m_{\text{bung}} \times v^2}{r}$$

- Where the centripetal force $F_{\text{centripetal}}$, is provided by the mass suspended on the mass carrier being pulled down by gravity.
- v is the speed of the rubber bung of mass m_{bung} , traveling around the horizontal circle of radius r .
- In this experiment the radius r , of the horizontal circle was fixed at 60 cm

- a. Manipulate the data in such a way that you can plot a straight line graph with a gradient that corresponds to an average value of : $\left(\frac{m_{\text{bung}}}{r} \right)$ (5)

b. Derive the units of v^2

(1)

$m^2 s^2$ ✓

c. Use the data to produce a graph. You may use the graph paper provided or use your graphics calculator to draw the graph. (4)

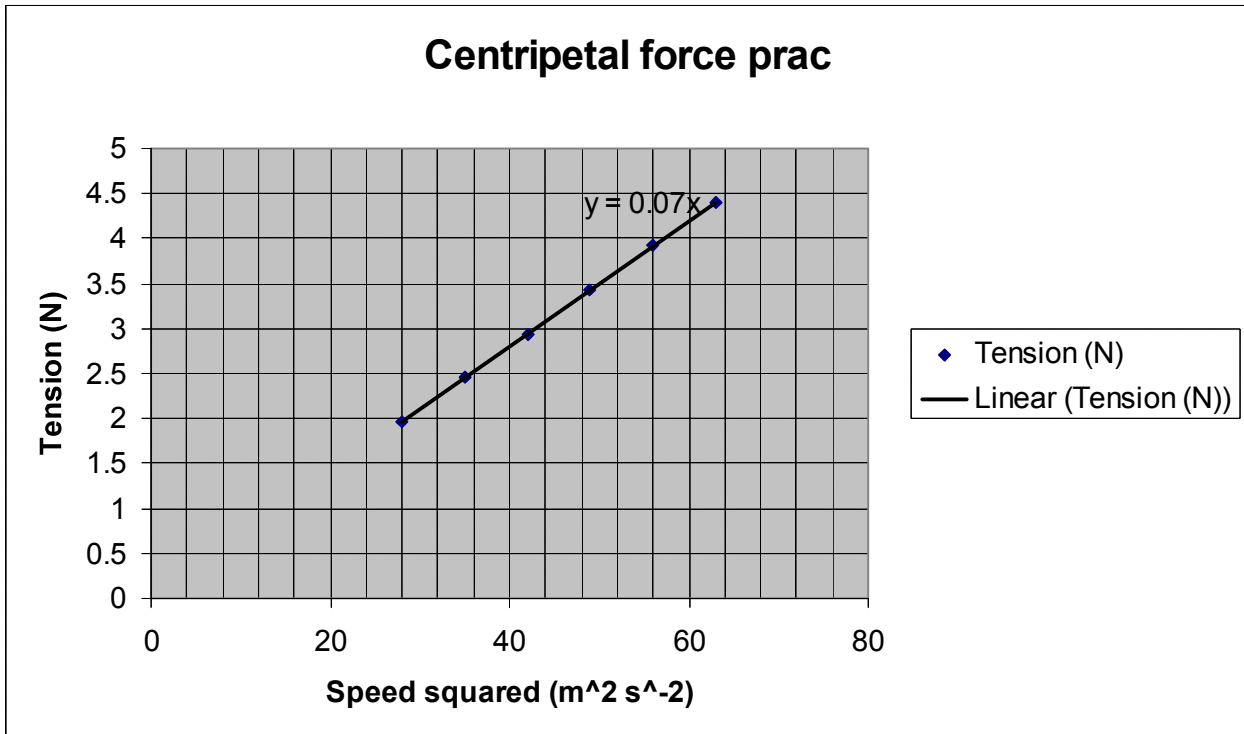
labels (tension/force v^2)

units (N) ($m^2 s^2$) ✓

scaling (zero/1.5 to 5) (zero/25 to 80)✓

accurate plots ✓

line of best fit ✓



- d. Calculate the gradient of your line of best fit from your graph showing all working. (2)

$$\text{rise} = 4.5 - 1.5 = 3.00$$

$$\text{run} = 64 - 22 = 42 \quad \checkmark$$

$$\text{gradient} = \text{rise} / \text{run} = 3 / 42 = 0.0714 \text{ N m}^{-2} \text{ s}^{-2} \quad \checkmark$$

