**Semester Two Examination, 2012**

**Question/Answer Booklet**

# 3AB PHYSICS

Please place your student identification label in this box

## 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

Special items: non-programmable calculators satisfying the conditions set by the SCSA 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.

| | A | B | C | Total |
|---|---|---|---|---|
| Score | | | | |
| Out of | 54 | 90 | 36 | 180 |
| % | | | | |

## 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 | 15 | 15 | 50 | 54 | 30 |
| Section Two: Problem-solving | 8 | 8 | 90 | 90 | 50 |
| Section Three: Comprehension | 2 | 2 | 40 | 36 | 20 |
| | | | | | 100 |

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2012.* 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 to follow any instructions that are specific to a particular question.

4. Working or reasoning should be clearly shown when calculating or estimating answers.

5. Spare pages are included at the end of this booklet. 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 at the top of the page.

   - 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. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

**Section One: Short response 30% (54 Marks)**

This section has **15** questions. Answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. 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 at the top of the page.
- 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. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 50 minutes.

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**Question 1**

**(3 marks)**

If a bullet was shot from a gun, straight up into the air, physics predicts that the bullet should return directly back to the gun and re-enter the top of the gun's barrel. Explain three reasons why (in practice) this does not occur.

**Question 2**

**(5 marks)**

A student has taken a part time job in a bakery. She is sick of spreading icing on the top of cakes. She decides to use an old record player to assist her. She places the cake in the middle of the record player and sets it turning at 33 ⅓ rpm (revolutions per minute). She places a blob of icing centrally on the cake. The icing blob has a diameter 8.00 cm.

a) What is the centripetal acceleration of the icing mixture at the edge of the blob?

(3 marks)

b) She switches off the record player when the icing reaches the edge of the 30.0 cm diameter cake. When she switches the record player off, where is the icing thickest? Why?

(2 marks)

**Question 3**

**(4 marks)**

a) How fast would you need to shoot a bullet horizontally so that its trajectory (flight path) is parallel to the surface of the earth? Assume the experiment is carried out a sea level, there is no air resistance and that the bullet does not collide with any objects as it circles the earth.

(3 marks)

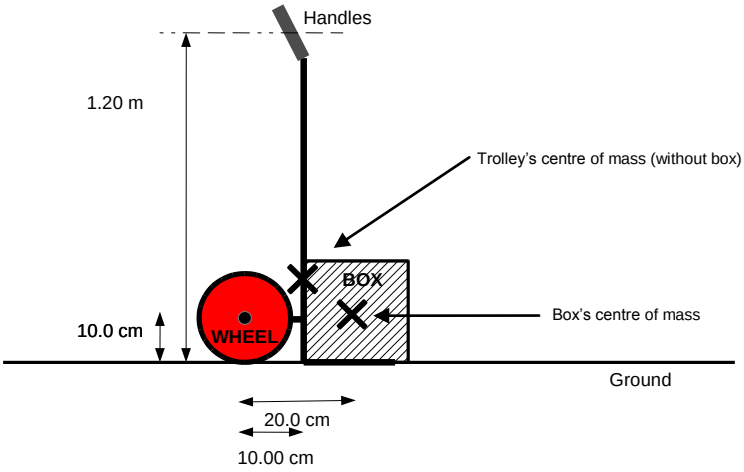
b) How much time does the person who fired the bullet have to get out of the way before the bullet circumnavigates the globe and hits them in the back?

(1 mark)

**Question 4**

**(4 marks)**

A person is moving house. They are using a "fridge trolley" to lift a heavy box. The box has a mass of 30.0 kg and the trolley has a mass of 10.0 kg.




a) With what force should the person pull on each of the two handles to tip the trolley?

(3 marks)

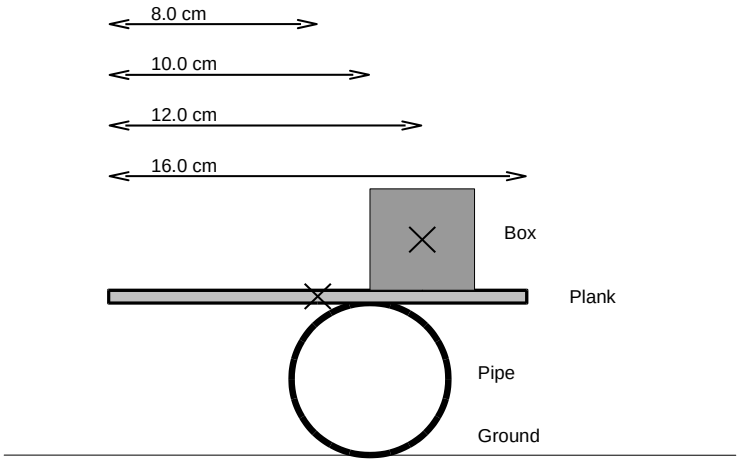
b) In which direction will the trolley move the moment the box lifts off the ground?

(1 mark)

**Question 5**

**(4 marks)**

A stationary box of side length 4.00 cm is resting on a 16.0 cm plank. The plank is resting on a hollow pipe. The hollow pipe is resting on the ground.




a) In what type of equilibrium are the combined plank and box in when sitting on the pipe? Explain?

(2 marks)

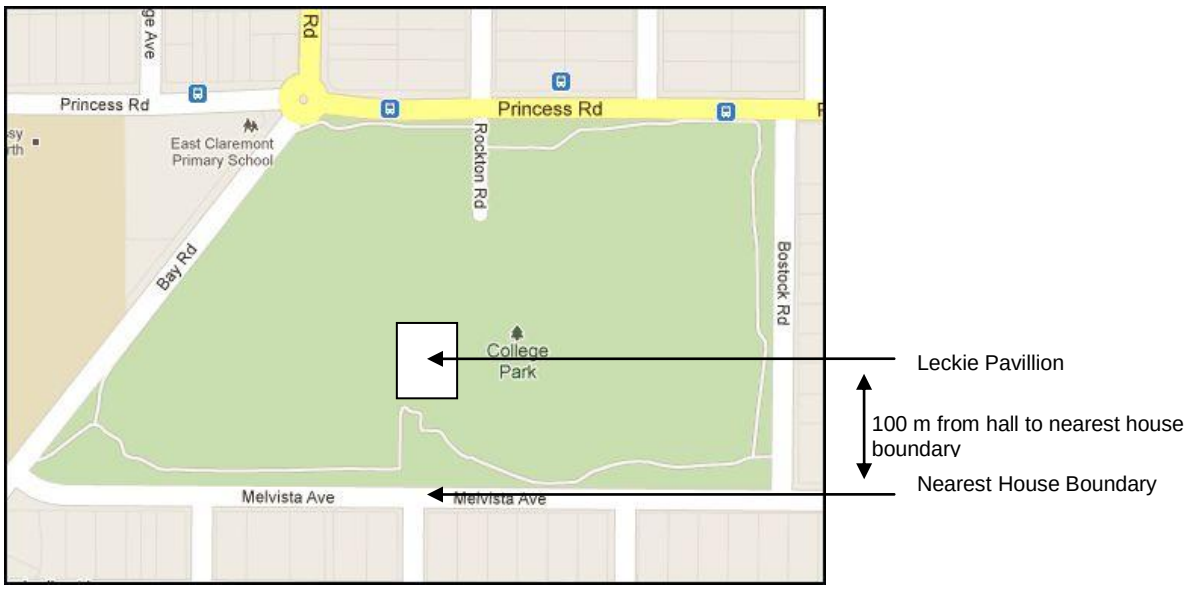
b) What is the ratio of the mass of the box to the mass of the plank?

(2 marks)

**Question 6**

**(5 marks)**

"Leckie Pavillion" is a hall that sits in the middle of a large oval called "College Park" in Nedlands. It has recently been refitted (modified) to allow musical rehearsals and performances to take place inside it. The orchestra that plays in the hall is able to produce an intensity of 100 W $m^{-2}$ when playing at its loudest as measured at 2.00 m distance. Assume the ground is a perfect absorber.




a) If the orchestra were playing at its loudest on the roof of the hall in the open air, what would be the intensity of the "music" measured at the nearest house boundary at roof height?

(3 marks)

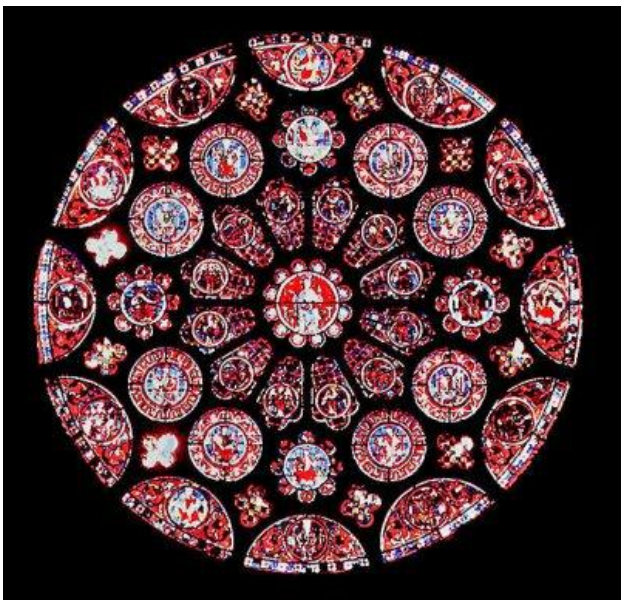
b) The council regulations state that the greatest intensity as measured at the nearest house boundary must not exceed 1 x $10^{-3}$ W $m^{-2}$. By moving into the hall and playing with the doors and windows shut, the materials of the building will absorb some of the energy and so reduce the intensity of the sound. What percentage of the orchestra's greatest intensity must the building absorb so that that they just meet council regulations at the shortest boundary?

(2 marks)

**Question 7**

**(4 marks)**

"Chartres Cathedral" in France is memorable for many reasons, one of which is its beautiful stained glass windows. A television documentary "Ancient Megastructures" states that the windows contain a particular blue coloured glass manufactured in memory of Jesus' mother Mary. The documentary says that during its manufacture the originally clear (transparent) liquid glass was given its blue colour by mixing chemical salt(s) into the glass. According to the documentary "The exact combination of chemical salts the glass manufacturer took to his grave" (was never recorded).



a) What type of spectra is likely to be produced by this blue glass as shown in the stained glass window above? Please circle one answer from <u>each</u> line.

(1 mark)

Absorption Spectra Emission Spectra

Line Band Continuous

b) Explain the reason for your answers above.

(1 mark)

c) Explain why physicists, using their knowledge of spectra, <u>could or could not</u> analyze the light transmitted by the blue glass to identify the chemical(s) present in the glass that give it its blue colour?

(2 marks)

**Question 8**

**(5 marks)**

A train carriage made of glass is moving forwards at 160 km $h^{-1}$. A person on the train throws a ball at 20.0 m $s^{-1}$ backwards towards the end of the carriage.

a) What is the velocity of the ball as observed by the person on the train?

(1 mark)

b) Calculate the velocity of the ball as observed by a person stationary on the ground outside the train watching the train go past?

(1 mark)

c) The glass carriage has its velocity increased to 1.6 x $10^8$ m $s^{-1}$ forwards. The same person on the train shines a beam of blue torchlight backwards towards the end of the carriage. What is the speed of the light as measured by the person on the train?

(1 mark)

d) What is the speed of the light as measured by the person on the platform?

(1 mark)

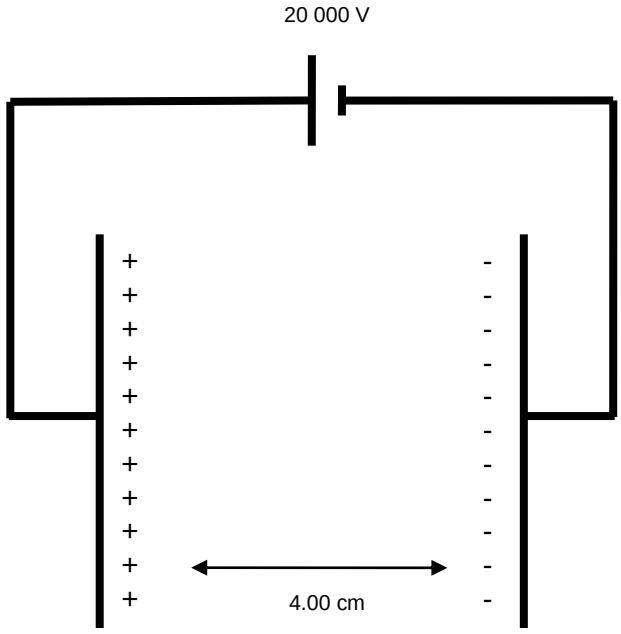
e) After the carriage has passed the observer on the platform steps on to the tracks and looks at the carriage that has passed them. Does the receding torch light appear any different to the light when it passes them? Explain.

(1 mark)

**Question 9**

**(3 marks)**

An electron is accelerated from rest by a uniform electric field that exists between two parallel plates separated by a distance of 4.00 cm. The potential difference between the plates is 20 000 V.




a) What is the speed of the electron just before it strikes the destination plate?

(2 marks)

b) If the distance of separation between the plates increased to 8.00 cm, and the process is repeated, will the electron accelerate faster or slower than in the original situation? Explain.

