N.P.B.H.S.

NZEST NEW ZEALAND EDUCATION & SCHOLARSHIP TRUST

cademic Achievement by Choice

SCHOLARSHIP EXAMINATION 1992

PHYSICS

Time allowed: Three hours

Ten minutes extra are allowed for reading this paper

NOTES TO CANDIDATES

1. The paper consists of three sections.
2. Sections I and II are compulsory, no choice is provided. Attempt all questions in both sections.
3. In Section III attempt FOUR questions out of the six questions offered.
4. If you are unable to calculate a quantity needed for a later part of a question, assign it a symbol or an arbitrary value, and continue the question.

INSTRUCTIONS

SECTION I (30 marks)

1. There are 20 questions. Attempt ALL questions. Each question is worth $1\frac{1}{2}$ marks.
2. All answers are to be recorded on the special ANSWER SHEET provided.
3. Except where otherwise indicated you are required to select the *best* answer from five alternatives. Ambiguous selections will not be accepted.

If you consider B is correct circle thus   A (B) C D E

To change your choice from B to C cross out B and circle C   A ~~(B)~~ (C) D E

SECTION II (30 marks)

This section contains 5 questions, each worth 6 marks. *Attempt ALL questions.* Your working out and answers are to be written in your Answer Book.

SECTION III (40 marks)

This section contains 6 questions, each worth 10 marks. *Attempt FOUR questions only.* Your working out and answers are to be written in your Answer Book.

BEFORE YOU HAND IN YOUR ANSWER BOOK TIE THE SPECIAL ANSWER SHEET SECURELY INSIDE THE FRONT COVER.

You may require the following:

$\mu_0 = 4\pi \times 10^{-7}$ N s^2 C^{-2}
$k = 1/(4\pi\varepsilon_0) = 9 \times 10^9$ N m^2 C^{-2}
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
$e = 1.6 \times 10^{-19}$ C
$h = 6.6 \times 10^{-34}$ J s

Unless otherwise instructed take:

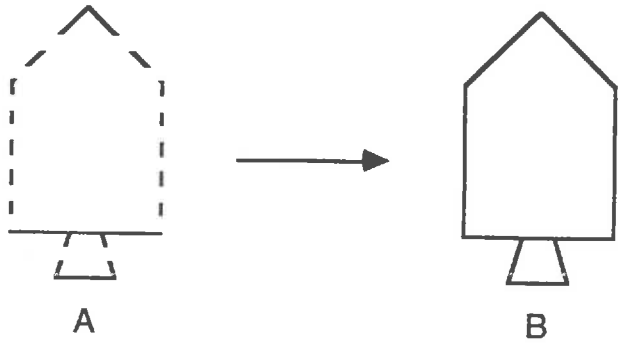
$g = 10$ m s^{-2}
$c = 3 \times 10^8$ m s^{-1}

SECTION I

(20 questions - 30 marks)

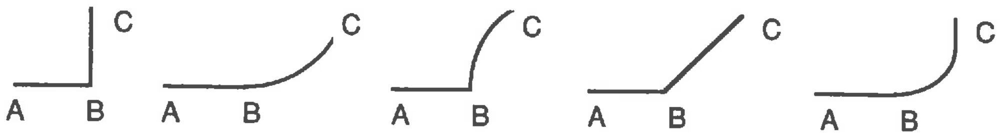
Answer ALL questions

Question 1



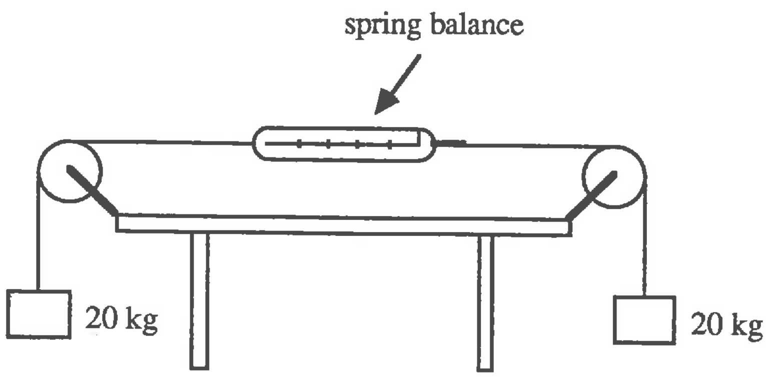
A rocket in space is moving sideways at constant speed with its motor shut off as in the diagram.
At the point B the rocket motor is started. The motor exerts a constant force on the rocket until it reaches point C.

