# WACE PHYSICS Stage 3

## Semester 2 Examination, 2010

## Question/Answer Booklet

Student Number: In figures | | | | | | | | |

In words ________________________________________

________________________________________

## 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.

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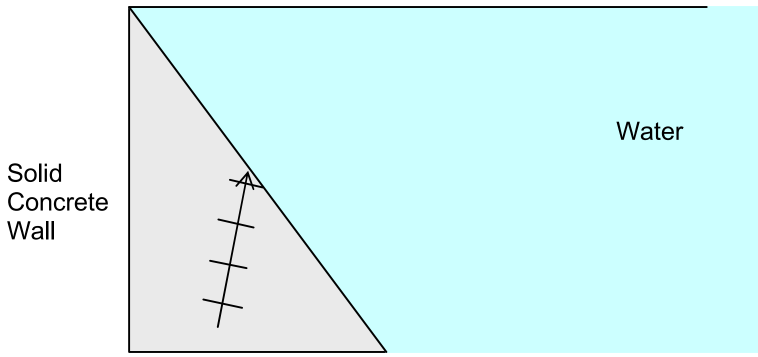
**Question 1**

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)

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)

c) Is it possible for total internal reflection to occur at this boundary? Explain briefly. (1)

**Question 2**

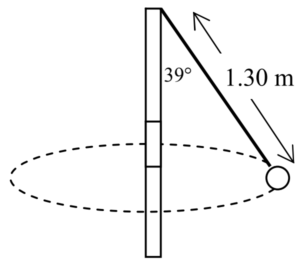
Molybdenum-102 undergoes **beta negative decay**.

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)

**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.




Vector diagram

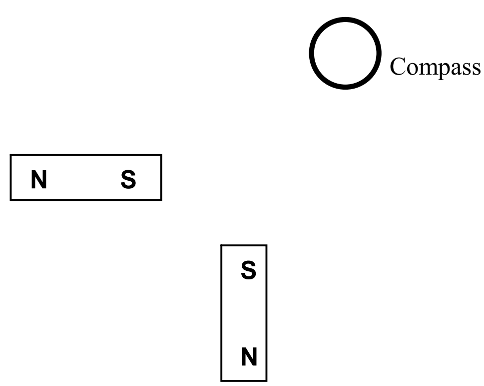
a) Draw a vector diagram showing the forces acting on the ball and the sum of those forces in the space indicated above.
(1)

b) Calculate the net force ($\Sigma F$) acting on the ball.
(2)

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

**Question 4**

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

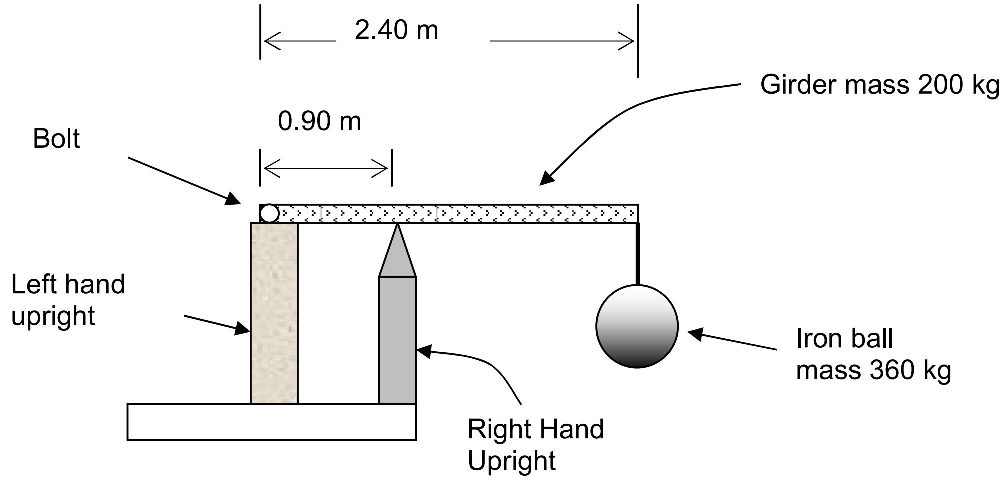



a) Sketch the magnetic field in the region around the magnets.
(1)

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.



