



MLC Semester 2 Physics Examination, 2011

Question/Answer Booklet

PHYSICS

Stage 3

Please place your name 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

PART	MARK
A	/54
B	/90
C	/36
TOTAL	/180
	%

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 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	13	13	50	54	30
Section Two: Problem-solving	8	8	90	90	50
Section Three: Comprehension	2	2	40	36	20
					100

Instructions to candidates

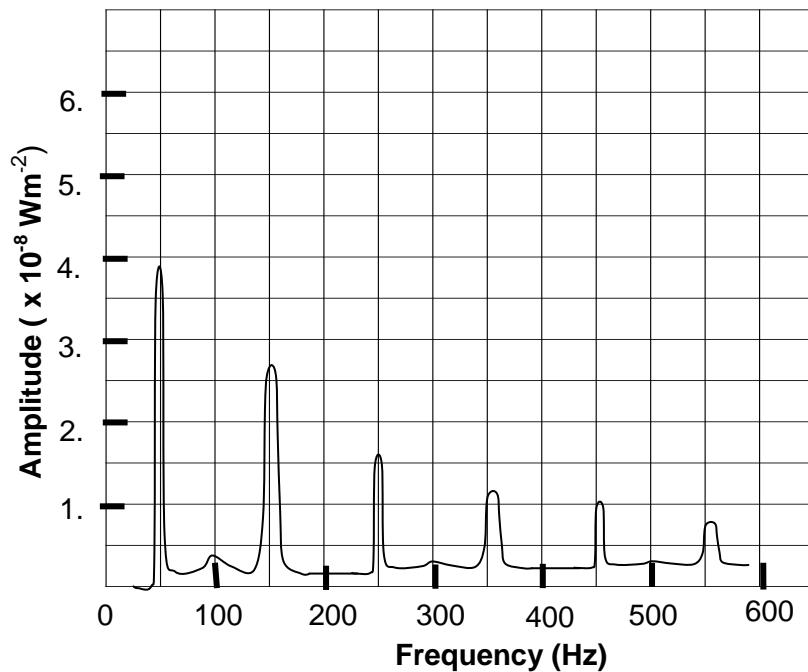
- The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2011*. Sitting this examination implies that you agree to abide by these rules.
- Write answers in this Question/Answer Booklet.
- You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
- Working or reasoning should be clearly shown when calculating or estimating answers.
- 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 answer**30% (54 Marks)**This section has **13** questions. Attempt **all** questions

Suggested working time 50 minutes.

Question 1**(4 marks)**

The graph below shows the sound spectrum for a woodwind musical instrument when a single note is being played. Study the graph and answer the questions.



- (a) What is the fundamental frequency of this instrument?
- (b) Is it an open or closed-pipe instrument? Explain your answer.

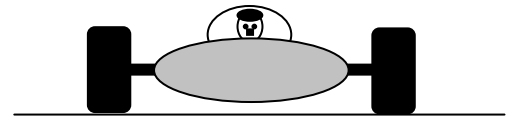
Question 2**(4 marks)**

The planet Neptune has a mass that is about 17 times that of Earth and a radius of 2.27×10^4 km. Calculate the magnitude of the gravitational field at the surface of the planet.

Question 3**(4 marks)**

Fast racing cars are built like the one illustrated in the diagram.

What two features of this racing car design make it particularly stable? Explain why each feature makes the car stable.



Feature 1:

Feature 2:

Question 4**(4 marks)**

By the year 1964 there had been over 100 sub-atomic particles discovered – so many that physicists of the time referred to the list as a “particle zoo”. Later that year Zweig and Gell-Mann suggested a simpler model using quarks, where less particles were required to describe the make-up of atoms.

(a) Explain how their model simplified our understanding of matter. (2 marks)

(b) Compare the composition of a **baryon** with that of a **meson**, according to the Zweig/Gell-Mann model. (2 marks)

Question 5**(4 marks)**

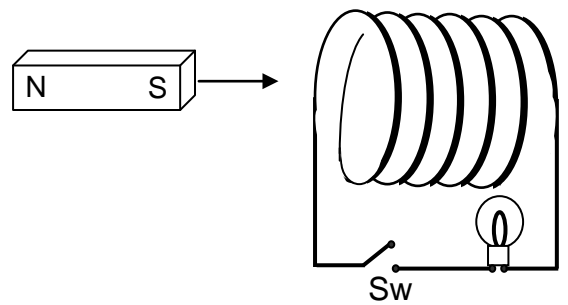
A Perth taxi has a vertical aerial on the back of it with a height of 1.85 m. If the taxi is driving westwards along the freeway at a speed of 90.0 km h^{-1} what would be the voltage induced in the aerial?

(Useful data: horizontal component of the Earth’s field strength is $2.11 \times 10^{-5} \text{ T}$ and the vertical component of the Earth’s field strength is $5.05 \times 10^{-5} \text{ T}$)

Question 6

(4 marks)

A magnet is pushed twice into the coil shown in the diagram. The first time it is pushed in the switch (Sw) is open, as shown, and the second time the switch is closed. The force needed to push the magnet into the coil is different in both cases.



Explain why the two forces are different.

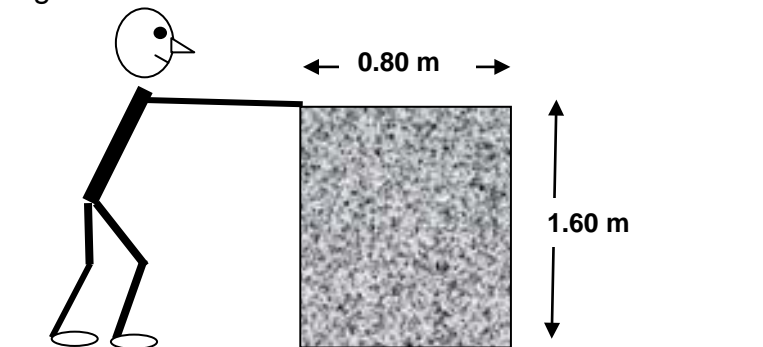
Question 7

(4 marks)

A man loading a truck wants to push a packing case over onto its side. The case has a mass of 250 kg and dimensions of 0.80 m (base) and 1.60 m (height).