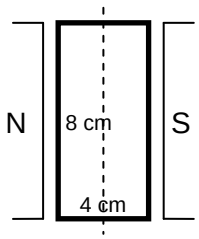
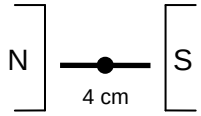
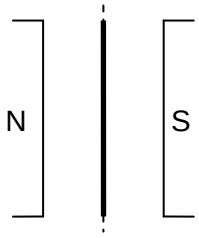
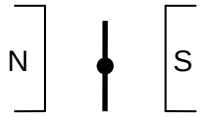
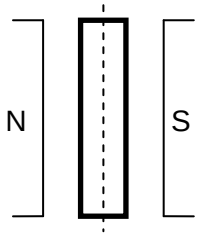
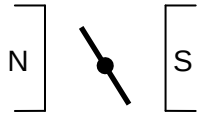
(1 mark)

**Question 10**

**(4 marks)**

A motor has 300 windings immersed in a uniform magnetic field of 0.0800 T. A current of 2.00 A runs in the windings. The rectangular armature has side lengths of 4.00 cm and 8.00 cm. What is the resultant force and resultant torque on the armature when the armature forms the following angles with the horizontal?

Note – perform calculations in the space **below the table** and put the answers into the table only.

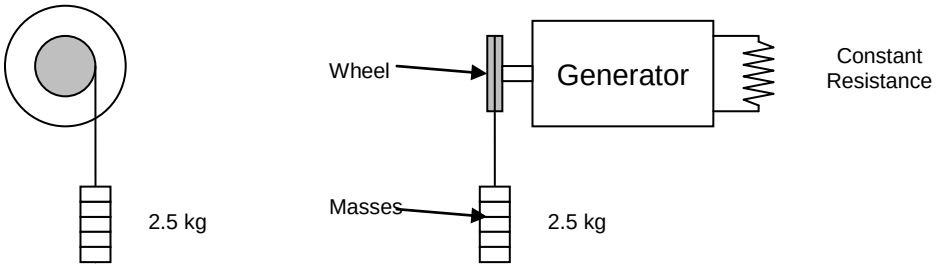
| Angle to field | Top View | Side View | Resultant Torque Magnitude | Resultant Force Magnitude |
|---|---|---|---|---|
| $0^0$ |  |  | | |
| $90^0$ |  |  | | |
| $60^0$ |  |  | | |

Space for working.

**Question 11**

**(4 marks)**

A 2.5 kg mass is attached to a string wrapped around a wheel. The wheel is connected to an electrical generator. The generator is connected to a constant size resistor. Once the mass gets going it falls at a constant rate of 12.0 cm per second. Assume there is no friction in the system.




a) If the potential to electrical conversion is 90.0 % efficient, what is the current output if the voltage output is 10.0 V?

(2 marks)

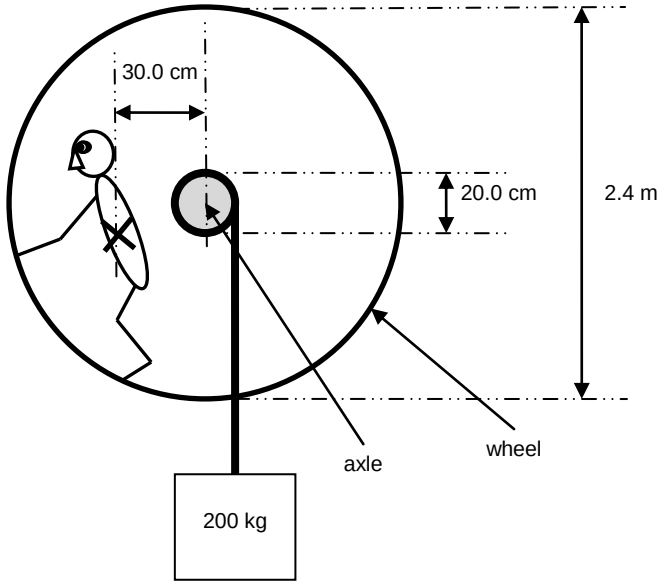
b) Why does the 2.50 kg mass fall at a constant rate (after initially accelerating up to the speed of 12.0 cm $s^{-1}$) instead of just accelerating continuously to the floor.

(2 marks)

**Question 12**

**(4 marks)**

A treadmill was a machine used to power mechanical devices during the medieval period. A person or persons walk around inside the barrel shaped circle like a mouse running around inside a mouse wheel.




a) What mass of person is required to hold the 200 kg stone on the end of the rope stationary in the diagram above?

(2 marks)

b) If the person inside the treadmill takes a step forward in which direction will the stone move. Why?

(1 mark)

c) The diameter of the treadmill is tripled and two 90.0 kg people are put walking inside it. As in the diagram for question a) the two people have their centres of mass 30.0 cm horizontally from the centre of the central shaft. The diameter of the shaft around which the rope is wrapped is not altered. What will be the maximum load liftable?

(1 mark)

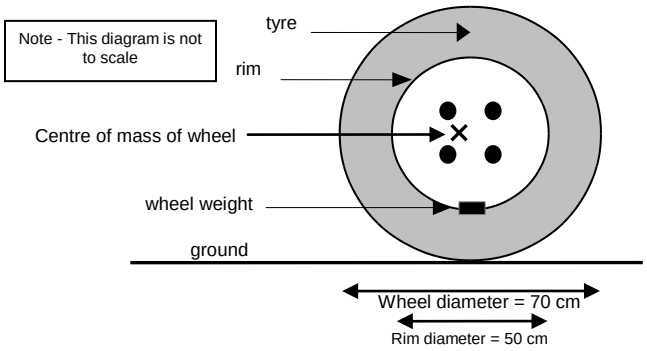
**Question 13**

**(5 marks)**

When car tyres are fitted to car wheel rims, the centre of mass of the tyre and rim are not usually in the exact centre of the wheel. This can cause an unbalanced centripetal force to act on the wheel creating a vibration that can be felt through the steering wheel.

a) If the centre of mass of the 30.0 kg wheel is 0.200 mm to the left of centre, what will be the unbalanced centripetal force acting on the wheel if the outer part of the tyre is rotating at 20 m $s^{-1}$?

(3 marks)




To fix the problem a wheel weight can be clipped to the outer rim of the wheel, to generate an equal but opposite centripetal force

Diagrams of a car wheel with a wheel weight clipped on to the rim.

b) On the line diagram at the top of the page place a "W" on the rim where the wheel weight must be attached to counter balance the centripetal force of the wheel.

(1 mark)

c) Wheel weights come in different sizes in 5 gram increments (e.g. 5 g, 10 g, 15 g etc) and the person that fits the tyre to the rim will use the correct weight required to the nearest 5 grams. Based on you answer to part a) what mass wheel weight to the nearest 5 g will be required to balance the wheel?

(1 mark)

**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.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

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Suggested working time for this section is 90 minutes.

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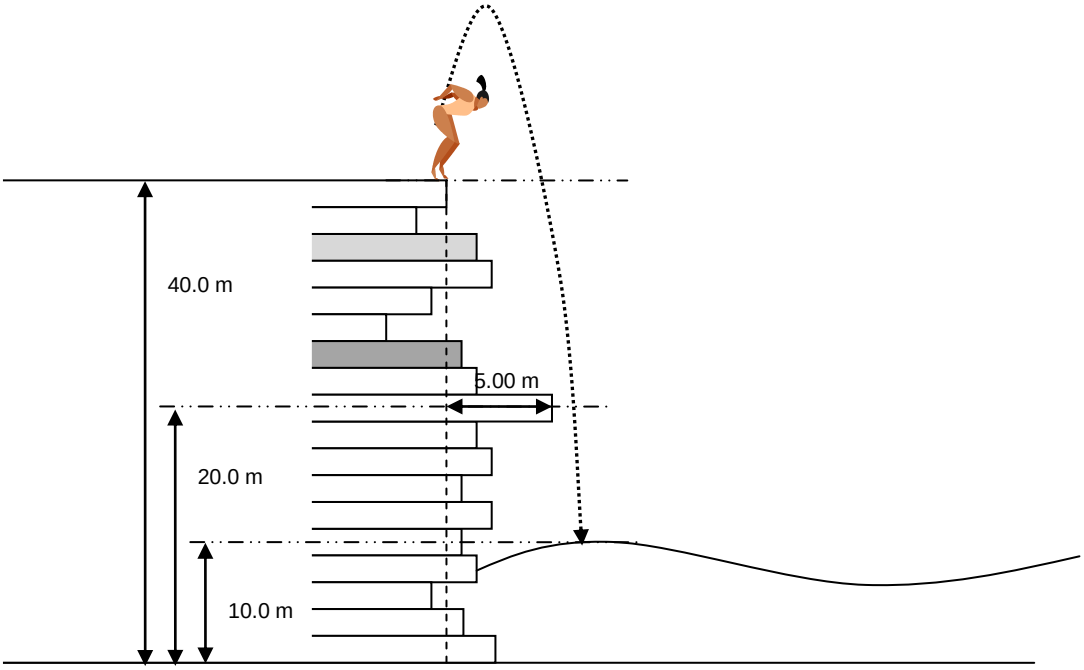
**Question 14**

**(11 marks)**

Cliff diving is a stupid idea. A physics student who is intelligent but lacks common sense decides to try it. Unfortunately the water at the bottom of the cliff is shallow. The student must time the jump just right so that they dive into the crest of a wave rather than a trough to avoid colliding with the sea floor.




a) The physics student jumps up and out away from the top of the cliff at an angle of $40.0^0$ above the horizontal with a velocity of 4.50 m $s^{-1}$. Assuming she times it right, how long will it take her to reach the crest of the wave she is diving into?

(2 marks)

b) What will be her maximum height in her trajectory above the sea floor?

(2 marks)

c) The cliff sticks out a maximum distance of 5.00 metres horizontally from the takeoff point. This occurs 20.0 m above the sea floor. By how much will the physics student clear this point?

(3 marks)

d) The waves at the bottom of the cliff have an amplitude of 1.50 m. If she miss-times her jump and lands in a wave trough, how much water will she be diving into?

(1 mark)

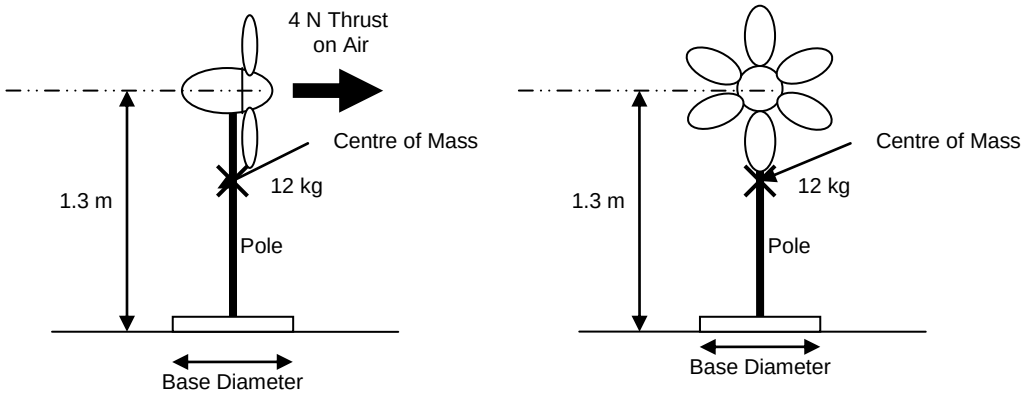
e) If the 55.0 kg student dives into the crest of a wave, what is the average frictional force of the water required to stop her in a distance of 8.00 m?

(3 marks)

**Question 15**

**(10 marks)**

A pedestal fan is a fan that sits at the top of a pole (pedestal) and directs air forwards to provide a cooling effect on hot days.




a) The electrical motor that turns the fan is connected to the mains in Australia. It has 200 windings in its single armature which has a total resistance of 22 Ω. It contains magnets with a magnetic field strength of 1.20 T. If the armature is square and encloses an area of 36 $cm^2$, what is the magnitude of the maximum torque exerted by the motor?

(3 marks)

b) As the fan spins faster and faster will the average torque exerted by the motor on the blades ...

(2 marks)

Increase Decrease Remains the Same

Explain

c) The fan blades when spinning at a constant rate, exert a force of 4.00 N on the air at right angles to the vertical pole holding the fan up. The mass of the fan setup is 12.0 kg. What is the minimum diameter of the circular base required by the fan to prevent the thrust of the fan from toppling it over?

(3 marks)

d) Spinning fans emit a low frequency hum when they turn. If the speed of the fan is increased, the frequency of the hum increases. If a fan with 6 blades turns at the rate of 3000 RPM, what is the frequency of the hum emitted by the fan?

(2 marks)

**Question 16**

**(9 marks)**

The earth is influenced by other objects with mass in the solar system.

a) What is the size of the moon's pull on the earth?

(3 marks)

b) What is the size of the Sun's pull on the earth?

(2 marks)

c) Why does the moon have a greater influence over the earth's tides than the sun?

(1 mark)

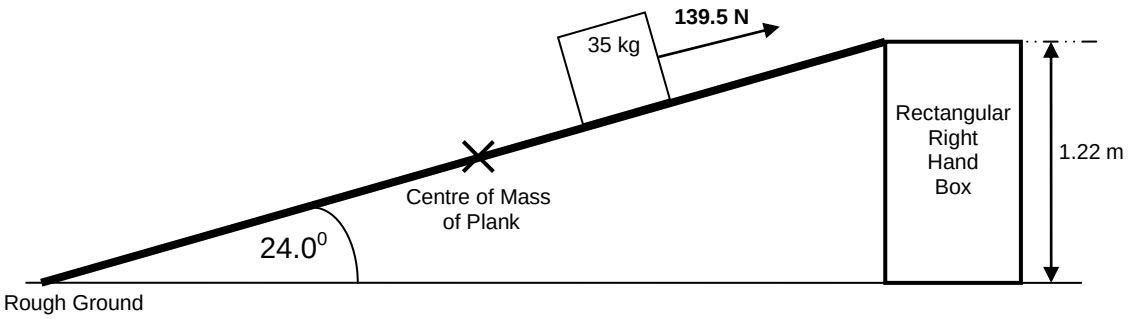
d) At what speed does the surface of the moon need to rotate on its axis if it always has the same side (face) pointing towards the earth. Note : Kepler's law may be useful here.