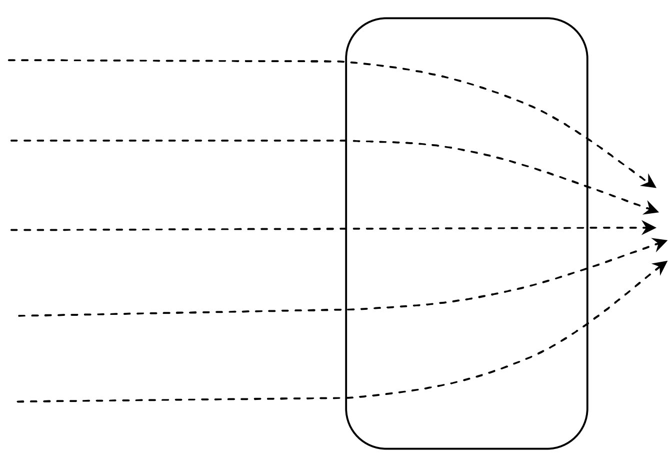

Calculate the forces acting on the girder from both the left and right uprights and state whether each upright is in compression or tension.

(5)

**Question 6**

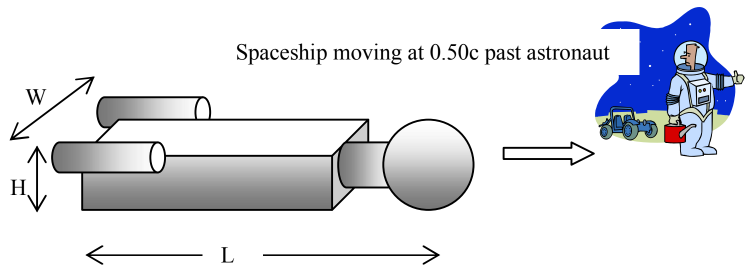
The diagram shows the path of electrons as they are deflected in a region of non uniform magnetic flux within the rectangle. Use magnetic field symbols to indicate the density and direction of the field that will cause these deflection paths. Place symbols in the rectangle.

(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 $L_o$, $W_o$ and $H_o$




(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.** $L<L_o$, $W<W_o$, $H=H_o$
**B.** $L>L_o$, $W=W_o$, $H=H_o$
**C.** $L<L_o$, $W=W_o$, $H=H_o$
**D.** $L<L_o$, $W<W_o$, $H<H_o$ Answer _______________

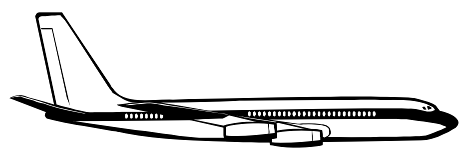
(b) Explain your answer.

(2)

**Question 8**

A jet airliner is flying due North above Perth where the Earth's magnetic field has a flux density of $4.90 \times 10^{-5}$ 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 $h^{-1}$.

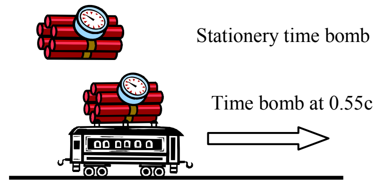
(3)

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

(1)

**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 stationery 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 stationery 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.

(2)

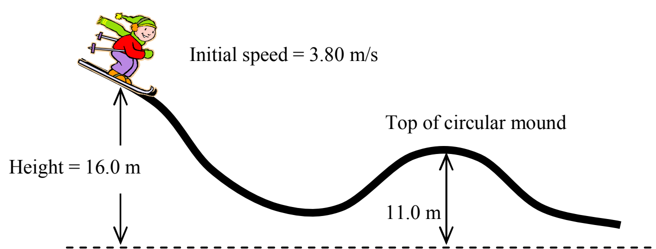
b) An imaginary observer on the moving train disagrees with the Physics team. Explain the order of explosions that the imaginary observer sees and then explain who is correct and why.