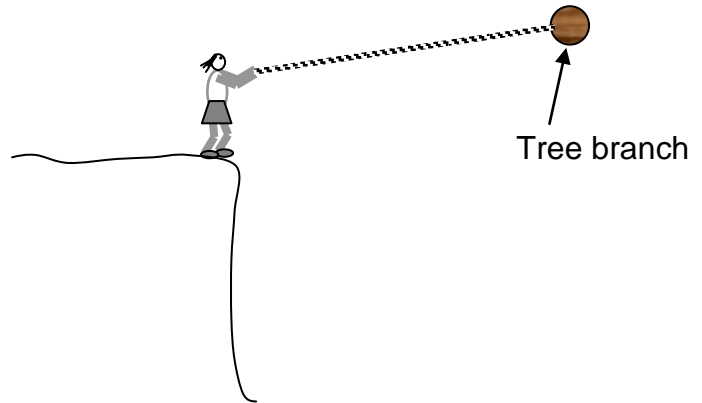
What minimum force must the man use if he is to tilt the case so the bottom end nearest to him rises off the ground?

(Assume a horizontal pushing force at the top and high friction at the bottom.)



Question 8**(4 marks)**

Jane swings from a cliff on a vine rope of length 9.50 m. At the bottom of his swing she has a speed of 8.50 m s^{-1} and can just hold onto the rope. Jane has a mass of 65.0 kg.



- (a) Calculate the centripetal force on Jane at the bottom.
- (b) Calculate the tension in the rope at the bottom of Jane's swing.

Question 9**(4 marks)**

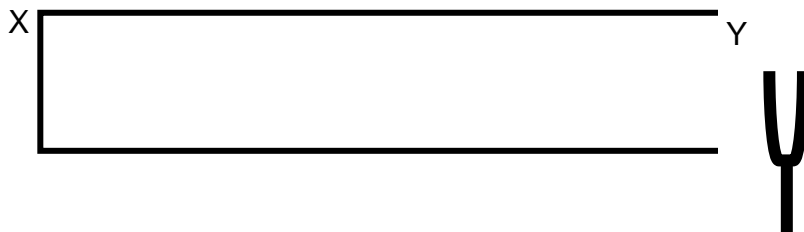
An engineer wants to design the banking for a curved section of road in the Victorian mountains that is often covered in ice. Calculate the banking angle that will allow a car to go round the bend safely on ice, without the need for friction from the tyres.

Use the following data: Mass of car = 1200 kg, Radius of curve = 80 m, Maximum speed of car = 72 km h^{-1} .

Question 10**(4 marks)**

Illustrate how a stationary wave can exist inside a closed length of pipe when a tuning fork is struck and held over its open end by drawing a pressure v's distance envelope for the 5th harmonic.

Describe the movement of air particles at each end X and Y.

**Question 11****(4 marks)**

A 5.40 metre long log rests on two bricks, each placed 1.00 m from its ends. The brick at the left end provides an upward force of 620 N while the other brick provides an upward force of 715 N.

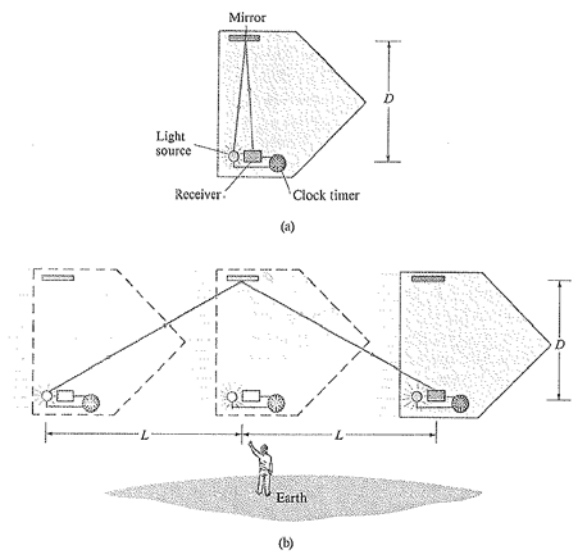
How far from the left end of the log is the centre of mass of the log?



Question 12

(6 marks)

The diagram at right shows a spacecraft moving past the Earth at very high speed. An astronaut on the spacecraft conducts a simple experiment (Figure (a)) whereby he reflects light emitted by a source from a mirror and back into a receiver, using a clock to measure the time taken by the light to cover this path. An observer on the Earth watches the experiment (Figure (b)) as the spacecraft flies past him and uses his own clock to measure the time taken by the light to cover the path from source to mirror and back to receiver.



- (a) Which physical quantity will the astronaut and the observer on Earth always measure to have exactly the same value?
- (b) The time measured by the astronaut for the light to cover this path is given by $t_1 = 2D/c$.
Derive an expression for the time t_2 measured by the observer on Earth for the light to leave the source, reflect from the mirror and reach the receiver.
- (c) What does the observer on Earth conclude about the clock on the spacecraft?
- (d) What would the astronaut notice about the clock belonging to the observer on Earth? Briefly explain your answer.

Question 13**(4 marks)**

The X-rays used by a dentist to assess the internal structure of a tooth are termed “Soft X-rays”, whereas the radiation needed to penetrate thick concrete beams are termed “Hard X-rays”. Using the terms: **Greater than**, **Less than** or **Equal to** in the spaces below to show how the different properties of the two types of X-rays compare.

The Penetrating Power of hard X-rays is _____ soft X-rays

The Velocity of hard X-rays is _____ soft X-rays

The Frequency of hard X-rays is _____ soft X-rays

The Wavelength of hard X-rays is _____ soft X-rays.

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Section Two: Extended answer

50% (90 marks)

This section has **eight (8)** questions. You should answer **all** questions and show full working. Unless otherwise indicated, all answers should be evaluated to 3 significant figures.

Write your answers in the spaces provided.

Suggested working time: 90 minutes.

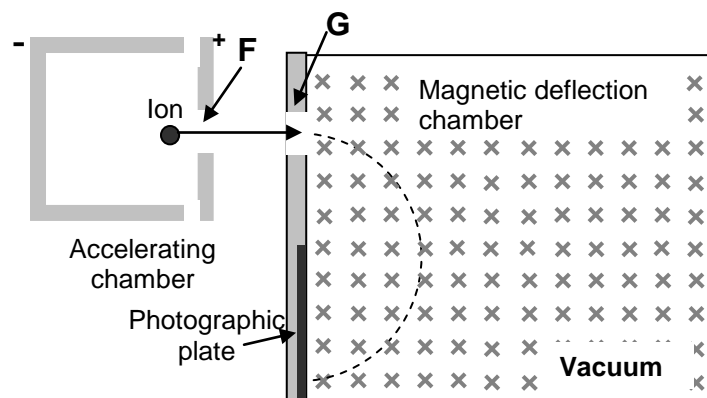
Question 14

(11 marks)

Electric and magnetic fields are used in mass spectrometers (instruments used to measure the mass of atoms). Singly-charged ions are focused into a narrow beam after being accelerated to a high velocity by an electric field in an accelerating chamber.