(3 marks)

**Question 17**

**(12 marks)**

A 35.0 kg crate of water is 2/3rds of the way up a frictionless 3.00 m long plank of wood. The plank has a mass of 20.0 kg. The plank has one end resting on rough ground. The other end of the plank is resting on the smooth corner of a rectangular box. The 139.5 N force acting on the 35.0 kg water crate holds the water crate stationary.




a) What is the force of the plank on the water crate?

(3 marks)

b) What is the force of the water crate on the plank?

(1 mark)

c) What is the force on the plank from the corner of the rectangular box? Assume the force of the corner of the box on the plank is at right angles to the plank.

(3 marks)

d) What is the force of the ground on the plank?

(3 marks)

e) If the 139.5 N force is removed, the 35.0 kg box slides down the slope. What is the speed of the box at the bottom of the slope?

(2 marks)

**Question 18**

**(12 marks)**

a) A closed organ pipe has a length of 1.60 m. What is the fundamental frequency of the pipe if the speed of sound in air is 346 m/s?

(3 marks)

b) A string on a double base starts to resonate to the sound of the organ pipe. The string has a length of 1.10 m. What is the speed of the vibrations (sound) in the string?

(3 marks)

c) The double base string is now made to resonate at its second harmonic. Will the organ pipe in turn resonate to the sound from the string? Explain.

(2 marks)

d) Draw the $7^{th}$ harmonic in the 1.60 m long closed pipe below and calculate the inter-nodal distance.

(2 marks)

Inter-nodal distance calculation.

e) The fundamental wavelength produced by the closed organ pipe was actually longer than predicted. This was caused by a phenomenon called “end effects”. Why was the actual wavelength produced by the pipe longer than that predicted by the formulae?

(2 marks)

**Question 19**

**(12 marks)**

The visible emission spectrum of a hydrogen atom has three bright lines – red, blue-green, and violet. The blue-green line is caused by the emission of a photon as it moves from energy level 4 to energy level 2. The energy of each level (in eV) can be calculated using the formula.

$$E_n = \frac{-13.6}{n^2}$$

a) What is the energy of the photon emitted (in eV) that causes the blue-green line?

(3 marks)

b) What is the wavelength of this line in nanometres?

(2 marks)

c) The blue-green line of the hydrogen spectrum from a close galaxy is observed at 537.4 nm. The red shift (Z) can be calculated using the formula ...

$$Z = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$$

Calculate the red shift of the galaxy.

(1 mark)

d) For close galaxies receding at a relatively low velocity, the recessional velocity of the galaxy can be calculated from...

$$Z = \frac{v}{c}$$

where c is the speed of light. Use the value of the red shift from (c) to calculate the recessional velocity of the galaxy. Give your answer in km $s^{-1}$.

(2 marks)

e) Using Hubble's law...

$$v = H_0 D$$

Where

| Symbol | Description | Unit |
|---|---|---|
| v | velocity | km $s^{-1}$ |
| D | distance | Mpc |
| $H_0$ | 74.2 ± 3.6 | km $s^{-1}$ $Mpc^{-1}$ |
| | | |

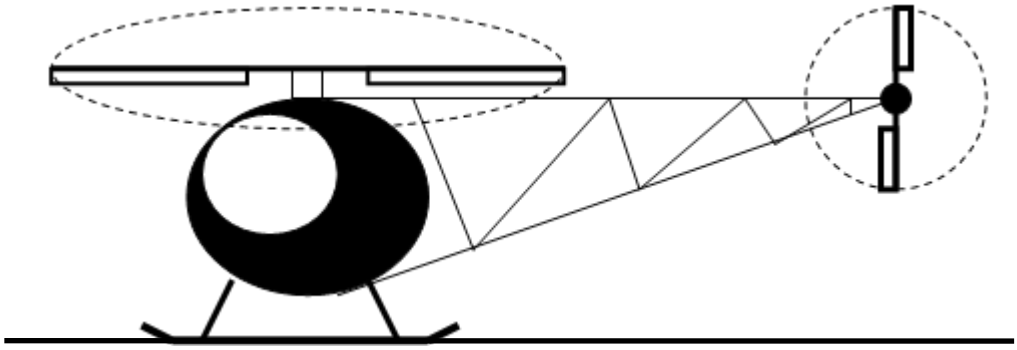
calculate the distance in light-years to this relatively close galaxy using the red shift value from part (c). Note 1megaparsec = 3.26 x $10^6$ light-years.

(4 marks)

**Question 20**

**(13 marks)**

A child has purchased a small remote control helicopter. The motor runs on a 7.20 V battery. The helicopter is sitting on the ground.



Ground

a) If the windings in the motor have a resistance when stationary of 7.00 ohms, what is the current flowing in the windings of the armature?

(2 marks)

b) The armature of the motor has 220 windings (turns) and a cross sectional area of 8.00 $cm^2$. The magnets in the motor have a field strength of 0.800 T. What is the maximum torque the motor can produce?

(3 marks)

c) If the helicopter blade has a diameter of 30.0 cm, what is the minimum force required on the tip of a blade to stop it from turning when the helicopter is first switched on, assuming the motor is exerting its maximum torque?

(2 marks)

d) An ammeter is connected to the motor in series. As the speed of the motor increases the current flowing in the motor decreases to almost zero when the motor is travelling at its top speed. Explain what is causing the current in the motor to reduce.

(3 marks)

e) Calculate the top theoretical speed of the motor in revolutions per minute (RPM) ignoring friction and air resistance?

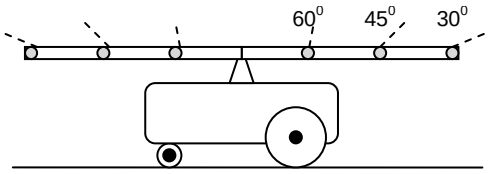
(3 marks)

**Question 21**

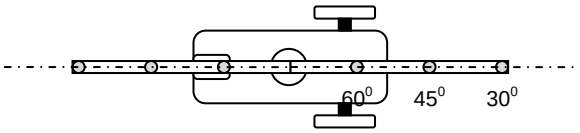
**(11 marks)**

A sprinkler has two hollow pipes that spin like helicopter blades squirting water out onto the lawn. Each blade has 3 holes spaced 10.0 cm apart. Each blade is 30.0 cm long. The hole closest to the centre of rotation projects the water at $60.0^0$ to the horizontal, the second at $45.0^0$ degrees and the last at $30.0^0$ degrees. Assume for simplicity that the droplets land at the same height from which they are released and that the arms of the sprinkler are not moving (not rotating).

Side View




Top View




For the questions below consider only one of the arms of the sprinkler.

a) If the water leaves each of the holes with a velocity of 7.00 m $s^{-1}$, circle and explain which hole or holes will produce water droplets with the greatest time of flight?

(2 marks)

b) Calculate the range of the droplets from each of the holes?

(3 marks)

c) The blades of the sprinkler now begin to rotate at a constant frequency of 45.0 RPM (revolutions per minute). What is the circular speed of $45^0$ holes in the blades of the sprinkle in m/s?

(3 marks)

d) Will the range of the droplets produced by the sprinkler increase, decrease or stay the same as a result of the circular motion of the sprinkler blades? Recalculate the range using the $45^0$ hole.

(3 marks)

Increase decrease stay the same Please circle on only

**End of Section Two**

**Section Three: Comprehension 20% (36 Marks)**

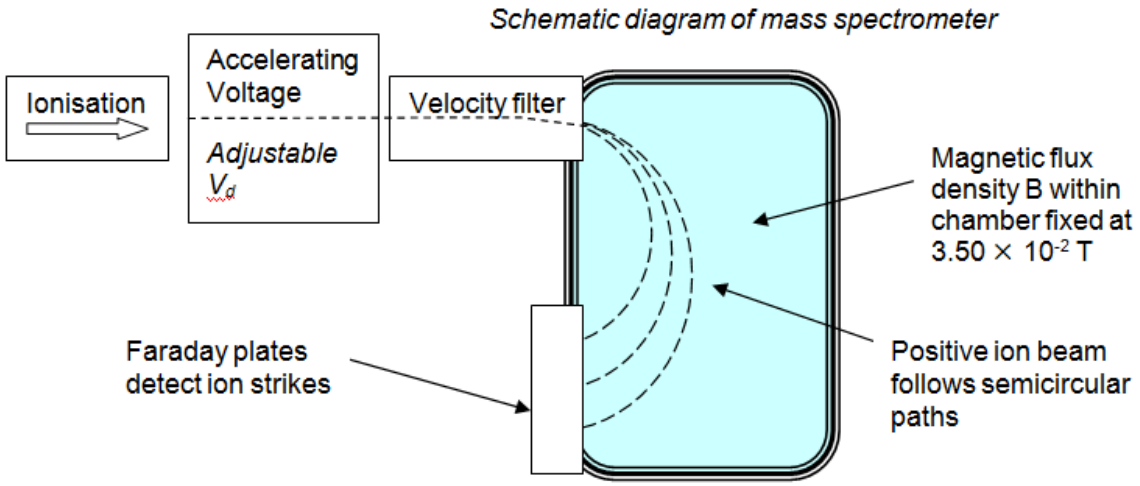
This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided. Suggested working time for this section is 40 minutes.

---

**Question 22 Using a mass spectrometer for a crime scene investigation. (18 marks)**

The Australian Federal Police has isolated an element found at a crime scene. They think the element may be sodium or potassium so have asked the forensic laboratory to run tests on the element to identify it. The laboratory is able to ionise the element to give it a single positive charge. They then accelerate the ions through a potential difference ($V_d$) and by use of a velocity filter are able to send ions that have reached their maximum kinetic energy into a mass spectrometer. When the ions enter the mass spectrometer they are acted on by a uniform magnetic field and follow a semi -circular path.

Technicians conduct a series of tests and measure the radius of circular motion for different values of potential difference used to accelerate the charged ions.




The table below shows the results obtained when the magnetic flux density B in the mass spectrometer was fixed at $3.50 \times 10^{-2}$ T. Measurements of radius have been expressed with an uncertainty of ±5% and radius squared with an uncertainty ±10%.

| Potential difference $V_d$ (volts) | Radius of circular path (metres) | Radius squared (metres squared) |
|---|---|---|
| 200 | 0.270 ± 0.014 | 0.073 ± 0.007 |
| 400 | 0.370 ± 0.019 | |
| 600 | 0.490 ± 0.025 | |
| 800 | 0.530 ± 0.053 | |
| 1000 | 0.620 ± 0.027 | |
| 1200 | 0.670 ± 0.034 | 0.449 ± 0.045 |

Mass of a potassium $K^+$ ion = $6.49 \times 10^{-26}$ kg  Mass of sodium $Na^+$ ion = $3.82 \times 10^{-26}$ kg

It can be shown that the radius ***r*** of circular motion for an ion of mass ***m*** and charge ***q***, entering the mass spectrometer at speed ***v*** and being deflected by a magnetic field of flux density ***B*** is as follows:

$$\boldsymbol{r = \frac{m.v}{q.B}}$$

Answer the following questions

a) Use the equation $r = \frac{m.v}{q.B}$ and other equations on the formulae and constant sheet that link the kinetic energy in (joules) attained by a mass of charge **q** (coulombs) in a potential difference $\mathbf{V_d}$ (volts) and derive the following expression:

(3 marks)

$$r^2 = \frac{2.m}{q.B^2}.V_d$$

The equation follows the format **y = mx + c** for values of $r^2$ plotted against $V_d$

b) Complete the table below by filling in the values of radius squared $\mathbf{r^2}$ with the appropriate uncertainty range. Two values have been done for you.

(3 marks)

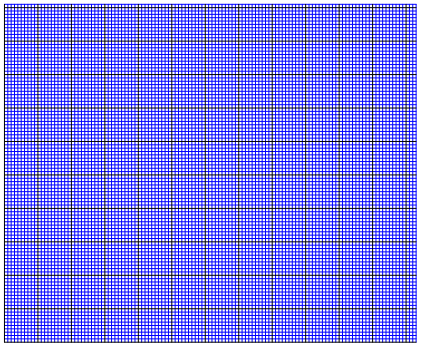
| Potential difference $V_d$ (volts) | Radius of circular path (metres) | Radius squared (metres squared) |
|---|---|---|
| 200 | 0.270 ± 0.014 | 0.073 ± 0.007 |
| 400 | 0.370 ± 0.019 | |
| 600 | 0.490 ± 0.025 | |
| 800 | 0.530 ± 0.053 | |
| 1000 | 0.620 ± 0.027 | |
| 1200 | 0.670 ± 0.034 | 0.449 ± 0.045 |

Mass of a potassium $K^+$ ion = $6.49 \times 10^{-26}$ kg  Mass of sodium $Na^+$ ion = $3.82 \times 10^{-26}$ kg

c) Plot the graph of $\mathbf{r^2}$ (vertical axis) versus **Potential difference $\mathbf{V_d}$** (horizontal axis) on the graph paper next to the table. Include error bars and a line of best fit.