(2)

**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.

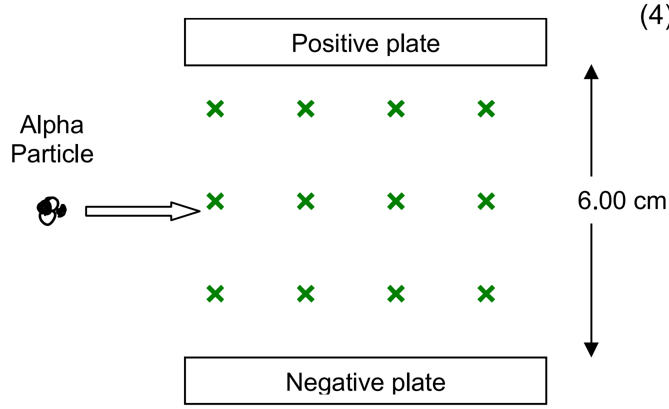



(4)

**Question 11**

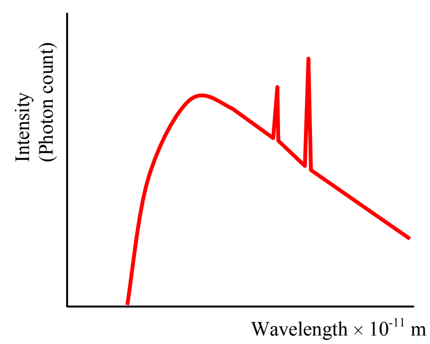
An alpha particle enters a vacuum chamber at a speed of $1.20 \times 10^5$ m $s^{-1}$. A uniform magnetic flux density of 54 mT is present as shown. 2 parallel charged plates are also present with a potential difference of 450 V across a gap of 6.00 cm. Determine the approximate path the alpha particle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

(4)




**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.

(2)

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

(2)

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

(1)

**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 ($\pi^+$) | $u\bar{d}$ |
| Sigma-plus | $uus$ |
| Lambda-zero | $uds$ |
| Charmed Omega | $ssc$ |

a) Determine the charge (C) of the Charmed Omega: ________________________________ (1)

b) Determine the charge (C) of the Pi-plus: ________________________________________ (1)

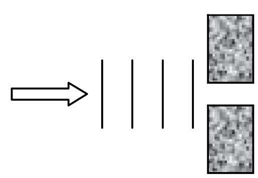
c) Identify the Mesons from the information above: __________________________________ (1)

d) Briefly explain the relevance of the **Colour Charge** of quarks in the composition of hadrons (1)

**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



(1)

a) List them in order from "most diffraction" to "least diffraction". (e.g. A D B C): _______________

b) Explain briefly why you have selected this order. (1)

**End of Section One**

**Section Two: Problem-solving** **50% (90 Marks)**

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.

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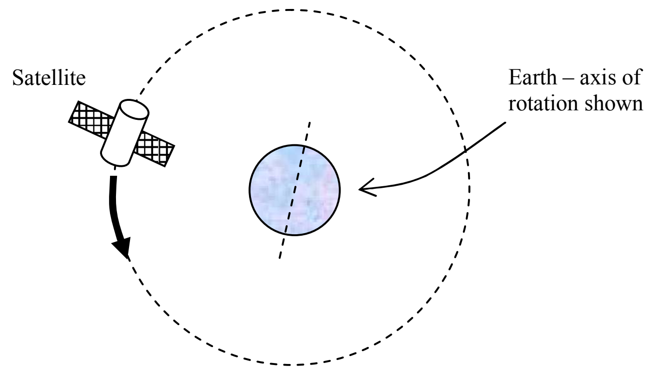
**Question 1 (13 marks)**

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.

(2)

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)

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

(4)

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.