- e. From the gradient of your line of best fit, calculate the mass of the bung that was describing circular motion. (3)

$$\text{gradient} = m_{\text{bung}} / \text{radius}$$

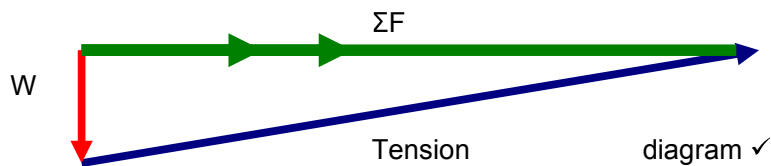
$$0.0714 = m_{\text{bung}} / 0.6 \quad \checkmark$$

$$m_{\text{bung}} = 0.0714 \times 0.6 \quad \checkmark$$

$$m_{\text{bung}} = 0.0429 \text{ kg} = 42.9 \text{ grams} \quad \checkmark$$

- f. Demonstrate with vectors, that it is impossible for the circular motion to be exactly on a horizontal plane. (2)

weight of bung must always be balanced in the vertical by a component of the tension acting in vertical. If tension has a vertical component it cannot act horizontally \checkmark



Question 2

(19 marks)

Piano Design

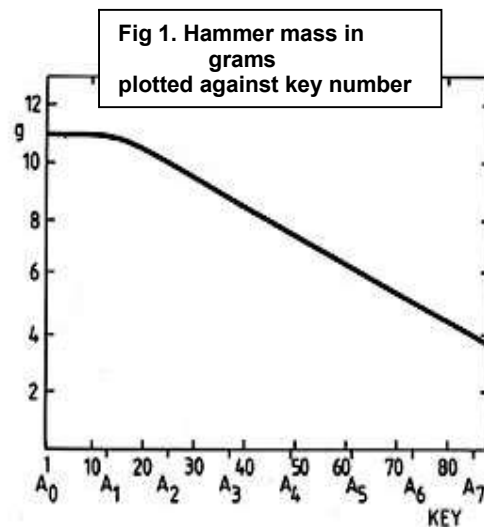
[para 1] The grand piano design dates from Cristofori's 1720 model. It is evident that the action of the 1720 piano is much simpler and less controllable than that of a modern Grand. After listening to the recording of the old piano one can say almost with certainty that the music played on the modern instrument could not be played properly with the action of Cristofori.



The Cristofori piano

[para 2] Cristofori glued his hammers onto wooden shanks as we are still doing today. In a modern grand piano the mechanical system of the hammer head on its somewhat flexible shank exhibits its own resonant vibrational mode around 260 Hz as installed in the piano. This mode is not normally audible in the lower half of the piano's spectrum, but it can be heard in the treble register, as part of the "knock" component of the tone, beginning somewhere around A4 (key 49), and can be shown to affect noticeably the tone of the instrument. An improvement in the tone can sometimes be obtained by shifting the frequency of this resonance.

[para 3] The hammers of the Cristofori piano are all about the same size. In a modern piano, the size and weight of the hammers increase from treble to bass in order to achieve the best compromise between tone quality, loudness, and playability. Fig. 1 shows typical hammer head weights for a modern grand piano.



[para 4] In the bass, tones having somewhat more fundamental energy could be obtained by using heavier hammers but then the piano would become harder to play. An increase in hammer weight can be counterbalanced statically by installing additional lead weights near the fronts of the key levers so that the force required to depress a key very slowly will remain at its nominal value (usually around 50 grams). However, this cannot compensate dynamically for increased hammer mass. Key velocities corresponding to higher musical dynamic levels can require a finger force corresponding to 200 newtons or so and the value of this force increases noticeably with an increase in hammer weight.