(5 marks)

If you need to make a second attempt, spare graph paper is at the end of this question. Indicate clearly if you have used the second graph and cancel the working on the first graph.



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

(3 marks)

e) Use the value of the gradient that you obtained to calculate the mass of the charged ions. (If you could not obtain a gradient use the numerical value $4.00 \times 10^{-4}$)

(3 marks)

f) Based on the results you have calculated, what is the identity of the charged ion?

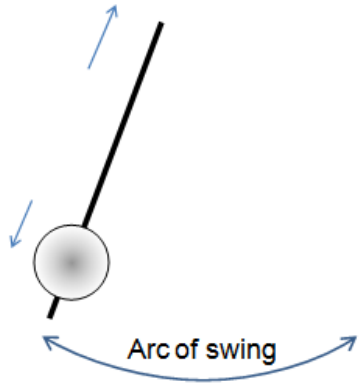
(1 mark)

**Question 23 Clocks (18 marks)**

Our lives are governed by time. The concept of a day divided into 24 hours originated in ancient Egypt. The hour divided into 60 minutes with each minute having 60 seconds has its origins in ancient Greece but is based on the astronomy of the older Babylonian and Sumerian cultures. It was not until the 14th century and the advent of mechanical clocks that hours of fixed length came into general use.

**Pendulum Clocks**

The pendulum clock was invented by the Dutch scientist Christiaan Huygens in 1656. A mass placed at the end of a string or rod will swing back and forth in a precise time interval depending on the length of the pendulum. The 'escapement' mechanism in this clock is powered by either a spiral spring that stores energy or by a weight hanging vertically down on a cord to turn a pulley. As the pendulum swings to one side the 'escapement' pushes on an arrangement of cogs and gears that rotate the hour and minute hands by small increments. This is audible as a 'tick'. The escapement also gives the pendulum a small push to compensate for the effects of atmospheric drag. A spring must be "wound up" every few days and a hanging weight needs to be lifted back to the top of its pulley position as it reaches its lowest point. A pendulum made from a bob (mass) attached at the end of an iron rod is susceptible to the effects of thermal expansion. For this reason the position of the bob can be adjusted on the rod to adjust the effective length of the pendulum. The introduction of pendulum clocks increased accuracy from about 15 minutes per day to about 15 seconds per day.




**Quartz Clocks**

If you look at your wristwatch or a wall mounted clock it is likely that you will see the word Quartz written on the face. Nowadays, timepieces using quartz technology are the most widely used in the world. A quartz clock uses an electronic oscillator regulated by a quartz crystal. The oscillator generates a very precise frequency which governs the mechanism.

Quartz (silicon dioxide) is a piezoelectric material. When it is bent it creates an electrical potential across planes in the crystal. This effect is used in reverse in a timepiece – when an electrical potential is connected across the crystal it resonates at a fixed frequency. The frequency is related to the shape, size and crystal plane of the quartz. Variations in temperature have a negligible effect on this frequency.


Quartz clocks use a quartz crystal that is a cantilever, laser trimmed into the shape of a small tuning fork and calibrated to oscillate at 32 768 Hz. This number is a power of two and is chosen so that simple digital logic circuits can derive the 1 Hz signal that indexes the second hand.

The formula for the fundamental frequency of vibration of a cantilever is as follows:

$$f = \frac{1.875^2}{2\pi} . \frac{a}{l^2} . \sqrt{\frac{E}{12\rho}}$$

Where

| Symbol | Definition |
|---|---|
| f | frequency |
| l | length |
| a | thickness |
| ρ | density |
| E | Young's Modulus |

A standard quality quartz watch will have an accuracy of around ±15 seconds per month. A quartz watch that has been 'rated' at the factory against an atomic clock can be regulated to have an accuracy of around ±10 seconds per year.

**Atomic Clocks**

The operation of an atomic clock is based on the principle of the emission of electromagnetic radiation when electrons in atoms change energy levels. Atomic clocks based on Caesium-133 have a cavity containing Cs-133 as a gas. The gas is stimulated by microwaves and controlled by an electronic amplifier which cause it to resonate and emit radiation at exactly 9 192 631 770 cycles per second. This is now the basis of the SI unit of time. Atomic clocks have an accuracy of one second per million years or better.

**Questions**

a) In a pendulum clock energy is required to advance the hour and minute hands. Describe one possible source of energy that the passage refers to and briefly describe the energy transformations that occur.

(2 marks)

b) Would it be practical to have a wristwatch based on a pendulum mechanism? Explain briefly.

(1 mark)

c) A certain pendulum clock is calibrated in the winter. In summertime the pendulum will need to be adjusted to keep more accurate time. The formula for the period of a pendulum is as follows:

$$T = 2.\pi\sqrt{\frac{l}{g}}$$

i. Explain what effect an increase in temperature would have on the accuracy of the clock. Will it run fast, slow or be unaffected?

(2 marks)

ii. Explain what adjustment would need to be made to the position of the bob on the end of the rod to compensate for the change in temperature.

(1 mark)

d) Is the quartz crystal in a watch behaving more like an electric generator or an electric motor? Explain briefly.

(2 marks)

e) The frequency of a crystal oscillator in a wristwatch is 32 768 Hz. Referring to the formula in the passage, calculate the length of a quartz crystal which has a thickness of 0.3 mm, Young's Modulus of $1.00 \times 10^{11}$ N $m^{-2}$ and a density of 2634 kg $m^{-3}$.

(3 marks)

f) The number 32 768 is a power of 2. (That means that 32 768 = $2^x$). Determine which power of 2 this is.

(1 mark)

g) Would a typical person's ear be able to hear the quartz crystal oscillating at 32 768 Hz? Explain briefly.

(2 marks)

h) Are atomic clocks based on the principle of "radioactivity"? Explain briefly.

(2 marks)

i) For the atomic clock described in the passage, calculate the difference in energy level values (joules) for the line emission referred to in the Caesium atom.

(2 marks)

**Semester Two Examination, 2012**

**Question/Answer Booklet**

# 3AB PHYSICS

Please place your student identification label in this box

## 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

Special items: non-programmable calculators satisfying the conditions set by the SCSA 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.

| | A | B | C | Total |
|---|---|---|---|---|
| Score | | | | |
| Out of | 54 | 90 | 36 | 180 |
| % | | | | |

## 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 | 15 | 15 | 50 | 54 | 30 |
| Section Two: Problem-solving | 8 | 8 | 90 | 90 | 50 |
| Section Three: Comprehension | 2 | 2 | 40 | 36 | 20 |
| | | | | | 100 |

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2012.* 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 to follow any instructions that are specific to a particular question.

4. Working or reasoning should be clearly shown when calculating or estimating answers.

5. Spare pages are included at the end of this booklet. 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 at the top of the page.

   - 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. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

**Section One: Short response 30% (54 Marks)**

This section has **15** questions. Answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. 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 at the top of the page.
- 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. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 50 minutes.

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**Question 1**

**(3 marks)**

If a bullet was shot from a gun, straight up into the air, physics predicts that the bullet should return directly back to the gun and re-enter the top of the gun's barrel. Explain three reasons why (in practice) this does not occur.

Air Resistance

The earth is spinning at a different speed to the speed of the bullet

Wind

Friction in the pipe / barrel of the gun is not even so results in a slight sideways movement.

**Question 2**

**(5 marks)**

A student has taken a part time job in a bakery. She is sick of spreading icing on the top of cakes. She decides to use an old record player to assist her. She places the cake in the middle of the record player and sets it turning at 33 ⅓ rpm (revolutions per minute). She places a blob of icing centrally on the cake. The icing blob has a diameter 8.00 cm.

a) What is the centripetal acceleration of the icing mixture at the edge of the blob?

(3 marks)

$a = v^2 / r$

$v = 2\pi r / T$

$f = 33.3 / 60 = 0.5555$ Hz
**$T = 1.80$ s**

$v = 2 \times 3.142 \times 0.04 / 1.8$
$v = 0.13964444$ m/s

$a = 0.13964444^2 / 0.04$
**$a = 0.487$ m s$^{-2}$ towards the centre of the circle.**

b) She switches off the record player when the icing reaches the edge of the 30.0 cm diameter cake. When she switches the record player off, where is the icing thickest? Why?

(2 marks)

The edge of the cake.

The inertia of the icing has carried the icing to the edge of the cake.

Other arguments can be made to the contrary. All marks are allocated to the explanation and none to the initial decision.

**Question 3**

**(4 marks)**

a) How fast would you need to shoot a bullet horizontally so that its trajectory (flight path) is parallel to the surface of the earth? Assume the experiment is carried out a sea level, there is no air resistance and that the bullet does not collide with any objects as it circles the earth.

(3 marks)

$mv^2 / r = G\ mm/r^2$
$v^2 = Gm/r$

$v^2 = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / 6.38 \times 10^6$
$v^2 = 6.241 \times 10^7$
**$v = 7910$ m/s ($7.91 \times 10^3$ m/s)**

Note that the rotation of the earth will have an effect. The assumption built into this answer is that it was show from pole to pole. For other answers see you teacher.

b) How much time does the person who fired the bullet have to get out of the way before the bullet circumnavigates the globe and hits them in the back?

(1 mark)

$v = 2\pi r/t$

$t = 2\pi r/v$

$t = 2 \times 3.142 \times 6.38 \times 10^6$ / **7910**

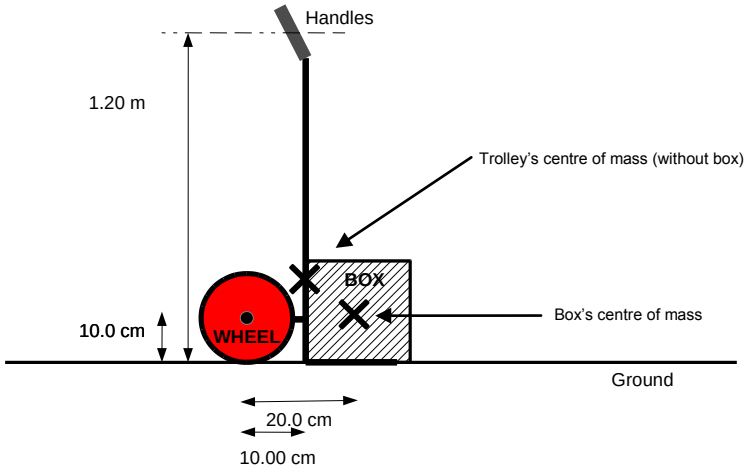
$t = 5074$ s

**$t = 5.07 \times 10^3$ s**

**Question 4**

**(4 marks)**

A person is moving house. They are using a "fridge trolley" to lift a heavy box. The box has a mass of 30.0 kg and the trolley has a mass of 10.0 kg.




a) With what force should the person pull <u>on each</u> of the two handles to tip the trolley?

(3 marks)

Take moments about the axle through the wheel
Mclock = M anti
(0.2 x 30 x 9.8) + (0.1 x 10 x 9.8) = (1.1 x 2F)
58.8 + 9.8 = 2.2 F
F = 31.1818 N
**F = 31.2 N**

b) In which direction will the trolley move the moment the box lifts off the ground?

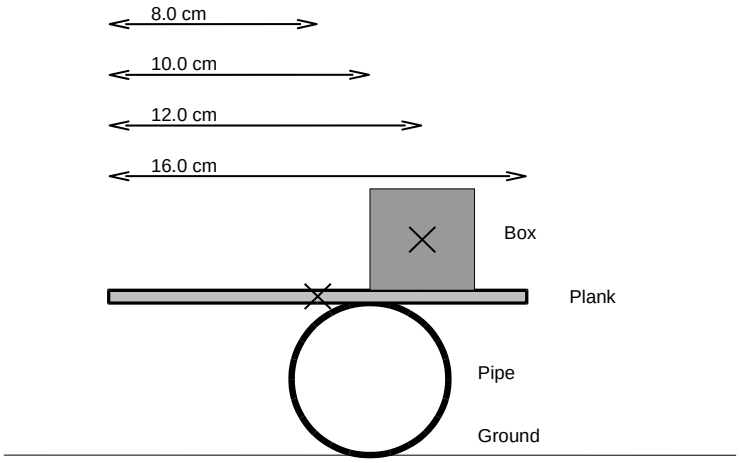
(1 mark)

To the left.

**Question 5**

**(4 marks)**

A stationary box of side length 4.00 cm is resting on a 16.0 cm plank. The plank is resting on a hollow pipe. The hollow pipe is resting on the ground.




a) In what type of equilibrium are the combined plank and box in when sitting on the pipe? Explain?

(2 marks)

Unstable equilibrium.

With a small nudge the system falls out of equilibrium and collapses.

The com of the box / plank system moves closer to the ground when nudged.

The com of the box / plank system acts outside of the base of the object causing it to topple.

b) What is the ratio of the mass of the box to the mass of the plank?

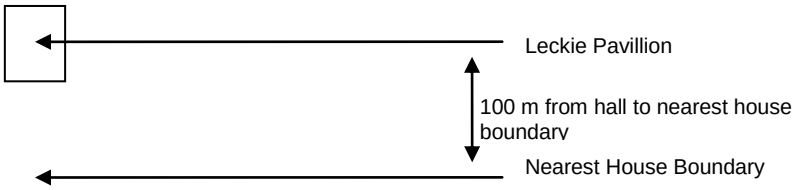
(2 marks)

Take moments about the point of contact between the plank and pipe.
M clock = M anti
$M_{box}$ x 0.02 = $M_{plank}$ x 0.02
**Ratio is 1:1**

**Question 6**

**(5 marks)**

"Leckie Pavillion" is a hall that sits in the middle of a large oval called "College Park" in Nedlands. It has recently been refitted (modified) to allow musical rehearsals and performances to take place inside it. The orchestra that plays in the hall is able to produce an intensity of 100 W $m^{-2}$ when playing at its loudest as measured at 2.00 m distance. Assume the ground is a perfect absorber.




a) If the orchestra were playing at its loudest on the roof of the hall in the open air, what would be the intensity of the "music" measured at the nearest house boundary at roof height?