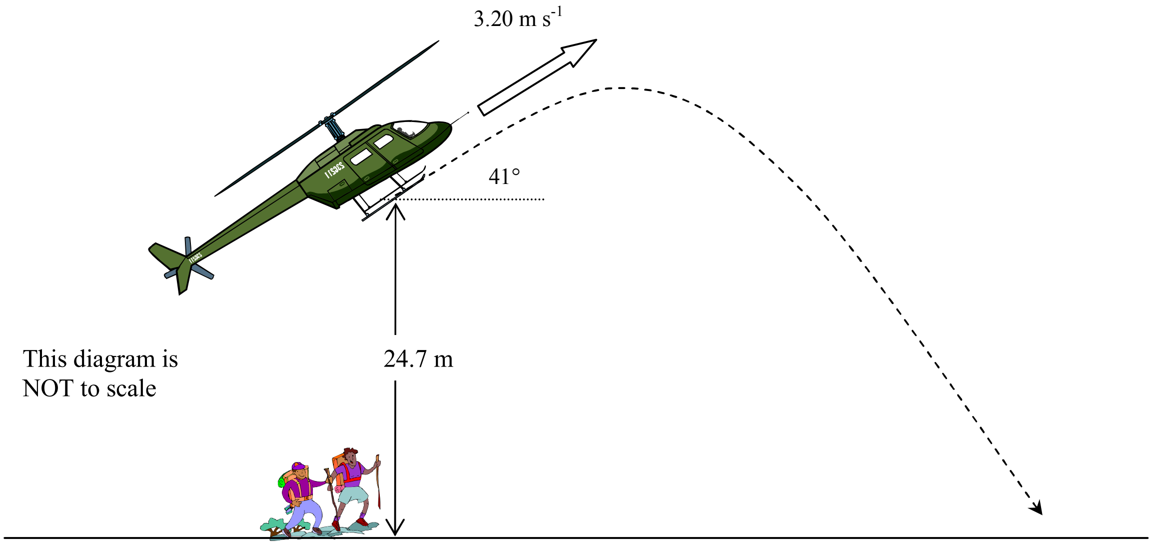
(3)

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.

(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.

(4)

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

(3)

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)

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

d) Sketch the altered flight path onto the diagram.

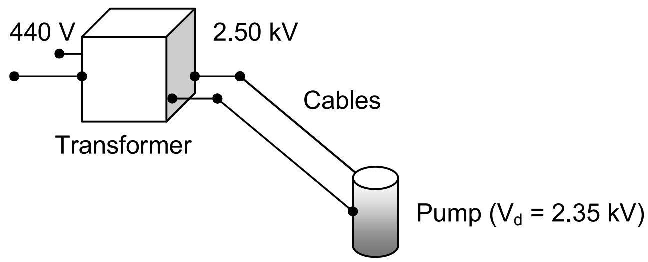
(1)

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)

**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)

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)

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

(2)

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

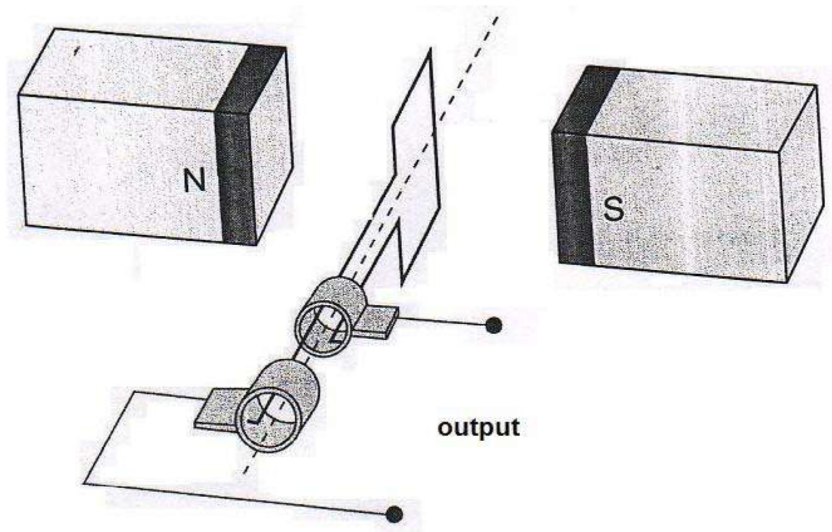
(3)

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)

**Question 4 (13 marks)**

The figure below shows an AC generator consisting of a rectangular coil which has dimensions of 15.0 cm $\times$ 20.0 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)

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)

c) The coil is rotated at 900 rpm. Calculate the magnitude of the average induced emf in the coil using the ¼ turn method.