The ions are then fired into a region where there is a magnetic field of strength 5.50 tesla and deflected into a semicircular arc to be detected by a photographic plate.

A simplified schematic diagram of this instrument is shown.



- (a) What is the magnitude of the charge on each ion? _____ (1 mark)
- (b) A different ionised atom with a charge of $3.20 \times 10^{-19} \text{ C}$ is accelerated in the acceleration chamber by a voltage of 6000 volts. If the ion has a mass of $3.84 \times 10^{-26} \text{ kg}$, calculate its velocity on reaching the slit F? (3 marks)

- (c) Calculate the ratio of the magnetic force on such an ion to the mass of the ion.
(3 marks)

- (d) At what distance from G will the ions strike the photographic plate, if they enter the chamber with a velocity of $5.20 \times 10^6 \text{ m s}^{-1}$?
(4 marks)

Question 15**(12 marks)**

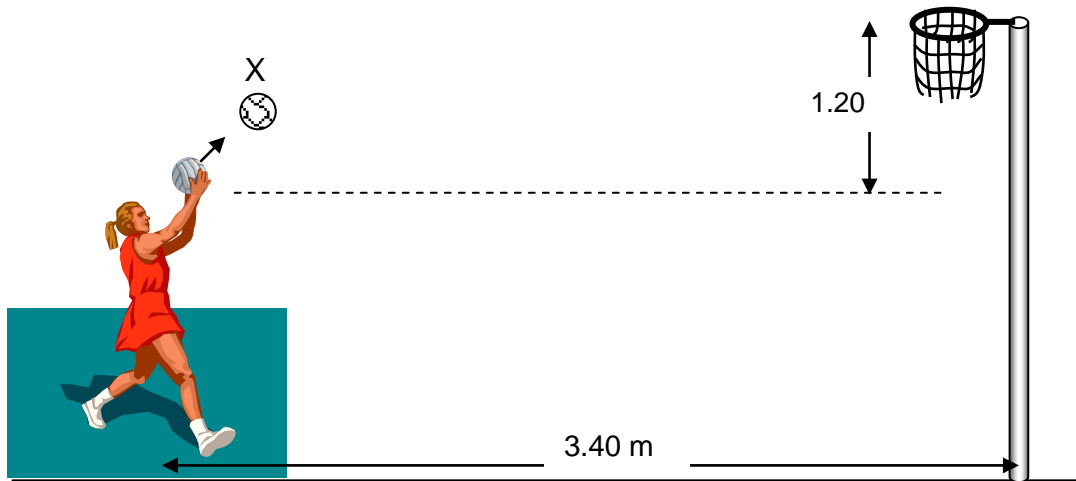
- (a) With the aid of a diagram, explain how the parallax angle from Earth to a distant star is determined.
(3 marks)
- (b) The brightest star seen from Earth is Sirius A, which is measured to have a parallax angle of 0.38 arc seconds. How far away from Earth is Sirius A? Give your answer in parsecs and in lightyears (1 pc = 3.26 lyr)
(2 marks)
- (c) Using an ion drive and a gravitational slingshot around Jupiter, an interstellar spaceprobe could leave the Solar system at speeds approaching 250 000 km/hr. How long would such a spaceprobe take to reach Sirius A?
(2 marks)

- (d) Sirius A has a mass that is slightly more than twice that of our Sun, but is about 25 times as luminous (bright). Given that our Sun is expected to shine for about 10 billion years, estimate an approximate value for the lifetime of Sirius A.
(2 marks)

- (e) A particular line in the emission spectrum of hydrogen is measured on Earth to have a wavelength of 410 nm. When detected in the light from a distant galaxy, the line is found to have a wavelength of 442 nm.
Explain how this wavelength shift occurs, and what it indicates about the distant galaxy.
(3 marks)

Question 16**(12 marks)**

During a game a netball player shoots in an attempt to put her team in the lead. The ball travels from her hands through the hoop and without touching the ring lands on the floor.



- (a) Draw and label all the forces on the ball at point X, just after it has been thrown. (2 marks)
- (b) During netball practice the ball is thrown horizontally with a velocity of 9.00 m s^{-1} to a team mate 2.50 m away. If the ball is thrown from a point 1.60 m above the ground, how far above ground level would the ball be when the team mate catches it? (Ignore air resistance in this case) (4 marks)

- (c) The diagram above shows the ball being thrown at an angle of 55.0° above the horizontal towards the basket 3.40 m in front of the player and 1.20 m above her. If the ball goes into the basket on its way down, at what speed did the ball leave the thrower's hands? (Ignore air resistance)

(4 marks)

- (d) The standard mass of a netball for competitions is 450 g but one of the opposing team has another type of netball that is the same size but has a larger mass of 600 g. If both balls are thrown horizontally at exactly the same speed the 600 g ball travels further. Explain why this is?

(2 marks)

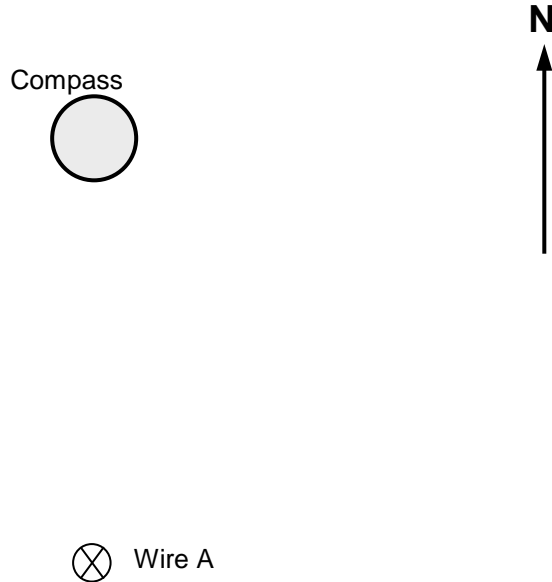
Question 17

(12 marks)

The diagram below represents the current in a wire 'A' looking down from above the wire. The current is going into the page and the North Pole of the Earth is towards the top of the page. A small compass is placed to the north of the wire, as shown.