[para 5] The modern iron framed piano dates from 1825 and uses a single piece of cast iron as the basis for his piano. The iron frame has advantages over the wooden frame that Cristofori used. Firstly it did not contract or expand with temperature changes as much as the wooden one did. Secondly the stretched strings that create the sound when set vibrating, could be thicker and tighter as the iron frame was strong enough to withstand the tension which could be more than 1000 N for each string.

[para 6] To distribute the tension more evenly the strings were set diagonally with one set of strings passing above those going to the other two corners. This had the extra advantage that the strings could be made longer and the sound louder. This arrangement was called "overstringing". All the strings were fixed in position starting at the tuning pins, which could be turned to alter the tension. They then passed over hard wooden bridges to steel hitch pins at the lower end of the iron frame. The bass (low) strings were single strings over-wound with copper or brass wire to increase their mass of the string.

The frequency (F_o) of the fundamental note being produced by that string is given by

$$F_o = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$

where L is string length, T is tension and μ is the mass per unit length.

[para 7] The middle strings had two wires for each note while the high strings have three wires to balance the loudness of the low notes, The strings were caused to vibrate by striking felt-covered wooden hammers. Each hammer must be the same distance from the string, otherwise in a chord or group of notes, one note would sound before the others. The soft or left pedal in most pianos is able to move the hammers closer the string so that they aren't stuck so hard. On some pianos the soft pedal also causes a piece of felt to be raised between the hammer and the string to deaden the sound. Another pedal on the left called the "loud" pedal removes the felt so the "undamped" string vibrates for a longer time.

QUESTIONS

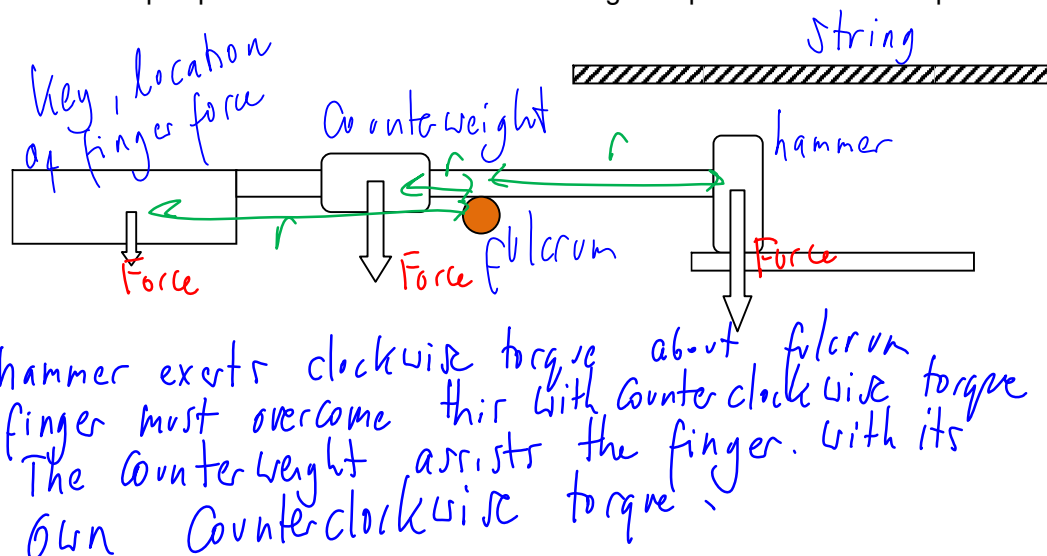
- a. [Para 2] The article mentions that the hammer striking the string has its own resonant mode of around 260 Hz. Explain what is meant by a "resonant mode" and how this arises in the hammer.