(3)

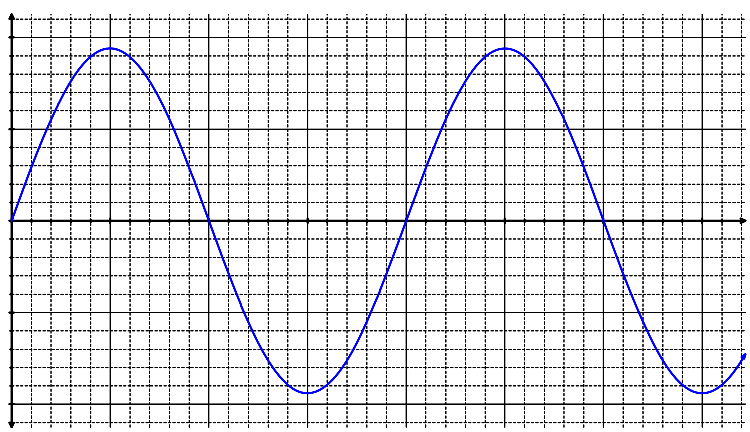
d) Explain why the value that you calculated is not exactly the same as the true RMS voltage of 20.0 V.

(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)

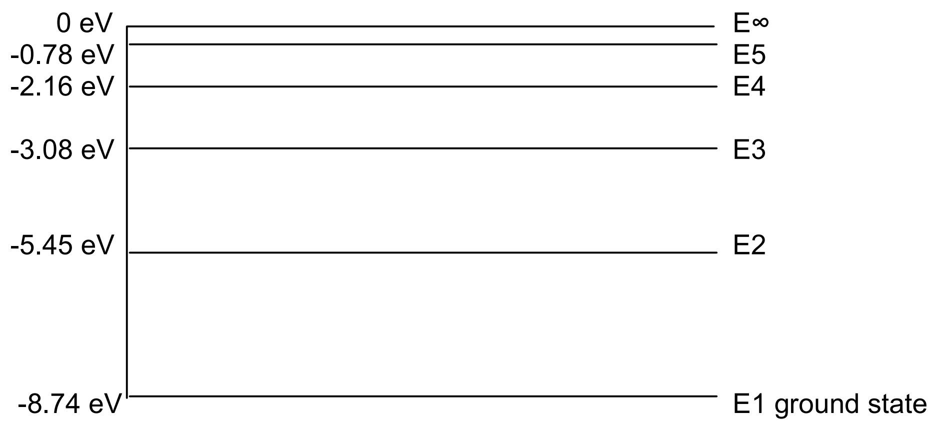


f) Indicate three times on the graph when the flux enclosed by the coil is a maximum value. Circle these times.

(1)

**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.

(1)

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)

Number of lines =

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

(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)

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.

(3)

| Possible photon energies on de-excitation (eV) | Possible bombarding electron energy after passing through the atom (eV) |
|---|---|
| | |

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.

(2)

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

(2)

**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'.

(2)

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

(2)

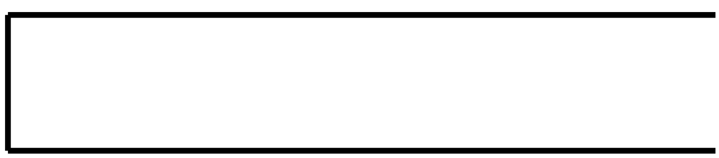
c) If the fundamental resonant frequency of the open pipe is 1225 Hz and the speed of sound in the pipe is 343 m $s^{-1}$, calculate the length of the pipe.