- (a) Draw in four field lines around the wire, indicating the field direction.

(1 mark)



- (b) (i) Inside the circle shown as the compass, draw in the needle as an arrow to show its resultant position with the current turned on. At this point the strength of the field from the wire is double that of the field from the Earth.

(1 marks)

- (ii) Draw in the letter X at the position where resultant flux density (field strength) around the wire is equal to zero.

(1 mark)

- (c) It is possible to measure the flux density B at any point near a current-carrying wire using an instrument called a Hall Probe. This gives a digital read-out of the flux density, in tesla. An experiment was conducted in a university laboratory to see how the flux density varied with distance from a wire by placing the Hall Probe at different distances from a long, thick wire carrying a current of 500 amps. The results are shown below.

Distance from wire r (cm)	Flux density B (mT)	
2	240	
5	100	
7	70	
9	50	
12	40	

The experimenters found, in a physics book, that the flux density B at a distance r from a wire carrying a current I is given by the formula:

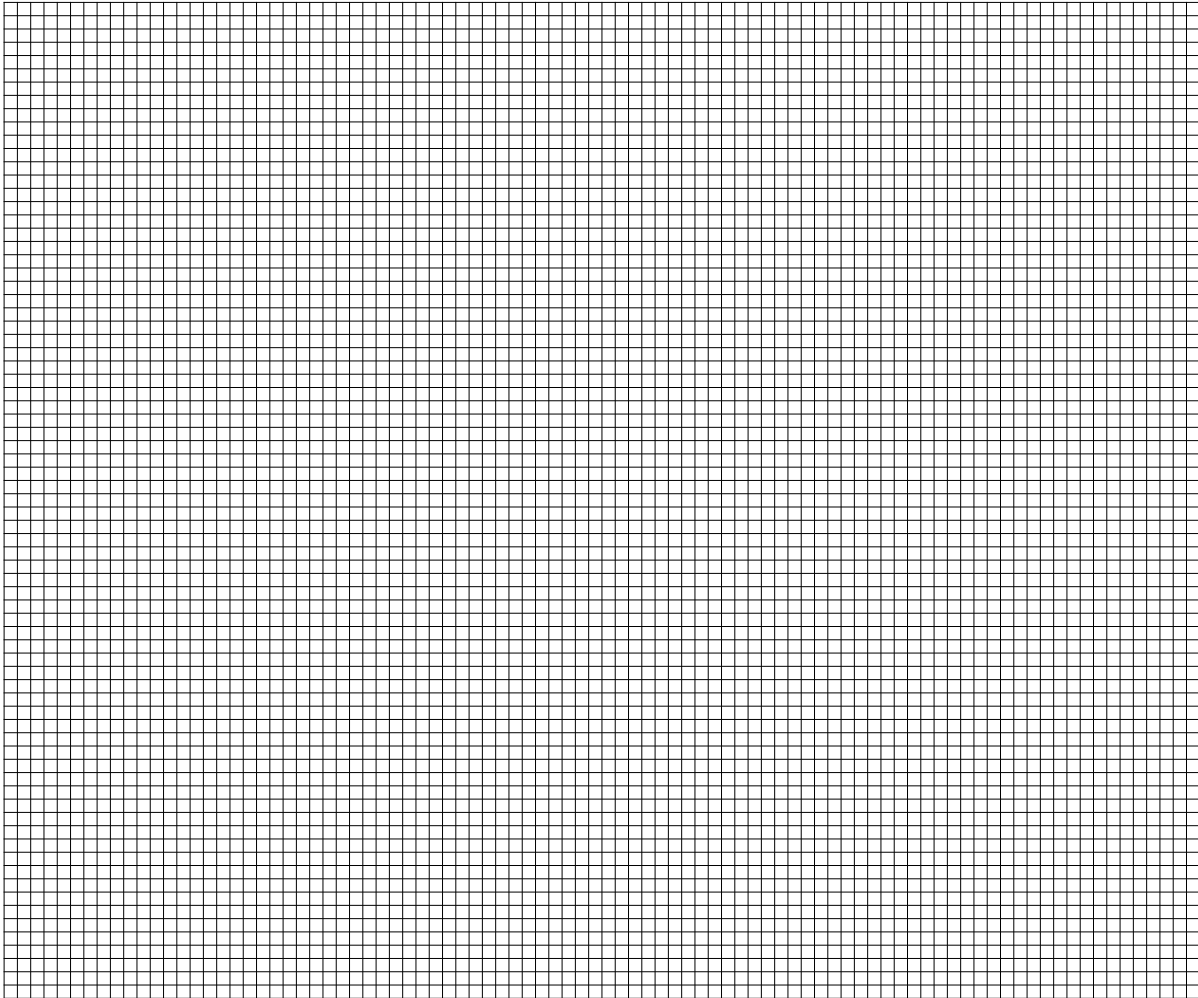
$$B = \frac{\mu I}{2 \pi r} \quad \mu \text{ is a constant}$$

- (i) Looking at this equation, if values of r were plotted against B , a curve would be produced. What variables should be plotted so that the resulting graph is a **straight line**?

(1 mark)

- (ii) Fill in the empty column of the table above with appropriate values then draw the straight line graph on the grid provided (label the axes carefully).