[2]

When the hammer starts to resonate, Because the frequency of a vibrating string matches the hammers natural frequency. Energy is drawn into the hammer causing it to vibrate or "knock"

- b. [Para 4] Some of the hammers used to strike the string can have quite large masses, which would make them difficult to lift with fingers. Sketch a diagram of the hammer as a lever to help explain how the counterbalance weight helps to overcome this problem.

[2]



- c. [Para 5] Explain how the use of a metal frame in more modern pianos enable it to stay in tune better than one of Cristofori's wooden-framed pianos.

[3]

Firstly it did not contract or expand with temperature changes as much as the wooden one did. ✓
Secondly the stretched strings that create the sound when set vibrating, could be thicker and tighter as the iron frame was strong enough to withstand the tension which could be more than 1000 N for each string. ✓ This is better to maintain tuning. ✓

- d. [Para 6] Explain, using Newton's Laws, why an "overwound" string would vibrate with a lower frequency than a plain, single-stranded string.

[2]

Greater mass on string, by Newton's first law of inertia greater tendency to resist a change in direction. ✓
A change in direction is required for each cycle of vibration. So greater mass has a tendency for lower frequency. ✓

- e. [Para 6] A string is needed that will vibrate at a frequency of Middle C (256 Hz) and will be 1.45 m long. If the tension in the string is 350 N, use the formula given to calculate a value of μ (mass per metre) needed for the string.

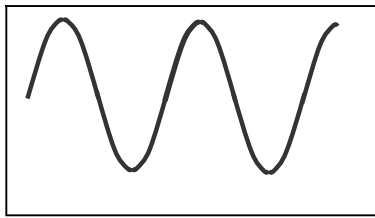
[3]

$$F_o = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$
$$256 = \frac{1}{2 \times 1.45} \sqrt{\frac{350}{\mu}}$$
$$742.4 = \sqrt{\frac{350}{\mu}}$$
$$\frac{350}{742.4^2} = \mu = 6.53 \times 10^{-4} \text{ kg m}^{-1}$$

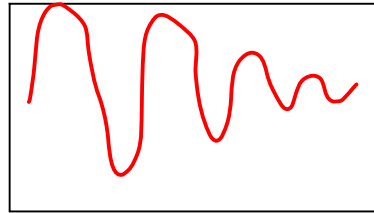
- f. [Para 7] The graph in Fig 2 shows an undamped note produced when a hammer strikes a string with the “loud” pedal pressed down and without the felt touching. In the empty box below sketch what the waveform would look like when the “loud” pedal is not being depressed.

amplitude decreases [2]

Fig 2



Undamped

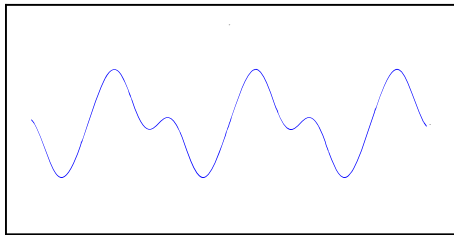


Damped

- g. Although a note played may be quoted as 256 Hz, this is not the only note being produced on the string. In fact the waveform of the note may not appear as a simple sine wave like the one above at all. Explain why the waveform below (Fig 3) for the 256 Hz note appears the way it does.

[3]

Fig 3



Overtone (harmonics are also present). ✓
 These occur simultaneously ✓ The graph is the
 superposition of many different waves together ✓

- h. When a note is played some of the harmonics produced in a string do not sound very musical and so the hammer is designed to strike the string at a position that will suppress a bad harmonic. If a string is 135 cm long, how far from the end of the string must the hammer strike in order to suppress the 9th harmonic? Explain your reasoning.

[2]

9th harmonic = 9 half waves along the length of string.
 If hammer strikes a displacement node rather than an
 antinode, then the harmonic will be suppressed. ✓
 $135 / 9 = 15$ cm so first node will be 15 cm from end of
 string. ✓

Acknowledgements