(3 marks)

Calculate the power
$P = I \times A$
$P = 100 \times 4\pi 2^2$
$P = 1600\ \pi$
**$P = 5027.2$ W**

Calculate Intensity at house boundary
$I = P / A$
$I = 5027.2 / 4\pi 100^2$
**$I = 0.04$ W $m^{-2}$**

b) The council regulations state that the greatest intensity as measured at the nearest house boundary must not exceed $1 \times 10^{-3}$ W $m^{-2}$. By moving into the hall and playing with the doors and windows shut, the materials of the building will absorb some of the energy and so reduce the intensity of the sound. What percentage of the orchestra's greatest intensity must the building absorb so that that they just meet council regulations at the shortest boundary?

(2 marks)

Use true value formula

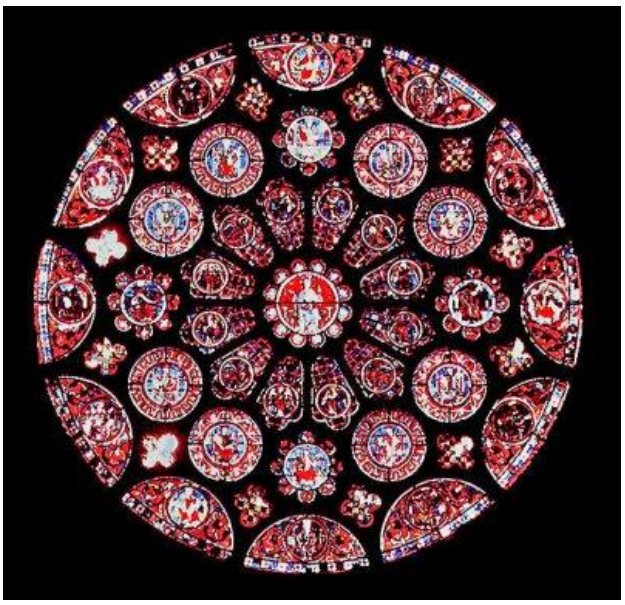
$$\% = \frac{(0.04 - 0.001)}{0.04} * 100$$

**% = 97.5 %**

**Question 7**

**(4 marks)**

"Chartres Cathedral" in France is memorable for many reasons, one of which is its beautiful stained glass windows. A television documentary "Ancient Megastructures" states that the windows contain a particular blue coloured glass manufactured in memory of Jesus' mother Mary. The documentary says that during its manufacture the originally clear (transparent) liquid glass was given its blue colour by mixing chemical salt(s) into the glass. According to the documentary "The exact combination of chemical salts the glass manufacturer took to his grave" (was never recorded).



a) What type of spectra is likely to be produced by this blue glass as shown in the stained glass window above? Please circle one answer from <u>each</u> line.

(1 mark)

Absorption Spectra  Emission Spectra

Line  Band  Continuous

b) Explain the reason for your answers above.

(1 mark)

White sunlight passes through the window and some of the colours are absorbed by the glass (removed leaving only the colour of the window to be transmitted.

The chemicals mixed into the glass are compounds rather than elements and so the absorption spectra is likely to be band.

c) Explain why physicists, using their knowledge of spectra, <u>could or could not</u> analyze the light transmitted by the blue glass to identify the chemical(s) present in the glass that give it its blue colour?

(2 marks)

Band spectra have indistinct boundaries and many chemicals absorb colours over the same bands. Consequently it is impossible to analyze the chemical.

**Question 8**

**(5 marks)**

A train carriage made of glass is moving forwards at 160 km $h^{-1}$. A person on the train throws a ball at 20.0 m $s^{-1}$ backwards towards the end of the carriage.

a) What is the velocity of the ball as observed by the person on the train?

(1 mark)

**20.0 m/s**

b) Calculate the velocity of the ball as observed by a person stationary on the ground outside the train watching the train go past?

(1 mark)

net velocity = (160 / 3.6) – 20
**v = 24.4 m/s**

c) The glass carriage has its velocity increased to 1.6 x $10^8$ m $s^{-1}$ forwards. The same person on the train shines a beam of blue torchlight backwards towards the end of the carriage. What is the speed of the light as measured by the person on the train?

(1 mark)

**3 x $10^8$ m/s**

d) What is the speed of the light as measured by the person on the platform?

(1 mark)

**3 x $10^8$ m/s**

e) After the carriage has passed the observer on the platform steps on to the tracks and looks at the carriage that has passed them. Does the receding torch light appear any different to the light when it passes them? Explain.

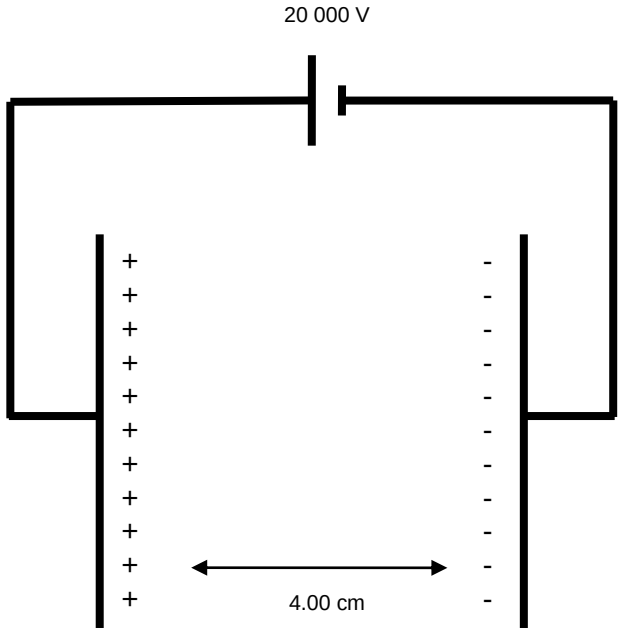
(1 mark)

Yes
The light has been red shifted.
It appears greener.

**Question 9**

**(3 marks)**

An electron is accelerated from rest by a uniform electric field that exists between two parallel plates separated by a distance of 4.00 cm. The potential difference between the plates is 20 000 V.




a) What is the speed of the electron just before it strikes the destination plate?

(2 marks)

$qV = \frac{1}{2} mv^2$
$1.6 \times 10^{-19} \times 20\,000 = \frac{1}{2} \times 9.11 \times 10^{-31} v^2$
$v^2 = 7.0252 \times 10^{15}$
**$v = 8.38 \times 10^7$ m/s**

b) If the distance of separation between the plates increased to 8.00 cm, and the process is repeated, will the electron accelerate faster or slower than in the original situation? Explain.

(1 mark)

Slower

The same velocity is accumulated over a larger distance.

The field strength is halved

The force is halved

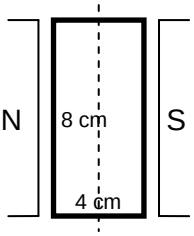
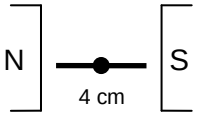
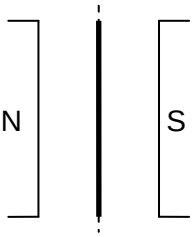
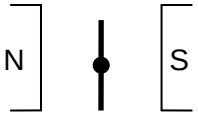
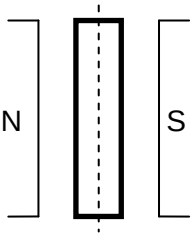
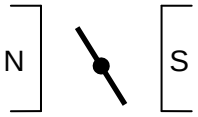
The acceleration is halved

**Question 10**

**(4 marks)**

A motor has 300 windings immersed in a uniform magnetic field of 0.0800 T. A current of 2.00 A runs in the windings. The rectangular armature has side lengths of 4.00 cm and 8.00 cm. What is the resultant force and resultant torque on the armature when the armature forms the following angles with the horizontal?

Note – perform calculations in the space **below the table** and put the answers into the table only.

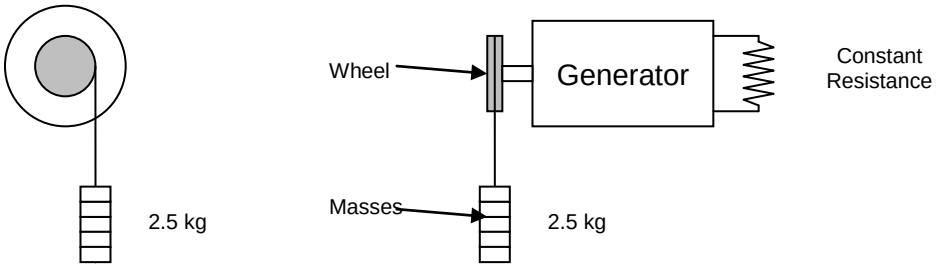
| Angle to field | Top View | Side View | Resultant Torque Magnitude | Resultant Force Magnitude |
|---|---|---|---|---|
| $0^0$ |  |  | M = 2r n IlB<br>M = 2x0.02x300x2x0.08 x 0.08<br>**M = 0.154 N m** | 0 N |
| $90^0$ |  |  | 0 N m | 0 N |
| $60^0$ |  |  | M = ½ x 0.154<br>**M = 0.0768 N m** | 0 N |

Space for working.

**Question 11**

**(4 marks)**

A 2.5 kg mass is attached to a string wrapped around a wheel. The wheel is connected to an electrical generator. The generator is connected to a constant size resistor. Once the mass gets going it falls at a constant rate of 12.0 cm per second. Assume there is no friction in the system.




a) If the potential to electrical conversion is 90.0 % efficient, what is the current output if the voltage output is 10.0 V?

(2 marks)

Power input is ...
P = Mgh / t = mgv
P = 2.5 x 9.8 x 0.12
**P = 2.94 W**

Power output is ....
P = 0.9 x 2.94
**P = 2.646 W**

P = VI
2.646 = 10 x I
**I = 0.265 A**

b) Why does the 2.50 kg mass fall at a constant rate (after initially accelerating up to the speed of 12.0 cm $s^{-1}$) instead of just accelerating continuously to the floor?

(2 marks)

Lenz's Law

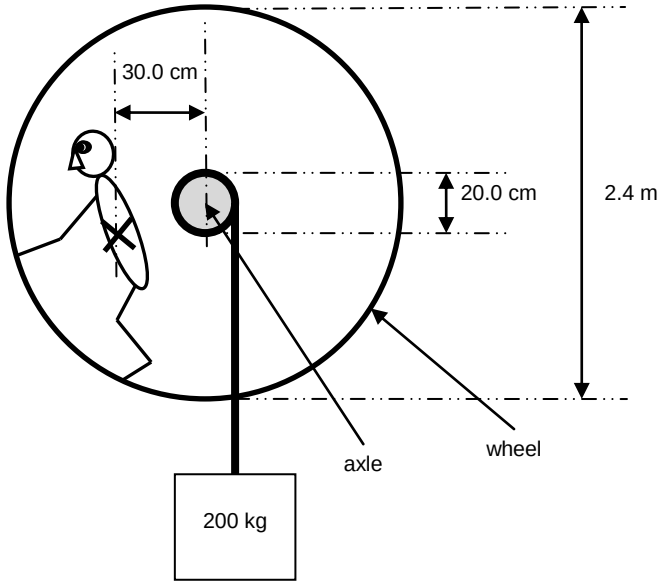
The weight force generates a current in the armature.

The current moving in the armature generates an opposing force to the movement of the armature.

**Question 12**

**(4 marks)**

A treadmill was a machine used to power mechanical devices during the medieval period. A person or persons walk around inside the barrel shaped circle like a mouse running around inside a mouse wheel.




a) What mass of person is required to hold the 200 kg stone on the end of the rope stationary in the diagram above?

(2 marks)

M clock = M anti
200 x 0.1 x 9.8 = 0.3 x m x 9.8
**m = 66.7 kg**

b) If the person inside the treadmill takes a step forward in which direction will the stone move. Why?

(1 mark)

Up.
The moments anticlockwise are greater than the moments clockwise. This causes the treadmill system to accelerate in an anticlockwise direction.

c) The diameter of the treadmill is tripled and two 90.0 kg people are put walking inside it. As in the diagram for question a) the two people have their centres of mass 30.0 cm horizontally from the centre of the central shaft. The diameter of the shaft around which the rope is wrapped is not altered. What will be the maximum load liftable?

(1 mark)

M clock = M anti
M x 0.1 x 9.8 = 0.3 x 2 x 90 x 9.8
**m = 540 kg or 5.30 x $10^3$ N**

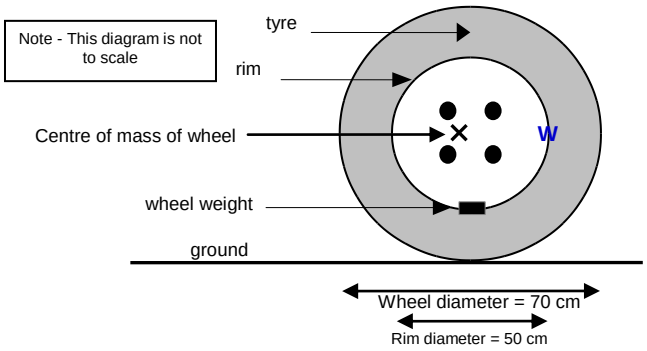
**Question 13**

**(5 marks)**

When car tyres are fitted to car wheel rims, the centre of mass of the tyre and rim are not usually in the exact centre of the wheel. This can cause an unbalanced centripetal force to act on the wheel creating a vibration that can be felt through the steering wheel.

a) If the centre of mass of the 30.0 kg wheel is 0.200 mm to the left of centre, what will be the unbalanced centripetal force acting on the wheel if the outer part of the tyre is rotating at 20 m $s^{-1}$?