(4 marks)



- (iii) Calculate the gradient of the line.
(show clearly the points used to calculate the gradient)

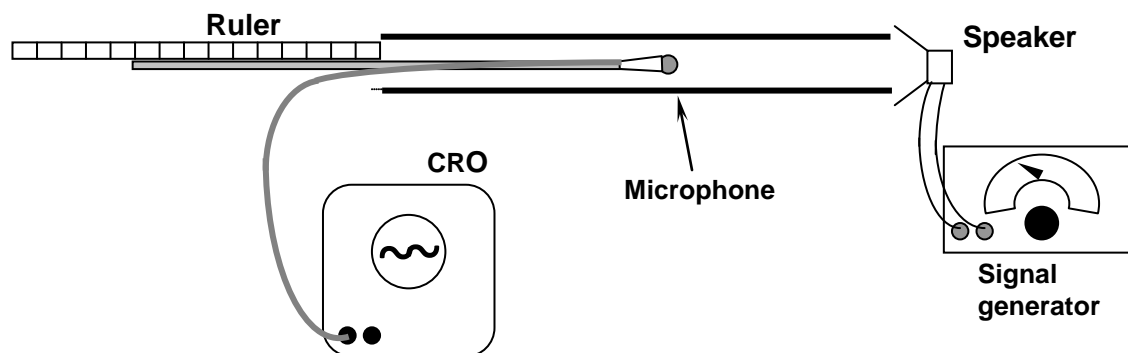
(2 marks)

- (iv) Use the slope from part (iii) to calculate a value for μ , display all your working below. (If you were unable to calculate the gradient of your graph use the following value for the magnitude: Gradient = 4.00×10^{-3})

(2 marks)

Question 18**(10 marks)**

A group of students conduct an experiment to determine the wavelengths of the harmonics in a plastic pipe. A signal generator is attached to a loudspeaker that is positioned at one end of the pipe to create the harmonics. A microphone, connected to a cathode ray oscilloscope, is attached to a wooden rod that can be moved to different positions inside the pipe. The positions of nodes and antinodes formed inside the pipe are found by observing the oscilloscope trace.



- (a) One of the experimenters mentions that there must be a standing wave occurring inside the tube. Explain how a standing wave could be formed in this apparatus.

(2 marks)

- (b) Describe the measurements that need to be taken from the apparatus to determine the wavelength of a wave formed inside the tube. Give an example calculation, making up your own results.

(3 marks)

- (c) At a frequency of 512 Hz the speed of sound in the pipe was found by the students to be 320 m s^{-1} . What would be the distance between two consecutive nodes in the pipe?

(2 marks)

- (d) Whilst the tube shown was resonating at 512 Hz, another tube (that was closed at one end) had air blown across it to produce a note. These two notes combined to cause beats to occur. If the number of beats per second produced from the two sounds was 6, calculate two possible lengths for the tube closed at one end. Assume the same speed of sound as in part (c).

(3 marks)

Question 19**(12 marks)**

A girl is persuaded to go on a roller-coaster amusement ride in Las Vegas called the Thrillseeker, which operates on top of a tall hotel. The loop shown in the picture has a diameter of 18.0 m and the carriage holding the passengers takes 4.75 s to complete one circle in a loop-the-loop.

- (a) Calculate the centripetal acceleration of the passengers as they go round the loop (assume a constant speed).

(2 marks)

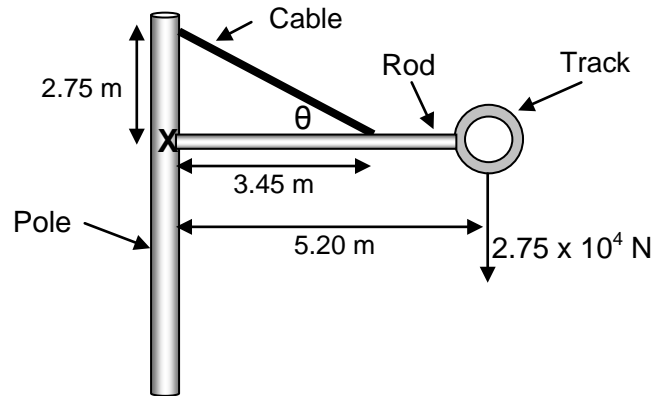


The Thrillseeker

- (b) Calculate the reaction force exerted by the seat on a 70.0 kg man at the top of the loop.

(2 marks)

- (c) One part of the Thrillseeker track is supported on a thick upright pole, a horizontal rod and a steel cable, as shown. The rod has a mass of 100.0 kg and the track weight supported at the end of the rod is $2.75 \times 10^4\text{ N}$ at a distance of 5.20 m from the pole. The cable connects to the rod 3.45 m along the pole and connects to the top of the pole 2.75 m from where the rod joins the pole, as shown in the diagram below.



- (i) Calculate the tension in the cable.

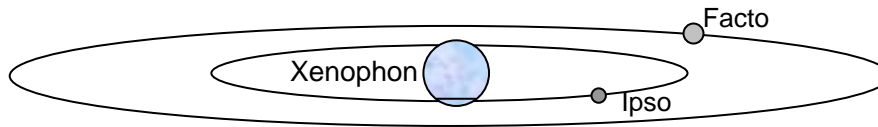
(4 marks)

- (ii) Calculate the magnitude and direction of the reaction force of the pole on the rod at the point where the rod joins the pole.

(4 marks)

Question 20**(10 marks)**

Two planets Ipso and Facto rotate in different orbits about a distant star Xenophon.



Data regarding this planetary system are show in the table below.

Planet	Mass (kg)	Radius of planet (m)	Orbital radius (m)	Length of day (s)	Orbital period (s)
Ipso	1.4×10^{26}	6.0×10^6	4.3×10^{11}	2.1×10^5	5.2×10^6
Facto	2.2×10^{27}	8.1×10^6	6.5×10^{11}	3.5×10^5	

- (a) Calculate the value of the gravitational acceleration at the surface of the planet Ipso.

(2 marks)

- (b) Calculate the maximum force that Ipso can exert on Facto during their orbits.

(2 marks)

(c) Calculate the mass of the star Xenophon.