Which one of the following diagrams best represents the path ABC ?



(a) (b) (c) (d) (e)

Question 2

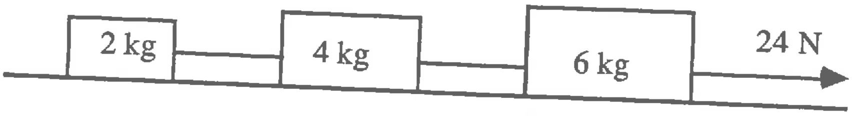


The two ends of a spring balance are attached as shown to two strings which pass over frictionless pulleys and support two masses of 20 kg each. The whole system is at rest.

The reading on the spring balance will be nearest to

(a) 0 (b) 400 N (c) 200 N (d) 300 N (e) 100 N

Question 3

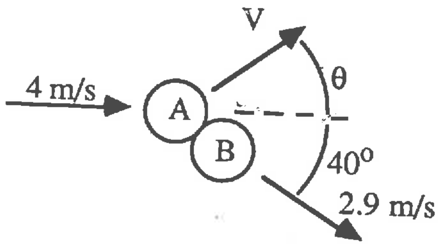


Three masses rest on a frictionless table and are connected by strings as shown. They are pulled by a force of 24 N and all three masses accelerate uniformly at 2 $m.s^{-2}$.

The tension in the string connecting the 2 kg and 4 kg masses is

(a) 0 (b) 2 N (c) 4 N (d) 12 N (e) 24 N

Question 4



Two identical smooth snooker balls, each of mass 100 g, collide as shown. Ball B is initially at rest and ball A approaches at a speed of 4 m/s.
After the collision ball B moves off at a speed of 2.9 m/s at an angle of 40° to the original path of ball A.

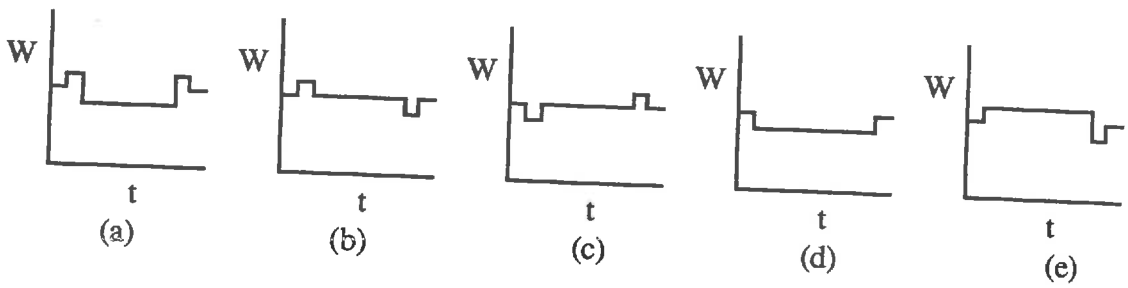
The angle of deflection θ of ball A is

(a) 40° (b) 50° (c) 41.8° (d) 42.3° (e) 46.3°

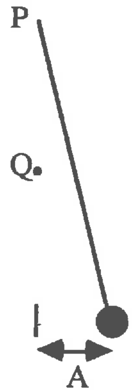
Question 5

A person stands on weighing scales holding a brick. The person then tosses the brick into the air and catches it again while still standing on the scales.

The weight W registered by the scales as a function of time during this process is best represented by



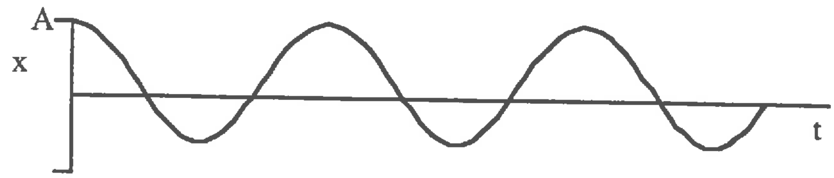
Question 6



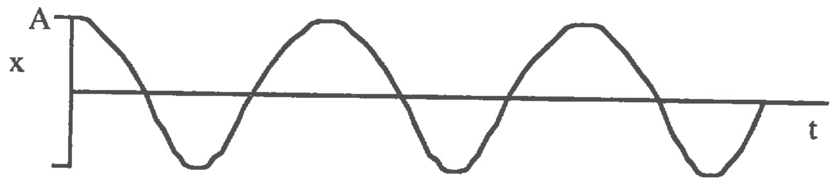
A pendulum is suspended from a point P and released as shown with amplitude A. A peg Q vertically below P prevents the upper part from moving to the left and significantly shortens the pendulum when it swings to the left.