(3 marks)




$F = mv^2 / r = m\ 4 \times \pi^2\ r^2/T^2 r = m4\pi^2 r/T^2$
$T = s / v = 2\ \pi\ 0.35/\ 20$
**$T = 0.10996$**
$F = 30 \times 4 \times 3.142^2\ 0.0002/$**$0.10996^2$**
**F = 19.6N towards the centre of the wheel**

To fix the problem a wheel weight can be clipped to the outer rim of the wheel, to generate an equal but opposite centripetal force

Diagrams of a car wheel with a wheel weight clipped on to the rim.

b) On the line diagram at the top of the page place a "W" on the rim where the wheel weight must be attached to counter balance the centripetal force of the wheel.

(1 mark)

c) Wheel weights come in different sizes in 5 gram increments (e.g. 5 g, 10 g, 15 g etc) and the person that fits the tyre to the rim will use the correct weight required to the nearest 5 grams. Based on you answer to part a) what mass wheel weight to the nearest 5 g will be required to balance the wheel?

(1 mark)

$F = mv^2/r = m4\pi^2 r/T^2$
$19.6N = m\ 4x3.142^2x0.25/$**$0.10996^2$**
$m = 0.024$
to the nearest 5 grams this is **25 grams**

**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.

Spare pages are included at the end of this booklet. 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 at the top of the page.
- 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. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 90 minutes.

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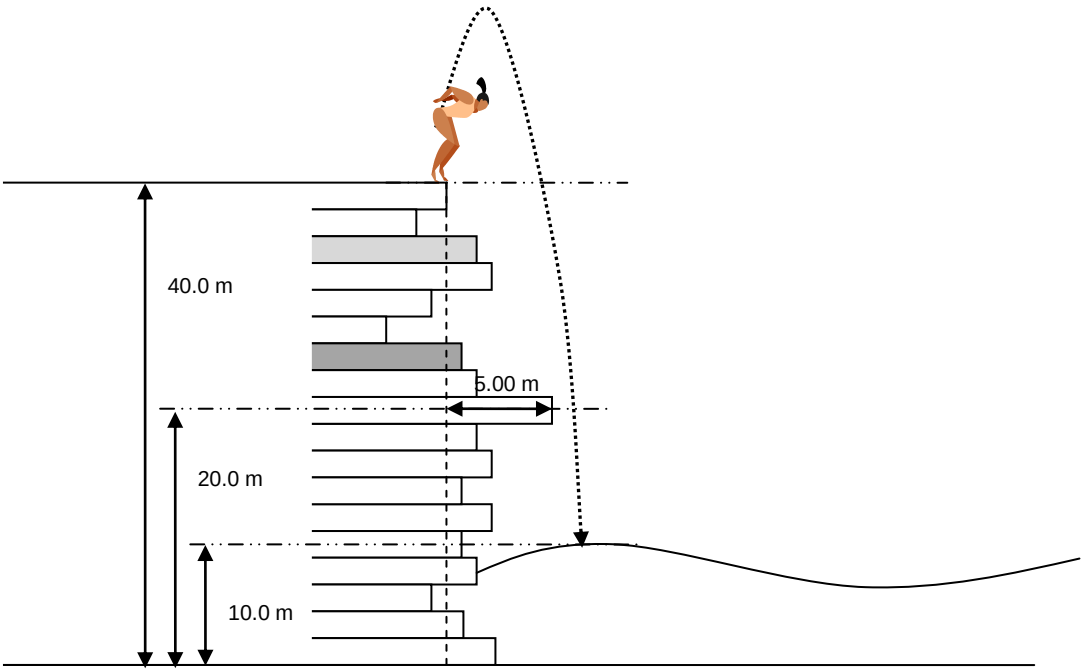
**Question 14**

**(11 marks)**

Cliff diving is a stupid idea. A physics student who is intelligent but lacks common sense decides to try it. Unfortunately the water at the bottom of the cliff is shallow. The student must time the jump just right so that they dive into the crest of a wave rather than a trough to avoid colliding with the sea floor.




a) The physics student jumps up and out away from the top of the cliff at an angle of $40.0^0$ above the horizontal with a velocity of 4.50 m $s^{-1}$. Assuming she times it right, how long will it take her to reach the crest of the wave she is diving into?

(2 marks)

$v^2 = u^2 + 2as$
$v^2 = (4.5 \text{ Sin } 40)^2 + 2 (-9.8) -30$
$v^2 = 8.3667 + 588$
$v^2 = 596.3667$
**v = 24.4 m/s down**

$v = u + at$
$-24.4 = 4.5 \text{ Sin } 40 + (-9.8) t$
**t = 2.79 s**

b) What will be her maximum height in her trajectory above the sea floor?

(2 marks)

$v^2 = u^2 + 2as$
$0 = 4.5 \text{ Sin } 40^2 + 2 \times (-9.8) \times s$
$0 = 8.3669 - 19.6s$
$-8.3669 = -19.6\ s$
**$s = 0.427$ m**

**$s_{\text{above sea floor}} = 40.427$ m**

c) The cliff sticks out a maximum distance of 5.00 metres horizontally from the takeoff point. This occurs 20.0 m above the sea floor. By how much will the physics student clear this point?

(3 marks)

| **V** | **H** |
|---|---|
| $v^2 = u^2 + 2as$<br>$v^2 = 4.5 \text{ Sin } 40^2 + 2 \times -9.8 \times -20$<br>$v^2 = 8.3669 + +392$<br>$v^2 = 400.3669$<br>**$v = 20.009$ m/s down**<br><br>$v = u + at$<br>$-20.0 = 4.5 \sin 40 + (-9.8)\ t$<br>$-22.89 = -9.8\ t$<br>**$t = 2.33$ s** | $v = s / t$<br>$4.5 \text{ Cos } 40 = s / 2.33$<br>$s = 4.5 \text{ Cos } 40 \times 2.33$<br>**$s = 8.03197$ m**<br><br>Clearance = 8.03197 – 5.00<br>**Clearance = 3.03 m** |

d) The waves at the bottom of the cliff have an amplitude of 1.50 m. If she miss-times her jump and lands in a wave trough, how much water will she be diving into?

(1 mark)

10 = 3.0 = **7.00 m**

e) If the 55.0 kg student dives into the crest of a wave, what is the average frictional force of the water required to stop her in a distance of 8.00 m?

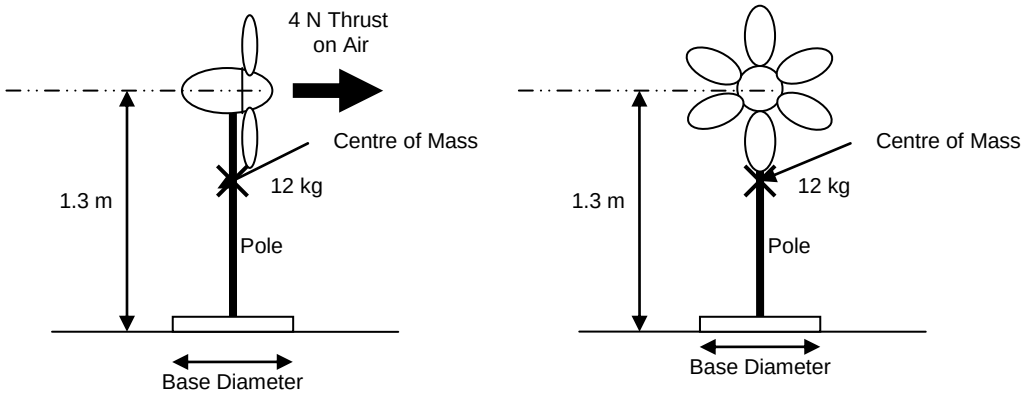
(3 marks)

$Fs = ½\ m\ v^2$
$F = 0.5 \times 55 \times 24.4^2 / 8$
**$F = 2046.55$ N**

**Question 15**

**(10 marks)**

A pedestal fan is a fan that sits at the top of a pole (pedestal) and directs air forwards to provide a cooling effect on hot days.




a) The electrical motor that turns the fan is connected to the mains in Australia. It has 200 windings in its single armature which has a total resistance of 22 Ω. It contains magnets with a magnetic field strength of 1.20 T. If the armature is square and encloses an area of 36 $cm^2$, what is the magnitude of the maximum torque exerted by the motor?

(3 marks)

V = IR
240 = I x 22
**I = 10.91A**

M = rF
M = 2rnIlB
M = AnIB
M = 36 x $10^{-4}$ x 200 x (240 / 22) 1.20
M = 9.4254 N m
**M = 9.43 N m**

b) As the fan spins faster and faster will the average torque exerted by the motor on the blades ...

(2 marks)

Increase (Decrease) Remains the Same

Explain

Lenz's Law

Back EMF

The current flowing in the magnetic field exerts a force on the wires creating movement. The movement of the wires in the magnetic field exerts a force on the charges in the opposite direction to the current. This can be described as an opposing EMF or back EMF which reduces the net voltage applied to the circuit and hence the current flowing and hence reduces the torque.

c) The fan blades when spinning at a constant rate, exert a force of 4.00 N on the air at right angles to the vertical pole holding the fan up. The mass of the fan setup is 12.0 kg. What is the minimum diameter of the circular base required by the fan to prevent the thrust of the fan from toppling it over?

(3 marks)

M clock = M anti
Wt x r of base = height x thrust
12 x 9.8 x r = 1.3 x 4
**r = 0.0442 m**

**d = 8.84 x $10^{-2}$ m**

d) Spinning fans emit a low frequency hum when they turn. If the speed of the fan is increased, the frequency of the hum increases. If a fan with 6 blades turns at the rate of 3000 RPM, what is the frequency of the hum emitted by the fan?

(2 marks)

f of 1 revolution = 3000 / 60
f = 50 turns per second

Each blade creates a pressure fluctuation or pulse.

F sound = 50 x 6
**F sound = 3.00 x $10^{2}$ Hz**

**Question 16**

**(9 marks)**

The earth is influenced by other objects with mass in the solar system.

a) What is the size of the moon's pull on the earth?

(3 marks)

$F = G\ m\ m / r^2$
$F = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 7.35 \times 10^{22} / (3.94 \times 10^{8})^2$
**$F = 1.89 \times 10^{20}$ N** **($3.166 \times 10^{-5}$ m s$^{-2}$ but not the best answer (-1))**

b) What is the size of the Sun's pull on the earth?

(2 marks)

$F = G\ m\ m / r^2$
$F = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 1.99 \times 10^{30} / (1.50 \times 10^{11})^2$
**$F = 3.52 \times 10^{22}$ N** **($3.896 \times 10^{-3}$ m s$^{-2}$ but not the best answer (-1))**

c) Why does the moon have a greater influence over the earth's tides than the sun?

(1 mark)

The rate of change of the moons gravitational field on the earth is greater than that of the sun on the earth. The moons field hence produces a greater difference on the acceleration of the waters of the earth from one side to the other.

d) At what speed does the surface of the moon need to rotate on its axis if it always has the same side (face) pointing towards the earth. Note : Kepler's law may be useful here.

(3 marks)

$R^3 / T^2 = GM / 4\pi^2$
$(3.94 \times 10^{8})^3 / T^2 = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / 4 \times 3.142^2$
$T^2 = 6.06384 \times 10^{12}$
**$T = 2.46 \times 10^{6}$ s**

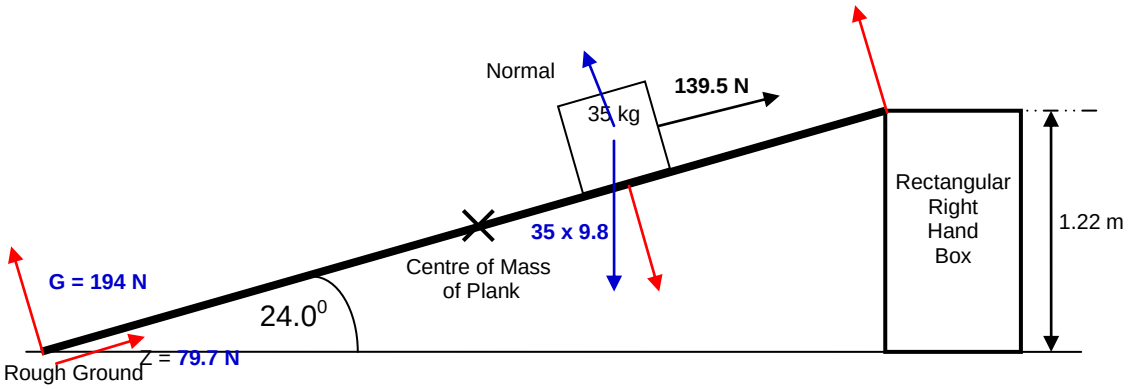
$v = s/t$
$v = 2\pi r / T$
$v = 2 \times 3.142 \times 1.74 \times 10^{6}$ / **$2.46 \times 10^{6}$ s**

**v = 4.44 m/s**

**Question 17**

**(12 marks)**

A 35.0 kg crate of water is 2/3rds of the way up a frictionless 3.00 m long plank of wood. The plank has a mass of 20.0 kg. The plank has one end resting on rough ground. The other end of the plank is resting on the smooth corner of a rectangular box. The 139.5 N force acting on the 35.0 kg water crate holds the water crate stationary.




a) What is the force of the plank on the water crate?