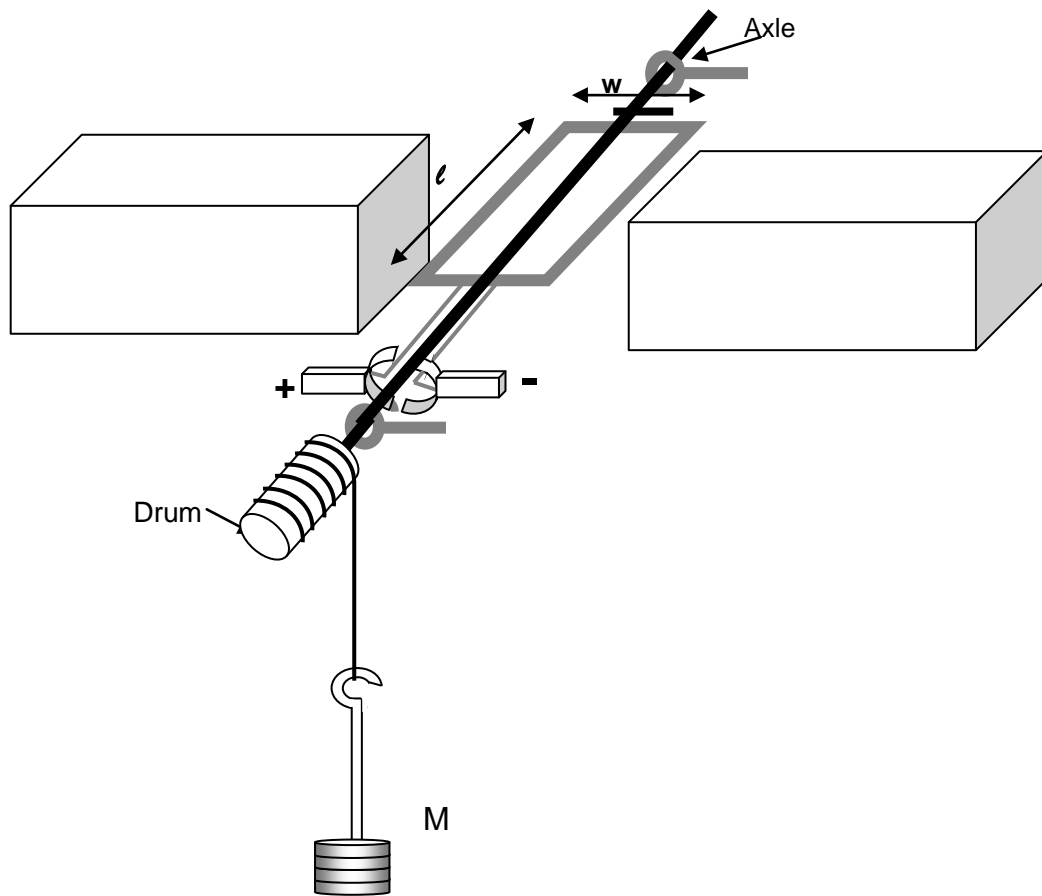
(3 marks)

(d) Find the orbital period of Facto around Xenophon missing in the table.

(3 marks)

Question 21

(11 marks)



The diagram above shows a DC electric motor that is designed to lift the masses M upwards.

- (a) Draw in the north and south poles of the magnets so that the motor turns in the correct direction.

(1 mark)

- (b) The important data related to the motor are shown below:

Length of coil (l) = 12.0 cm
 Width of coil (w) = 5.60 cm
 Number of turns = 150
 Coil resistance = 1.85 Ω

Voltage of battery connected = 12.0 V
 Flux density of magnet = 1.25×10^{-2} T
 Drum diameter = 4.20 cm

Use these values to calculate the maximum torque available from this motor.

(3 marks)

- (c) The torque available from a simple motor like this varies over one complete rotation of the motor. Explain why this is so.
(2 marks)
- (d) Assuming that the maximum torque is available from the motor. Calculate the maximum mass that it would be capable of lifting (if you were not able to calculate the motor torque from the previous question take the value as 8.0×10^{-2} Nm).
(3 marks)
- (e) An ammeter is connected to the motor to measure the current in the circuit. It is noticed that without the load attached the current in the circuit is much less than when the motor is used to lift the load. Explain why the current increases when the load is attached.
(2 marks)

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Section Three: Comprehension and data analysis.**20% (36 marks)**

This section contains **two (2)** questions. You should answer **both** questions and show full working. Unless otherwise indicated, all answers should be evaluated to 3 significant figures.

Write your answers in the spaces provided.

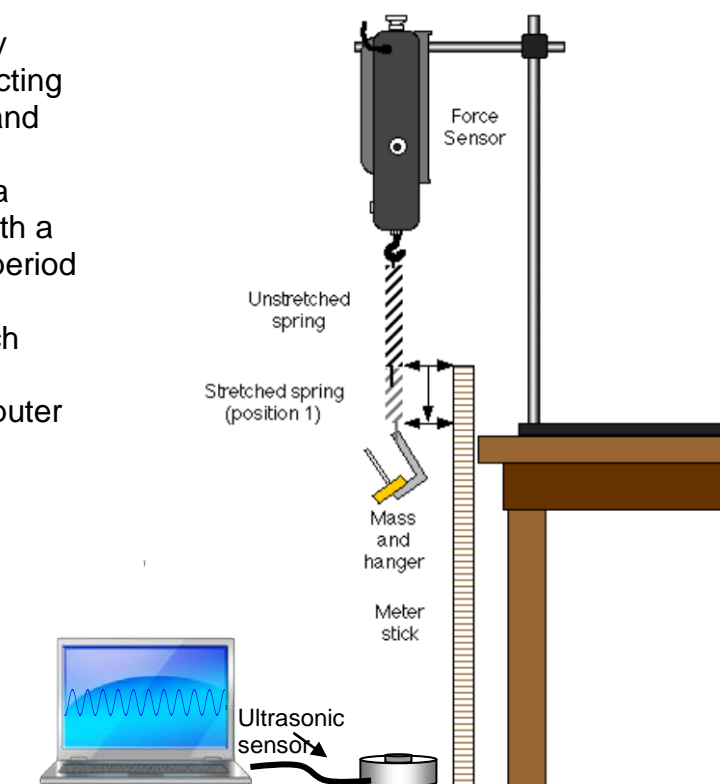
Suggested working time: 40 minutes.

Read each passage carefully and answer all of the questions at the end of each passage. You are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and /or numerical results should be included as appropriate.

Question 22**(18 marks)****Oscillating spring**

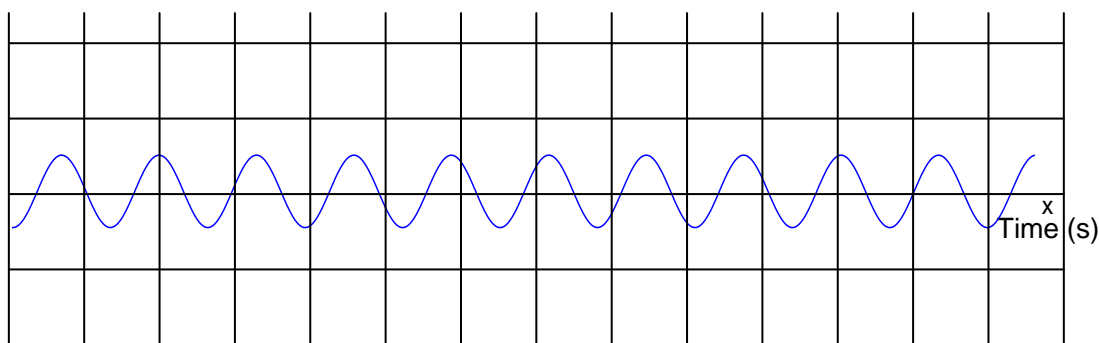
An experiment was set up in a university laboratory to investigate the factors affecting the time period of a mass bouncing up and down on a spring.