(3)

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

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

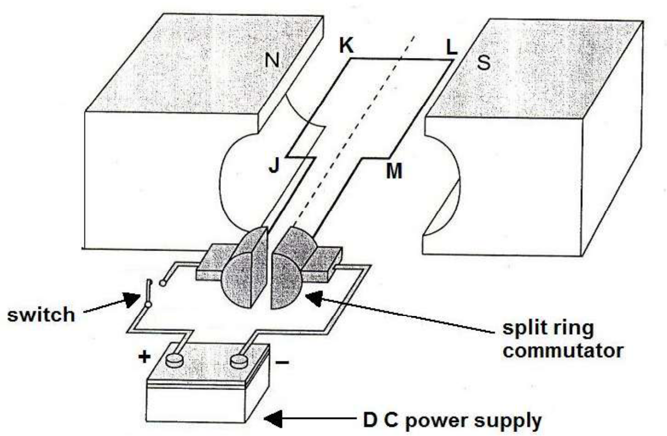
f) Sketch the pressure variation wave envelope for the second overtone in the closed pipe. (2)



**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 125 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? ________________________ (1)

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

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

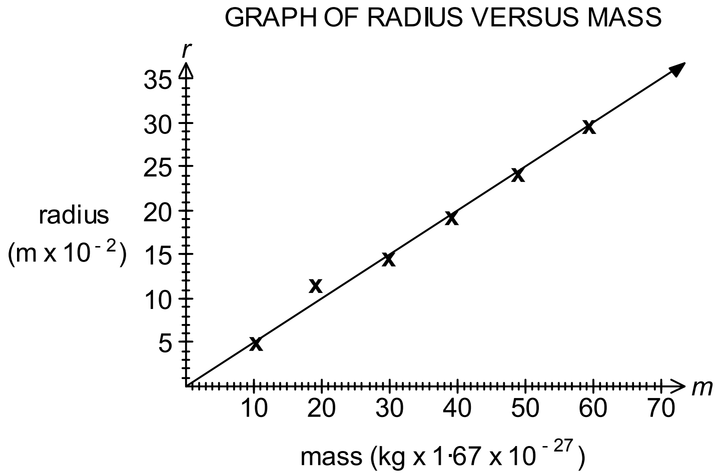
d) Explain why the torque is not constant. (2)

**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 x $10^{5}$ m $s^{-1}$

The results were graphed with the radius of the curved path on the vertical axis ($\times 10^{-2}$ m) and mass of ions ($\times$ 1.67 $\times$ $10^{-27}$ 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)* (1)

A m (kg) B $\frac{v}{B.q}$ C $\frac{B.q}{v}$ D $\frac{m}{B.q}$

b) From the graph obtain a value for the gradient of the line of best fit. (2)

c) From the gradient of the line of best fit obtained, calculate the magnetic flux density B in this experiment. (3)

## 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.

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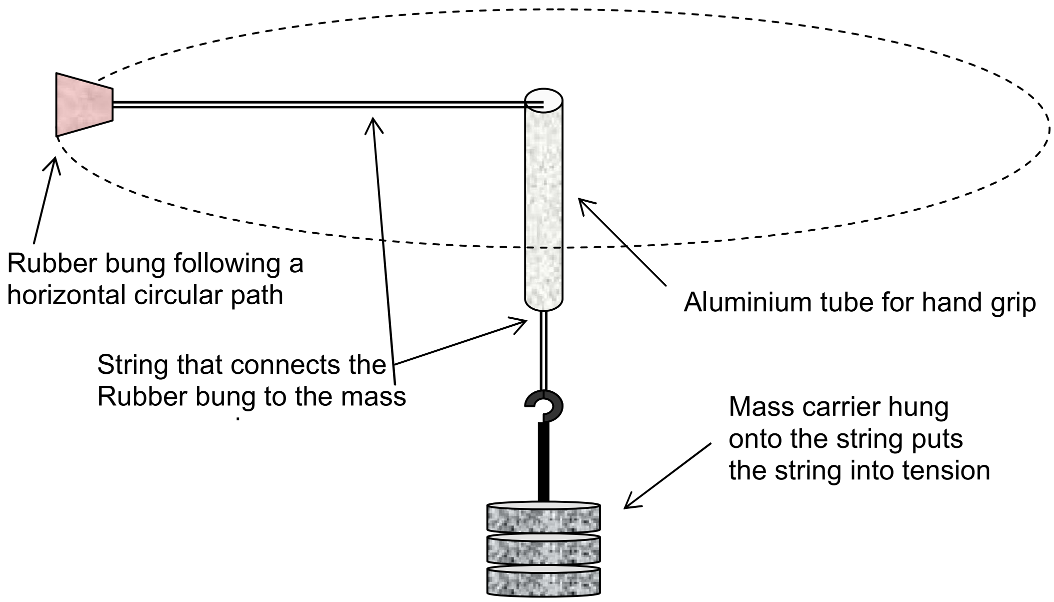
**Question 1** **Investigating Circular Motion. (17)**