(3 marks)

Lami's Theorem

$$\frac{F}{\sin\theta} = \frac{F}{\sin\theta}$$

$$\frac{343}{\sin 90} = \frac{\text{Normal}}{\sin(90 + 24)}$$

Normal = 313.34 N
**Normal = 313 N**

b) What is the force of the water crate on the plank?

(1 mark)

**313 N (into the plank at right angles)**

c) What is the force on the plank from the corner of the rectangular box? Assume the force of the corner of the box on the plank is at right angles to the plank.

(3 marks)

Take moments about the bottom of the plank

M clock = M anti

$(2 \times 313) + (1.5 \times 20 \times 9.8 \cos 24) = 3 \times F_{box}$
$(626) + (268.58) = 3 \times F_{box}$

**$F_{box}$ = 298 N**

d) What is the force of the ground on the plank?

(3 marks)

Sum of the forces at right angles to the plank

F up and to left = F down and to the right
298 + G = 313 + 20 x 9.8 x Cos 24
298 + G = 313 + 179
**G = 194 N**

Sum of the forces parallel with the plank that actually acts on the plank.

Note there is no friction between the box and the plank so the box does not contribute a force along the plank

F down the plank = F up the plank
20 x 9.8 x Sin 24 = Z
**Z = 79.7 N up the plank**

Sum the forces

$R^2 = 194^2 + 79.7^2$
R = 209.7 N
R = 210 N

Angle

Tan θ = 194 / 79.7
θ = 67.6 degrees

Final Answer
**210 N at 67.6 degrees to the plank (above the plank)**

**Or**

**210 N at 1.66 degrees to the vertical away from the plank**

e) If the 139.5 N force is removed, the 35.0 kg box slides down the slope. What is the speed of the box at the bottom of the slope?

(2 marks)

W = Fs
$Fs = ½ mv^2$
$139.5 \times 2 = ½ \times 35 \times v^2$
$v^2 = 15.94$
**v = 3.99 m/s**

**Question 18**

**(12 marks)**

a) A closed organ pipe has a length of 1.60 m. What is the fundamental frequency of the pipe if the speed of sound in air is 346 m/s?

(3 marks)

f = nv/4L
f = 1 x 346 / 4 x 1.6
**f = 54.0625 Hz**
**f = 54.1 Hz**

b) A string on a double base starts to resonate to the sound of the organ pipe. The string has a length of 1.10 m. What is the speed of the vibrations (sound) in the string?

(3 marks)

f = nv / 2L
54.0625 = 1 x v / 2 x 1.10
v = 118.9375
**v = 119 m/s**

c) The double base string is now made to resonate at its second harmonic. Will the organ pipe in turn resonate to the sound from the string? Explain.

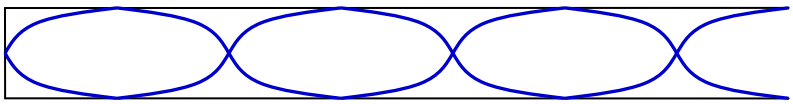
(2 marks)

No

The closed pipe will not resonate to a second harmonic. It only resonates to odd numbered harmonics.

d) Draw the $7^{th}$ harmonic in the 1.60 m long closed pipe below and calculate the inter-nodal distance.

(2 marks)



Inter-nodal distance calculation.

Internodal distance is 2/7ths of pipe
1.6 x 2 / 7 = internodal distance

**Internodal distance = 0.457 m**

e) The fundamental wavelength produced by the closed organ pipe was actually longer than predicted. This was caused by a phenomenon called “end effects”. Why was the actual wavelength produced by the pipe longer than that predicted by the formulae?

(2 marks)

The air continues to resonate beyond the pipe. This is because the air in the pipe becomes collimated even beyond the end of the pipe so performing an extension to the pipe.

**Question 19**

**(12 marks)**

The visible emission spectrum of a hydrogen atom has three bright lines – red, blue-green, and violet. The blue-green line is caused by the emission of a photon as it moves from energy level 4 to energy level 2. The energy of each level (in eV) can be calculated using the formula.

$$E_n = \frac{-13.6}{n^2}$$

a) What is the energy of the photon emitted (in eV) that causes the blue-green line?

(3 marks)

It is suspected that this is due to a transition between n = 4 and n = 2 based on our knowledge of the Balmer series.

$E_2$ = -13.6 / 4
**$E_2$ = 3.4 eV**

$E_4$ = -13.6 / 16
**$E_4$ = 0.85 eV**

Energy released when electron transitions downwards
ΔE = 3.4 – 0.85
**ΔE = 2.55 eV = 4.08 x $10^{-19}$ J**

To confirm suspicions
ΔE = hf
4.08 x $10^{-19}$ = 6.63 x $10^{-34}$ x f
**f = 6.154 x $10^{14}$ Hz**

b) What is the wavelength of this line in nanometres?

(2 marks)

c = f x λ
3 x $10^8$ = 6.154 x $10^{14}$ x λ
**λ = 4.875 x $10^{-7}$ = 487.5 nm**

c) The blue-green line of the hydrogen spectrum from a close galaxy is observed at 537.4 nm. The red shift (Z) can be calculated using the formula ...

$$Z = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$$

Calculate the red shift of the galaxy.

(1 mark)

Z = (537.4 – 487.5) / 487.5
Z = 0.10236
**Z = 0.102**

d) For close galaxies receding at a relatively low velocity, the recessional velocity of the galaxy can be calculated from...

$$Z = \frac{v}{c}$$

where c is the speed of light. Use the value of the red shift from (c) to calculate the recessional velocity of the galaxy. Give your answer in km $s^{-1}$.

(2 marks)

$Z = v / c$
$0.102 = v / 3 \times 10^8$
$v = 30707692.31$ m/s
$v = 30707.69231$ km/s
**$v = 3.07 \times 10^4$ km/s**

e) Using Hubble's law...

$$v = H_0 D$$

Where

| Symbol | Description | Unit |
|---|---|---|
| v | velocity | km $s^{-1}$ |
| D | distance | Mpc |
| $H_0$ | 74.2 ± 3.6 | km $s^{-1}$ $Mpc^{-1}$ |
| | | |

calculate the distance in light-years to this relatively close galaxy using the red shift value from part (c). Note 1megaparsec = $3.26 \times 10^6$ light-years.

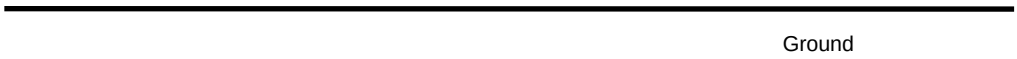
(4 marks)

$v = H_0 D$
$3.07 \times 10^4 = 74.2 \times D$
**D = 414 M pc**

**Question 20**

**(13 marks)**

A child has purchased a small remote control helicopter. The motor runs on a 7.20 V battery. The helicopter is sitting on the ground.




a) If the windings in the motor have a resistance when stationary of 7.00 ohms, what is the current flowing in the windings of the armature?

(2 marks)

$V = IR$
$7.2 = I \times 7$
**$I = 1.0285$ A**
**$I = 1.03$ A**

b) The armature of the motor has 220 windings (turns) and a cross sectional area of 8.00 $cm^2$. The magnets in the motor have a field strength of 0.800 T. What is the maximum torque the motor can produce?

(3 marks)

$M = nAIB$
$M = 220 \times 8 \times 10^{-4} \times 1.03 \times 0.8$
**$M = 0.145$ N m**

c) If the helicopter blade has a diameter of 30.0 cm, what is the minimum force required on the tip of a blade to stop it from turning when the helicopter is first switched on, assuming the motor is exerting its maximum torque?

(2 marks)

$M = rF$
$0.145 = 0.15 \times F$
**$F = 0.967$ N**

d) An ammeter is connected to the motor in series. As the speed of the motor increases the current flowing in the motor decreases to almost zero when the motor is travelling at its top speed. Explain what is causing the current in the motor to reduce.

(3 marks)

Back EmF

Lenz's Law

As the current flows in the armature a force is exerted on the armature resulting in motion.

The motion of the wires through the magnetic field exerts a force on the charges in the wire in the opposite direction of the current. The opposing current reduces the net current flow and hence reduces the torque on the motor.

e) Calculate the top theoretical speed of the motor in revolutions per minute (RPM) ignoring friction and air resistance?

(3 marks)

EMF = -n (BA – BA) / T
$7.2 = 220 (0.8 \times 8 \times 10^{-4} - 0) / \frac{1}{4} T$
$\frac{1}{4} T = 0.01955555555$
$T = 0.078222222$ s
$f = 12.78409$ Hz

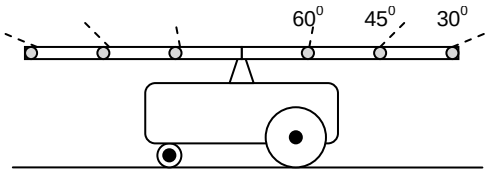
**f(RPM)= 767 RPM**

**Question 21**

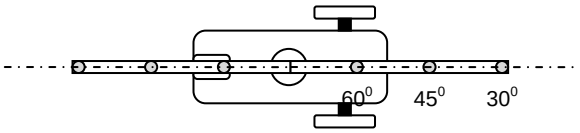
**(11 marks)**

A sprinkler has two hollow pipes that spin like helicopter blades squirting water out onto the lawn. Each blade has 3 holes spaced 10.0 cm apart. Each blade is 30.0 cm long. The hole closest to the centre of rotation projects the water at $60.0^0$ to the horizontal, the second at $45.0^0$ degrees and the last at $30.0^0$ degrees. Assume for simplicity that the droplets land at the same height from which they are released and that the arms of the sprinkler are not moving (not rotating).

Side View




Top View




For the questions below consider only one of the arms of the sprinkler.

a) If the water leaves each of the holes with a velocity of 7.00 m $s^{-1}$, circle and explain which hole or holes will produce water droplets with the greatest time of flight?

(2 marks)

**60 $^0$**

The water droplets fly the highest and so will spend the greatest time in the air.

b) Calculate the range of the droplets from each of the holes?

(3 marks)

| **60 $^0$** | **45 $^0$** | **30 $^0$** |
|---|---|---|
| v = u + at<br>-7 Sin 60 = 7 Sin 60 + (-9.8) t<br>-6.06 = +6.06 -9.8t<br>-12.12 = -9.8 t<br>**t = 1.237**<br><br>v = s / t<br>7 Cos 60 = s / 1.237<br>3.5 = s / 1.237<br>**s = 4.33 m** | v = u + at<br>-4.95 = 4.95 -9.8t<br>-9.90 = -9.8 t<br>**1.01 s**<br><br>v = s / t<br>7 Cos 45 = s / 1.01<br>4.95 = s / 1.01<br>**s = 5.00 m** | For projectiles landing at the same height 30 degrees and 60 degrees are equivalent ranges<br><br>**4.33 m** |

c) The blades of the sprinkler now begin to rotate at a constant frequency of 45.0 RPM (revolutions per minute). What is the circular speed of the $45^0$ holes in the blades of the sprinkle in m/s?

(3 marks)

$v = 2\pi r / t$

$f = 45$ rpm
$f = 45/60$
$f = 0.75$
**$T = 1.333$ s**

$v = 2 \times 3.142 \times 0.2 / 1.333$ s
**$v = 0.943$ m/s**

d) Will the range of the droplets produced by the sprinkler increase, decrease or stay the same as a result of the circular motion of the sprinkler blades? Recalculate the range using the $45^0$ hole.

(3 marks)

Increase (circled) decrease stay the same Please circle on only

The time of flight remains the same regardless as the vertical velocity is not altered.

The time of flight is 1.01 s

The horizontal range in line with the blade is as stated previously ... 5.00 m

The Horizontal range at right angles to the blade is due to the sideways velocity of the blade
$v_{horizontal} = 0.943$ m/s

**Sideways displacement**
$v = s / t$
$0.943 = s / 1.01$
**$s = 0.952$ m**

The total range is found using Pythagoras

$s_{total}^2 = (5^2 + 0.952^2)$
$s_{total}^2 = 25.9$
**$s_{total} = 5.09$ m**

**End of Section Two**

**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 40 minutes.

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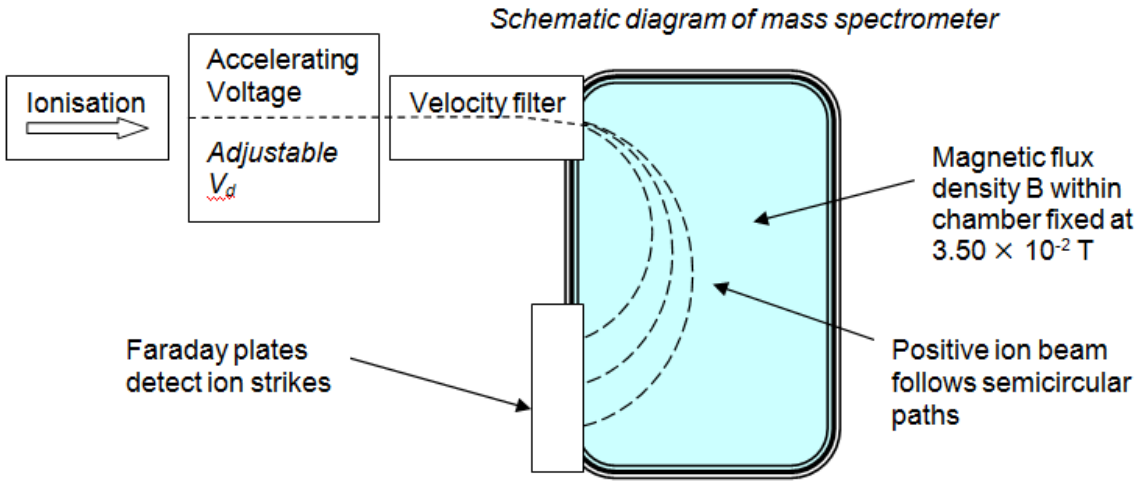
**Question 22 Using a mass spectrometer for a crime scene investigation. (18 marks)**

The Australian Federal Police has isolated an element found at a crime scene. They think the element may be sodium or potassium so have asked the forensic laboratory to run tests on the element to identify it. The laboratory is able to ionise the element to give it a single positive charge. They then accelerate the ions through a potential difference ($V_d$) and by use of a velocity filter are able to send ions that have reached their maximum kinetic energy into a mass spectrometer. When the ions enter the mass spectrometer they are acted on by a uniform magnetic field and follow a semi -circular path.