The apparatus is shown here including a metal spring attached to force sensor with a mass loaded onto the spring. The time period of the oscillations were found from an ultrasonic sensor directed upwards which detected the movement of the mass and displayed its displacement using a computer program.



- (a) A section of the computer display is shown below over a time axis. Use this to calculate accurately the periodic time of oscillation of the mass, given that each horizontal square represents a time of 500 ms.

(1 mark)



Readings of the added mass on the spring (m) and the time period of oscillation are shown below in the table.

Time t (s)		Mass m (kg)
0.314		0.1
0.385		0.15
0.446		0.25
0.566		0.325
0.666		0.45

The students performing the investigation have found a textbook that gives the formula linking the variables as:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

T = time period

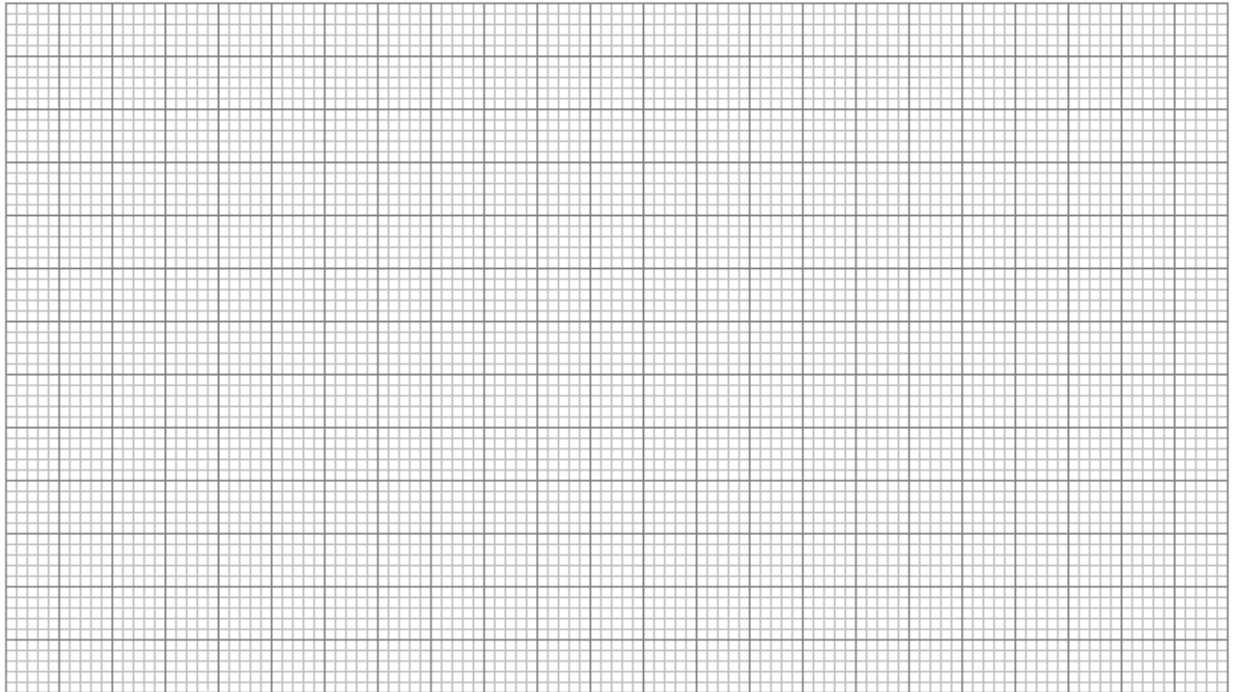
m = added mass

k = spring constant

The students realise that they can use these data to find the spring constant of the spring by plotting a graph. Looking at this formula they decide to plot a graph of T^2 on the y-axis against m on the x-axis.

- (b) Fill in appropriate values in the middle column that will allow you to plot the correct graph and plot the graph on the paper below.

(3 marks)



- (c) Calculate a value for the gradient of the graph, in the correct units, showing how you obtained this value.

(3 marks)

- (d) Using the gradient, calculate a value for the spring constant (k) of the spring. Show all working. (If you were unable to calculate the gradient from part (c) use a value of 1.00 for your calculation).

(2 marks)

- (e) One of the students suspects that one of the readings of time had an error in it. Which reading is this likely to be and estimate what the correct reading should be?

(2 marks)

- (f) In physics, why do we manipulate data so we always have a straight line, and what are the advantages of drawing a line of best fit through the points, rather than joining one point to the next?

(3 marks)

(g) The sensor being used is an *ultrasonic sensor*, which uses sound waves to judge the position of the oscillating mass above it.

(i) What does ultrasonic mean?

(1 mark)

(ii) Why can ordinary sound waves not be used for measurement in this case?

(1 mark)

(iii) How does the computer calculate the distance of the mass from the sensor, using the ultrasonic signals that are received by the sensor?

[2 marks]

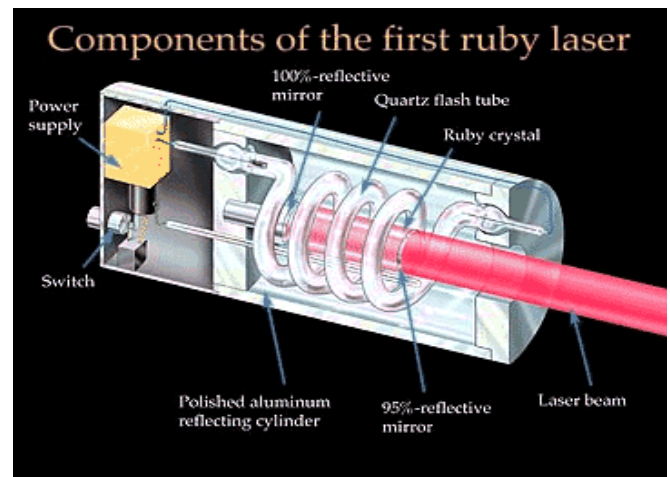
Question 23

(18 marks)

LASERS

(Paragraph 1)

The word 'laser' stands for 'Light Amplification by Stimulated Emission of Radiation'. A laser is an instrument made of a certain material that can be stimulated by an external energy source to emit light. Light from everyday sources, such as a light bulb, is produced in a haphazard process called spontaneous emission which gives an incoherent source of light (the photons have a random phase difference) which is emitted in all directions.