Students were investigating circular motion by revolving a rubber bung on the end of a string at a constant rate. They recorded the relationship between the mass hung from the string that was providing centripetal force to the rubber bung and the time taken for the bung to make 20 revolutions in a horizontal circle. The data they obtained is recorded in the table below.




| Mass on string (g) | | Time for 20 revolutions (s) | | | |
|---|---|---|---|---|---|
| 200 | | 14.3 | | | |
| 250 | | 12.7 | | | |
| 300 | | 11.6 | | | |
| 350 | | 10.8 | | | |
| 400 | | 10.1 | | | |
| 450 | | 9.50 | | | |

For this experiment it can be assumed that:

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

- Where the centripetal force $F_{centripetal}$, 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 $\mathbf{m_{bung}}$, 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 : $\left(\frac{m_{bung}}{r}\right)$ (5)

b. Derive the units of $v^2$ (1)

c. Use the data to produce a graph. (4)

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

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

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

Spare graph paper

**Question 2** **(19 marks)**

**Piano Design**

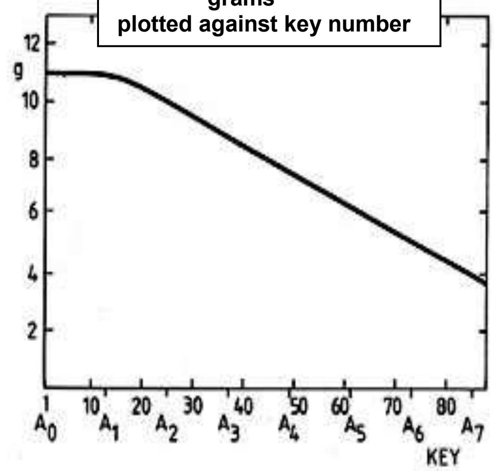
The Christofori piano

[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.

[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.

**Fig 1. Hammer mass in grams plotted against key number**




[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 modem 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]

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]

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]

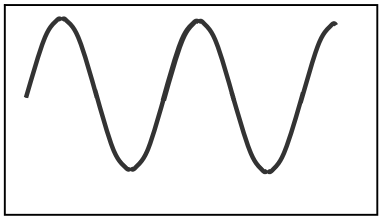
e. [Para 6] A string is needed that will vibrate at a frequency of Middle C (256 Hz) and will be 1.45 m long. If the tension in the string is 350 N, use the formula given to calculate a value of **μ (mass per metre) needed for the string**.

[3]

f. [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.

[2]

Fig 2



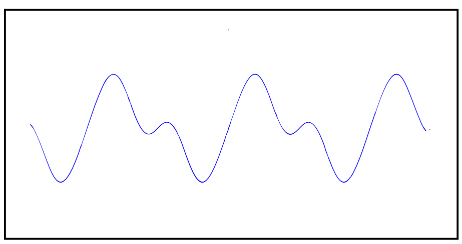
Undamped

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



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]

**Additional working space**