Technicians conduct a series of tests and measure the radius of circular motion for different values of potential difference used to accelerate the charged ions.




The table below shows the results obtained when the magnetic flux density B in the mass spectrometer was fixed at $3.50 \times 10^{-2}$ T. Measurements of radius have been expressed with an uncertainty of ±5% and radius squared with an uncertainty ±10%.

| Potential difference $V_d$ (volts) | Radius of circular path (metres) | Radius squared (metres squared) |
|---|---|---|
| 200 | 0.270 ± 0.014 | 0.073 ± 0.007 |
| 400 | 0.370 ± 0.019 | |
| 600 | 0.490 ± 0.025 | |
| 800 | 0.530 ± 0.053 | |
| 1000 | 0.620 ± 0.027 | |
| 1200 | 0.670 ± 0.034 | 0.449 ± 0.045 |

Mass of a potassium $K^+$ ion = $6.49 \times 10^{-26}$ kg  Mass of sodium $Na^+$ ion = $3.82 \times 10^{-26}$ kg

It can be shown that the radius ***r*** of circular motion for an ion of mass ***m*** and charge ***q***, entering the mass spectrometer at speed ***v*** and being deflected by a magnetic field of flux density ***B*** is as follows:

$$\boldsymbol{r = \frac{m.v}{q.B}}$$

Answer the following questions

a) Use the equation $r = \frac{m.v}{q.B}$ and other equations on the formulae and constant sheet that link the kinetic energy in (joules) attained by a mass of charge **q** (coulombs) in a potential difference $\mathbf{V_d}$ (volts) and derive the following expression:

(3 marks)

$$r^2 = \frac{2.m}{q.B^2}.V_d$$

The equation follows the format **y = mx + c** for values of $r^2$ plotted against $V_d$

$qV = ½\ mv^2$
$2qV/m = v^2$ (1)

$r = mv / qB$
$r^2 = m^2\ v^2 / q^2\ B^2$ (2)

Sub (1) into (2)

$r^2 = m^2\ 2qV / q^2B^2m$

**$r^2 = 2mV / qB^2$**

b) Complete the table below by filling in the values of radius squared $\mathbf{r^2}$ with the appropriate uncertainty range. Two values have been done for you.

(3 marks)

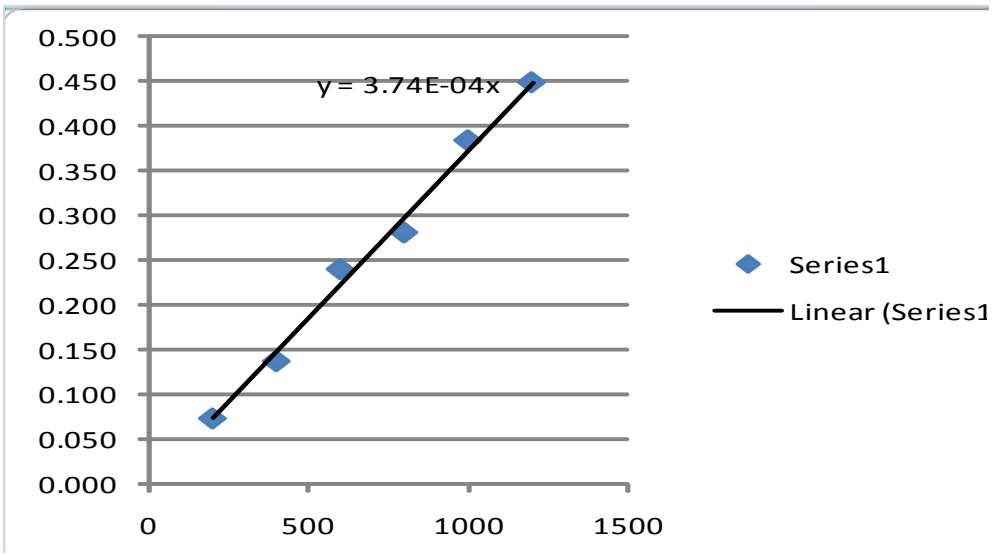
| Potential difference $V_d$ (volts) | Radius of circular path (metres) | Radius squared (metres squared) |
|---|---|---|
| 200 | 0.270 ± 0.014 | 0.073 ± 0.007 |
| 400 | 0.370 ± 0.019 | **0.137 + or – 0.014** |
| 600 | 0.490 ± 0.025 | **0.240 + or – 0.024** |
| 800 | 0.530 ± 0.053 | **0.281 + or – 0.028** |
| 1000 | 0.620 ± 0.027 | **0.384 + or – 0.038** |
| 1200 | 0.670 ± 0.034 | 0.449 ± 0.045 |

Mass of a potassium $K^+$ ion = $6.49 \times 10^{-26}$ kg  Mass of sodium $Na^+$ ion = $3.82 \times 10^{-26}$ kg

c) Plot the graph of $\mathbf{r^2}$ (vertical axis) versus **Potential difference $V_d$** (horizontal axis) on the graph paper next to the table. Include error bars and a line of best fit.

(5 marks)

If you need to make a second attempt, spare graph paper is at the end of this question. Indicate clearly if you have used the second graph and cancel the working on the first graph.




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

(3 marks)

**Slope = $3.74 \times 10^{-4}$**

e) Use the value of the gradient that you obtained to calculate the mass of the charged ions. (If you could not obtain a gradient use the numerical value $4.00 \times 10^{-4}$)

(3 marks)

Slope = $2m / qB^2$

$3.74 \times 10^{-4} = 2 \times m / 1.6 \times 10^{-19} \times (3.5 \times 10^{-2})^2$

**M = $3.6652 \times 10^{-26}$ kg**

f) Based on the results you have calculated, what is the identity of the charged ion?

(1 mark)

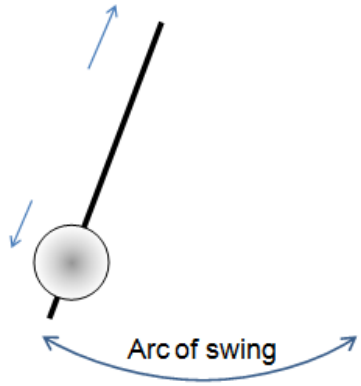
**Sodium (Na)**

**Question 23 Clocks (18 marks)**

Our lives are governed by time. The concept of a day divided into 24 hours originated in ancient Egypt. The hour divided into 60 minutes with each minute having 60 seconds has its origins in ancient Greece but is based on the astronomy of the older Babylonian and Sumerian cultures. It was not until the 14th century and the advent of mechanical clocks that hours of fixed length came into general use.

**Pendulum Clocks**

The pendulum clock was invented by the Dutch scientist Christiaan Huygens in 1656. A mass placed at the end of a string or rod will swing back and forth in a precise time interval depending on the length of the pendulum. The 'escapement' mechanism in this clock is powered by either a spiral spring that stores energy or by a weight hanging vertically down on a cord to turn a pulley. As the pendulum swings to one side the 'escapement' pushes on an arrangement of cogs and gears that rotate the hour and minute hands by small increments. This is audible as a 'tick'. The escapement also gives the pendulum a small push to compensate for the effects of atmospheric drag. A spring must be "wound up" every few days and a hanging weight needs to be lifted back to the top of its pulley position as it reaches its lowest point. A pendulum made from a bob (mass) attached at the end of an iron rod is susceptible to the effects of thermal expansion. For this reason the position of the bob can be adjusted on the rod to adjust the effective length of the pendulum. The introduction of pendulum clocks increased accuracy from about 15 minutes per day to about 15 seconds per day.




**Quartz Clocks**

If you look at your wristwatch or a wall mounted clock it is likely that you will see the word Quartz written on the face. Nowadays, timepieces using quartz technology are the most widely used in the world. A quartz clock uses an electronic oscillator regulated by a quartz crystal. The oscillator generates a very precise frequency which governs the mechanism.

Quartz (silicon dioxide) is a piezoelectric material. When it is bent it creates an electrical potential across planes in the crystal. This effect is used in reverse in a timepiece – when an electrical potential is connected across the crystal it resonates at a fixed frequency. The frequency is related to the shape, size and crystal plane of the quartz. Variations in temperature have a negligible effect on this frequency.


Quartz clocks use a quartz crystal that is a cantilever, laser trimmed into the shape of a small tuning fork and calibrated to oscillate at 32 768 Hz. This number is a power of two and is chosen so that simple digital logic circuits can derive the 1 Hz signal that indexes the second hand.

The formula for the fundamental frequency of vibration of a cantilever is as follows:

$$f = \frac{1.875^2}{2\pi} . \frac{a}{l^2} . \sqrt{\frac{E}{12\rho}}$$

Where

| Symbol | Definition |
|---|---|
| f | frequency |
| l | length |
| a | thickness |
| ρ | density |
| E | Young's Modulus |

A standard quality quartz watch will have an accuracy of around ±15 seconds per month. A quartz watch that has been 'rated' at the factory against an atomic clock can be regulated to have an accuracy of around ±10 seconds per year.

**Atomic Clocks**

The operation of an atomic clock is based on the principle of the emission of electromagnetic radiation when electrons in atoms change energy levels. Atomic clocks based on Caesium-133 have a cavity containing Cs-133 as a gas. The gas is stimulated by microwaves and controlled by an electronic amplifier which cause it to resonate and emit radiation at exactly 9 192 631 770 cycles per second. This is now the basis of the SI unit of time. Atomic clocks have an accuracy of one second per million years or better.

**Questions**

a) In a pendulum clock energy is required to advance the hour and minute hands. Describe one possible source of energy that the passage refers to and briefly describe the energy transformations that occur.

(2 marks)

Either a wound spring or a mass attached to a cord over a pulley.

Spring = elastic potential energy to kinetic

Mass = gravitational potential energy to kinetic.

b) Would it be practical to have a wristwatch based on a pendulum mechanism? Explain briefly.

(1 mark)

No.
The movement of the person would affect the swing of the pendulum and so distort the keeping of time.

c) A certain pendulum clock is calibrated in the winter. In summertime the pendulum will need to be adjusted to keep more accurate time. The formula for the period of a pendulum is as follows:

$$T = 2.\pi \sqrt{\frac{l}{g}}$$

i. Explain what effect an increase in temperature would have on the accuracy of the clock. Will it run fast, slow or be unaffected?

(2 marks)

It will run slow.
This is because the rod will expand increasing the effective length (expansion) of the pendulum.

ii. Explain what adjustment would need to be made to the position of the bob on the end of the rod to compensate for the change in temperature.

(1 mark)

The bob will have to be moved up the rod further from the ground to shorten the effective length of the pendulum.

d) Is the quartz crystal in a watch behaving more like an electric generator or an electric motor? Explain briefly.

(2 marks)

Like a motor
Electricity is applied to generate movement.

e) The frequency of a crystal oscillator in a wristwatch is 32 768 Hz. Referring to the formula in the passage, calculate the length of a quartz crystal which has a thickness of 0.3 mm, Young's Modulus of $1.00 \times 10^{11}$ N $m^{-2}$ and a density of 2634 kg $m^{-3}$.

(3 marks)

$$f = \frac{1.875^2}{2\pi} . \frac{a}{l^2} . \sqrt{\frac{E}{12\rho}}$$

$32\ 768 = 1.875^2 \times 0.0003 \times (1 \times 10^{11})^{½} / 2 \times \pi \times L^2 (12 \times 2634)^{1/2}$

$L^2 = 1.875^2 \times 0.0003 \times (1 \times 10^{11})^{½} / 2 \times \pi \times 32768 \times (12 \times 2634)^{1/2}$

$L^2 = 333.52 / 36603980.19$

**$L = 3.02 \times 10^{-3}$ m**

f) The number 32 768 is a power of 2. (That means that 32 768 = $2^x$). Determine which power of 2 this is.

(1 mark)

X = 15

g) Would a typical person's ear be able to hear the quartz crystal oscillating at 32 768 Hz? Explain briefly.

(2 marks)

No

Upper threshold of hearing is 20 000 Hz

h) Are atomic clocks based on the principle of "radioactivity"? Explain briefly.

(2 marks)

No

They are based on electron transitions between energy levels.

i) For the atomic clock described in the passage, calculate the difference in energy level values (joules) for the line emission referred to in the Caesium atom.

(2 marks)

f = 9 192 631 770

E = hf

E = $6.63 \times 10^{-34} \times 9\ 192\ 631\ 770$

**E = $6.09 \times 10^{-24}$ J**

**End of Exam**