The displacement x of the pendulum as a function of time t is best represented by

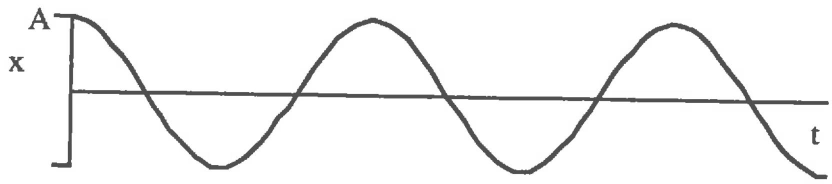
(a)



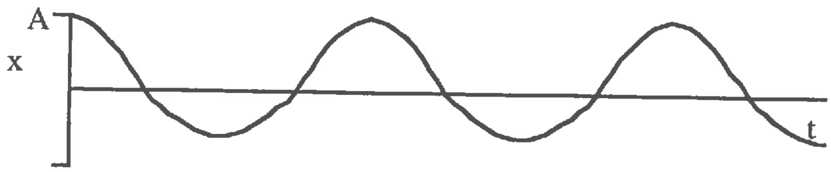
(b) ✓



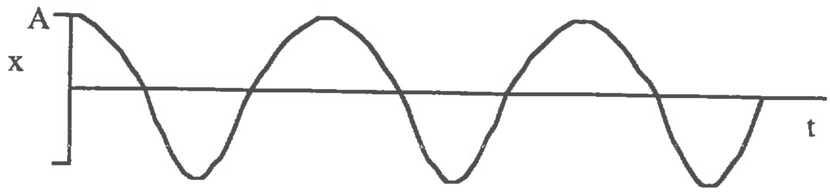
(c)



(d)



(e)



Question 7

A car travels over a hilltop at constant speed. The hilltop can be taken as an arc of a circle of radius 20 m.
The highest speed of the car if it just stays in contact with the road is closest to

(a) 45 km/hr (b) 51 km/hr (c) 58km/hr (d) 85 km/hr (e) 118 km/hr

Question 8

In an experimental bus of mass 4000 kg the braking is provided by transfer of energy to a flywheel which has a moment of inertia of 16 kg.m^2. The energy transfer can be taken as 100% efficient. The bus is initially travelling at 20 m.s^{-1} and the flywheel is at rest.

When the bus is brought to rest the angular velocity of the flywheel in radians per second is

(a) 316 (b) 1000 (c) 100 (d) 1240 (e) 1440

Question 9

In a certain region, seismic compressional waves (P waves) travel at a speed of 6000 m.s^{-1} and shear waves (S waves) travel at 4000 m.s^{-1}.
The P waves from a shallow earthquake arrive 14 seconds before the S waves.

The distance to the centre of the earthquake is

(a) 28 km (b) 536 km (c) 168 km (d) 112 km (e) 284 km

Question 10

A violin string of length 60 cm is tuned to a fundamental frequency of 440 Hz.

To make a note of 512 Hz it must be held so that its length is

(a) 46.8 cm (b) 50.4 cm (c) 48.6 cm (d) 51.6 cm (e) 55.0 cm

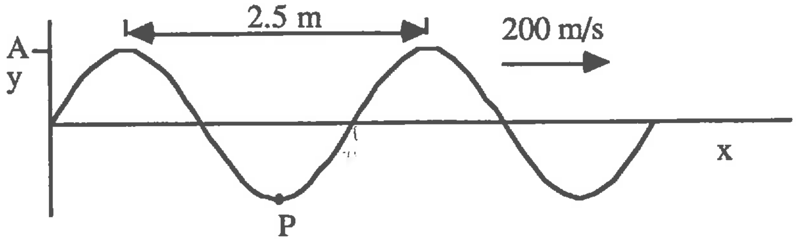
Question 11

A beam of light of wavelength 500 nm falls on a diffraction grating placed at right angles to the beam. The diffraction grating has 4000 rulings per cm. Diffracted beams are produced at various angles to the original beam.

Which one of the following angles will NOT have a diffracted beam?