(Paragraph 2)

In the Bohr atomic model electrons orbit the nucleus with a definite energy, which increases with distance from the centre of the atom. Most atoms are in the ground state (electrons in the lowest energy level) and this distribution is called a normal population. If energy is supplied to the atoms then electrons can be forced to higher energy levels and the atoms are said to be in an excited state. For most substances the absorbed energy is emitted 'spontaneously' (in a very short time, less than 10^{-8} s).

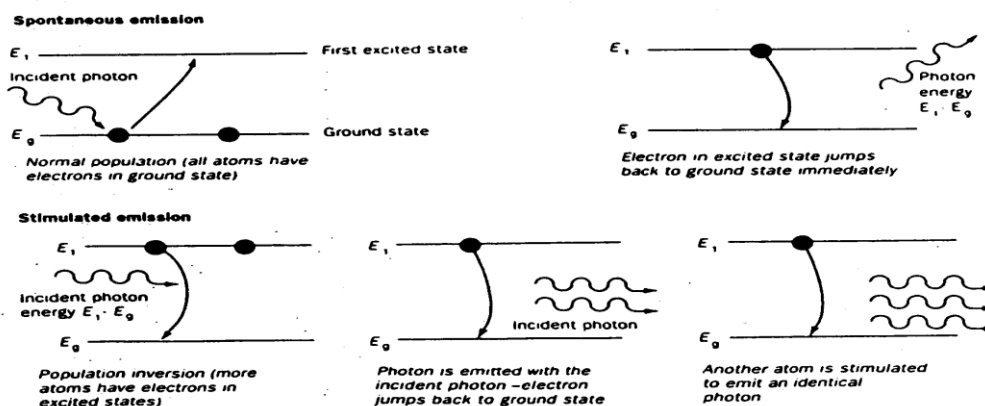
(Paragraph 3)

A laser on the other hand requires a substance that has a metastable state (an energy level in which an electron will remain for a time in the order of 10^{-3} s or longer) and atoms which are in an inverted population (more atoms are in the excited state than in the ground state).

These two conditions are necessary so that a coherent beam of light can be obtained by the process of stimulated emission. The stimulated emission process is shown below in figure 1. When light of the same energy as the difference in energy between the ground state and excited state hits an excited atom it causes the electron to fall back down to the ground state emitting light of the same frequency which is in phase with the first photon and travels in the same direction. These photons strike other excited atoms causing an avalanche of photons with the same wavelength and in phase. A monochromatic laser beam is formed by having a resonating tube, which has two mirrors at either end, one fully reflecting, the other partially reflecting which allows a small percentage of the photons to pass through.

An example of a laser unit is shown in figure 2.

Figure 1



SEE NEXT PAGE

(Paragraph 4)

The excitation of the atoms in a laser can be done in several ways to produce the necessary inverted population. In a ruby laser, the lasing material is a ruby rod consisting of Al_2O_3 with a small percentage of aluminium (Al) atoms replaced by chromium (Cr) atoms. The Cr atoms are the ones involved in lasing. The atoms are excited by strong flashes of light of wavelength 550 nm, which correspond to a photon energy of 2.20 eV. As shown in figure 3, the atoms are excited from state E_0 to state E_2 . This process is called optical pumping. The atoms quickly decay either back to E_0 or to the intermediate state E_1 , which is metastable with a lifetime of about 3×10^{-3} s. With strong pumping action an inverted population can be formed. As soon as a few atoms in the E_1 state jump down to E_0 they emit photons that produce stimulated emission and the lasing action begins. A ruby laser thus emits a beam whose photons have energy 1.80 eV and a wavelength of 694.3nm (or "ruby-red" light).

Figure 2 : A laser unit

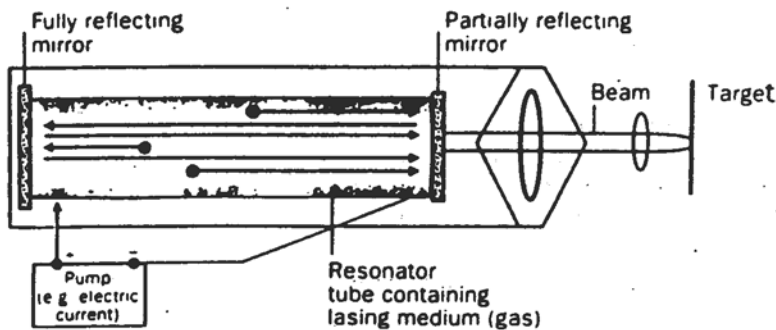
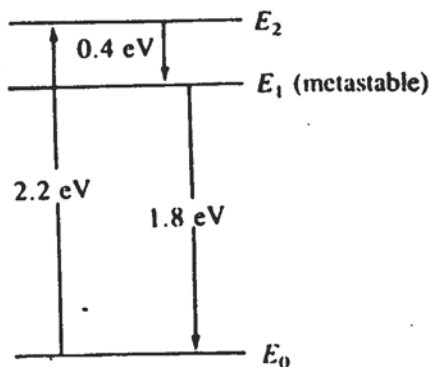


Figure 3 : Energy levels of chromium in a ruby crystal. Photons of energy 2.2 eV "pump" atoms from E_0 to E_2 , which then decay to metastable state E_1 . Lasing action occurs by stimulated emission of photons in transition from E_1 to E_0 .



- (a) What two conditions are necessary for stimulated emission to take place?
(4 marks)
- (b) What are the main differences between an everyday light source and a laser?
(4 marks)
- (c) To what part of the electromagnetic spectrum does the transition from E_2 to E_1 in the ruby laser (figure 3) correspond and what implication does this have on the operation of the laser?
(4 marks)

(d) What is the theoretical maximum efficiency of the ruby laser? (3 marks)

(e) What conditions would be required of the optical pump and emitted photons to achieve this maximum efficiency and are these realistic? (3 marks)

Section C references

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