(a) 11.5° (b) 36.9° (c) 53.1° (d) 23.6° (e) 17.4°

Question 12



The figure shows the position of a travelling wave on a wire at time t = 0.

The displacement of the point P as a function of time is given by

(a) $y(t) = A\cos[160\pi t - \pi]$

(b) $y(t) = -A\cos[200\pi t]$

(c) $y(t) = A\sin[160\pi t + \pi]$

(d) $y(t) = -A\sin[200\pi t]$

(e) $y(t) = A\sin[160\pi t + \pi/2]$

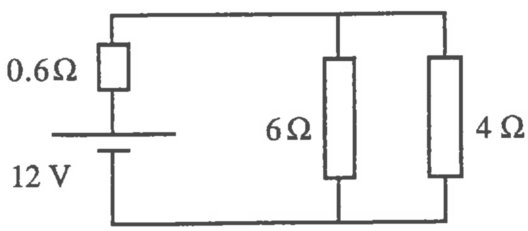
Question 13

A police car approaches a stationary observer in still air at a speed of 30 $m.s^{-1}$. The observer hears a frequency of 1600 Hz from the siren on the moving police car. The speed of sound in air can be taken as 340 $m.s^{-1}$.

When the police car stops beside the observer the frequency of the siren will be heard as

(a) 1410 Hz (b) 1459 Hz (c) 1470 Hz (d) 1587 Hz (e) 1665 Hz

Question 14

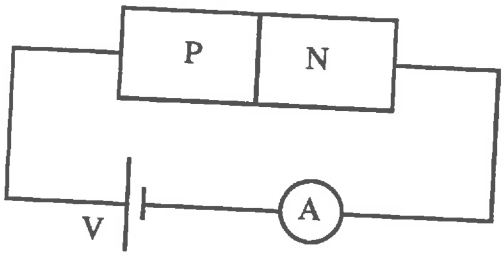


A 12 volt battery of internal resistance 0.6 ohms is connected as shown to resistances of 6 ohms and 4 ohms.

The current delivered by the battery is closest to

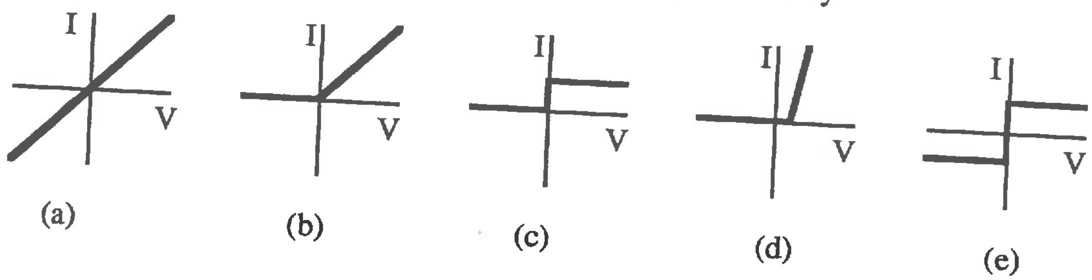
(a) 1.13 A (b) 1.28 A (c) 1.82 A (d) 2.14 A (e) 4.00 A

Question 15

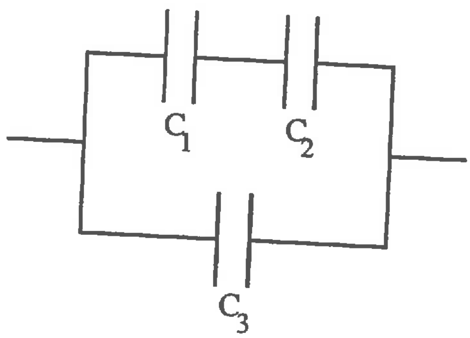


The diagram shows a p-n semiconductor junction. The voltage V is varied and the current is measured on the ammeter A.

The current I as a function of the voltage V is best represented by



Question 16



Capacitors C_1, C_2 and C_3 are connected as shown. The total capacitance of the system is

(a) $C_1 + C_2 + C_3$

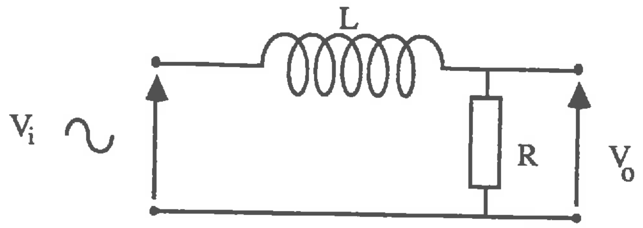
(b) $(C_1C_2+C_2C_3+C_3C_1) / (C_1+C_2)$

(c) $C_3 (C_1+C_2)/ (C_1+C_2+C_3)$

(d) $(C_3 C_1+C_3C_2+C_1C_2) / (C_1+C_2+C_3)$

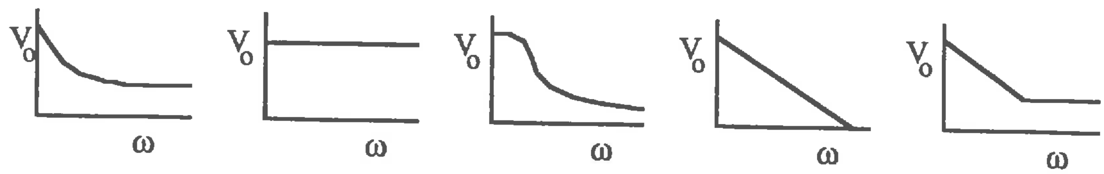
(e) $C_1(C_2+C_3) / (C_1+C_2)$

Question 17



In the circuit shown the input voltage V_i is an AC voltage at an angular frequency ω.

The r.m.s value of the output voltage V_o as a function of ω is best represented by



(a) (b) (c) (d) (e)

Question 18

Two wires X and Y carry current I out of the page. Lines XY and YP are at right angles.

The magnetic field at point P is best represented by

(a) (b) (c) (d) (e)

Question 19

Which one of the following statements concerning photons, atoms and nuclei is INCORRECT?

(a) The energy of a photon depends on its wavelength.

(b) A hydrogen atom can completely absorb a photon if the photon energy matches a difference in electron energy levels in the atom.

(c) The binding energy of a nucleus is the energy equivalent of the difference in mass between the sum of the masses of the protons and neutrons and the mass of the nucleus.

(d) Nuclear fission releases energy and nuclear fusion absorbs energy.

(e) In a nuclear fission reactor the energy released comes from the change in mass which occurs during nuclear fission.

Question 20

A nuclear reaction is represented by Misprint $^{9}_{4}Be$

$$\alpha + {}^{9}_{4}B \rightarrow {}^{12}_{6}C + X$$

In the above reaction X represents

(a) a proton (b) a gamma ray (c) an electron (d) a positron (e) a neutron

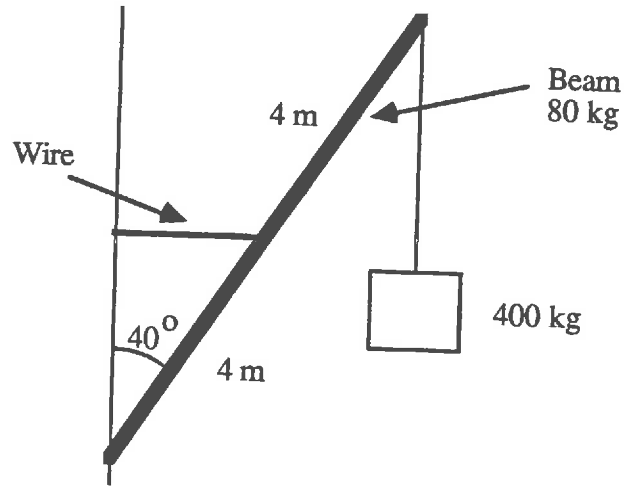
SECTION II (30 marks)

Answer ALL questions

Each question is worth 6 marks.

Question 1

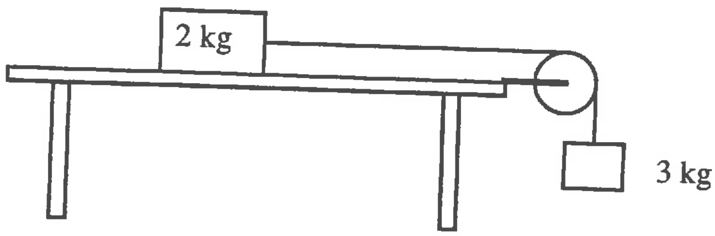
(a)



The diagram shows a mass of 400 kg suspended from the end of a uniform beam 8 m long. The beam makes an angle of 40° with a vertical wall and the lower end is hinged to the wall. The beam is supported by a horizontal wire attached to its mid point.
The mass of the beam is 80 kg.

Calculate the tension in the horizontal wire. (3)

(b)



A mass of 2 kg rests on a table as shown and is connected by a light inextensible string to a mass of 3 kg which hangs vertically. The string passes over a smooth frictionless pulley.
The system is released from rest and the 3 kg block accelerates downwards at 3 $m.s^{-2}$.

(i) Find the force of friction between the table and the 2 kg block. (2)

(ii) If the 3 kg is replaced by another block of mass M, find the value of M for which the 2 kg block can move at constant speed. (1)

Question 2

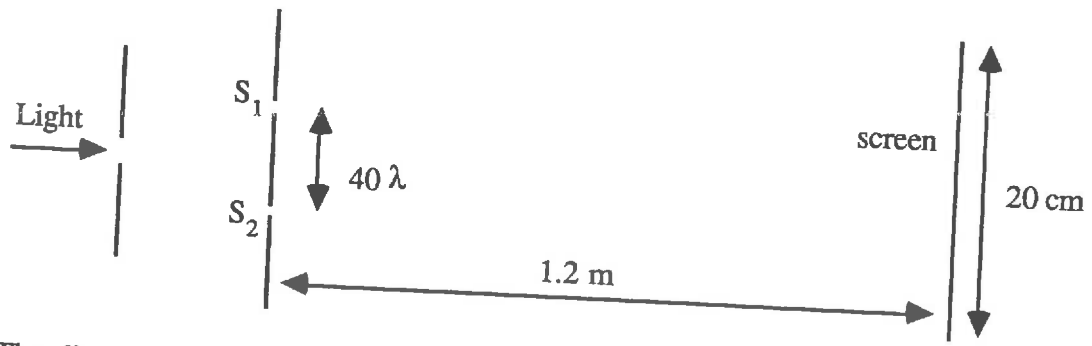
(a) An observer views light reflected from a thin soap bubble film. The angles of incidence and reflection can be taken as 0^{o}. The soap bubble film can be considered as a thin layer of water of refractive index 1.33.

The strongly reflected light appears yellow and the wavelength can be taken as 560 nm.

Calculate the minimum thickness of the soap film.

(2)

(b)



The diagram shows a typical arrangement to demonstrate double slit interference of visible light. The diagram is not to scale. Light of wavelength λ passes through a narrow single slit and then a double slit. The separation of the narrow slits S_1 and S_2 is 40λ and the screen is at a distance of 1.2 m from the slits. The screen has width 20 cm as shown.

(i) Sketch the intensity pattern as a function of position y across the screen.

(2)

(ii) Sketch the new intensity pattern if the width of slit S_1 is now doubled.

(2)

Question 3

(a) An earth observation satellite in a circular orbit has an orbital period of 2 hours.

Determine the height of the satellite above the earth's surface using the following data

Mass of earth $= 5.97 \times 10^{24}$ kg

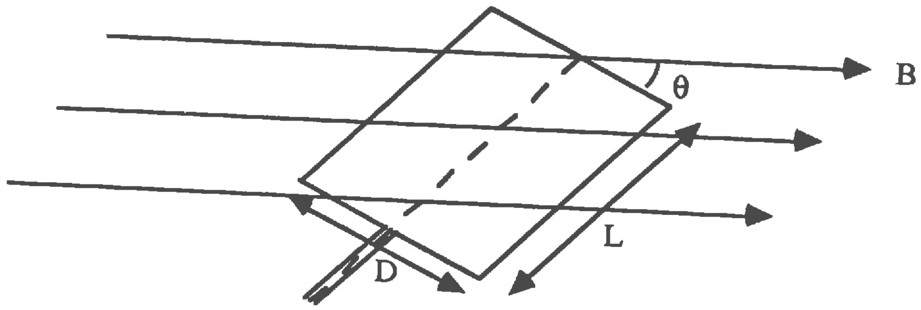
Radius of earth $= 6.37 \times 10^{6}$ m

(4)

(b) Calculate how long the satellite would take to travel from horizon to horizon as viewed from a point on the earth's surface. (Neglect the rotation of the earth).

(2)

Question 4



A rectangular loop of wire of width D and length L is able to rotate in a uniform magnetic field as shown. The dashed line shows the axis of rotation which is perpendicular to the magnetic field. At the instant shown the plane of the loop makes an angle θ with the magnetic field.

In a short time Δt the loop rotates while the angle θ increases to $\theta + \Delta\theta$ and a voltage is generated between the ends of the loop.

(a) Find an expression for the instantaneous voltage. (2)

(b) If the loop now rotates with constant angular velocity ω sketch the voltage as a function of time for one complete revolution beginning when $\theta = 0$. Indicate suitable voltage and time values in terms of the parameters given. (2)

(c) The metal atoms of the wire contain charged particles. Explain briefly what happens to these charged particles as the loop rotates. (2)

Question 5

The energy levels for the electron in a hydrogen atom are given in electron volts by

$$E_n = -13.6 / n^2 \qquad \text{where n is an integer.}$$

(a) Sketch an energy level diagram for the hydrogen atom and explain how it is related to the line spectrum of hydrogen. (3)

(b) Explain why the energy level corresponding to n=1 is not involved in giving lines in the visible spectrum. (1)

(c) Calculate the wavelength of the longest wavelength line in the visible spectrum. (2)

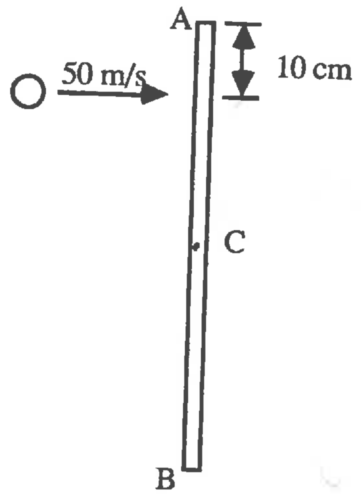
SECTION III (40 marks)

*Answer **FOUR** questions only*

Each question is worth 10 marks

Question 1

A uniform rod of length 60 cm lies on a smooth frictionless surface. It is free to move and rotate in a horizontal plane. The rod has a mass of 4 kg and a moment of inertia of 0.24 $kg.m^2$ about its centre of mass C.
A ball of mass 0.6 kg travelling at 50 m/s strikes the rod at right angles, 10 cm from the end A of the rod as shown.
The ball bounces back with a speed of 30 $m.s^{-1}$.



(a) (i) Find the change in momentum of the ball during the collision. (1)

(ii) Find the angular momentum of the ball about the point C before the collision. (1)

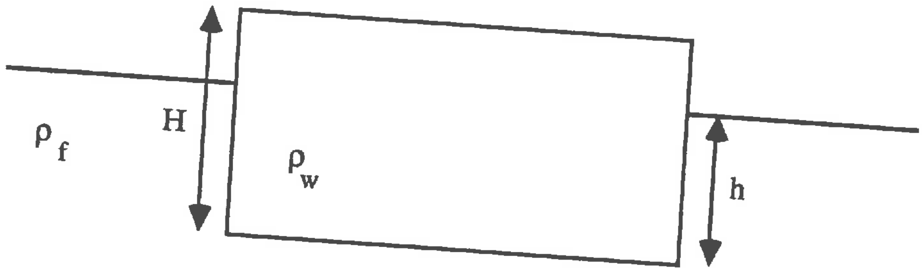
(b) (i) Calculate the speed of the centre of mass of the rod after the collision. (2)

(ii) Calculate the angular velocity of the rod about its centre of mass after the collision. (2)

(iii) Calculate the initial velocity of the end B of the rod after the collision. (2)

(c) Calculate the energy lost in the collision. (2)

Question 2



(a) A rectangular block of wood of density ρ_w, height H and horizontal area A floats at rest in a liquid of density ρ_f with its upper surface parallel to the surface of the fluid. The block floats in the fluid to a depth h as shown.

(i) State Archimedes' Principle as it applies to the floating block. (1)

(ii) Find an expression for h in terms of the other parameters. (1)

(b) A string is now tied carefully to the bottom of the block so that it holds the block at rest a distance x below its previous position. The surface of the block remains above and parallel to the fluid surface.

Find an expression for the tension force F in the string in terms of x and the other parameters.

(2)

(c) The string is now cut.

(i) Explain why the block now moves in Simple Harmonic Motion. (1)

(ii) Find an expression for the period T of the Simple Harmonic Motion. (3)

(d) A piece of lead is now placed carefully on the floating block so that the surface of the block remains above and parallel to the surface of the fluid at all times.

Explain whether the period of oscillations is the same, greater or less than the period in part (c).

(2)

Question 3

(a) A guitar string of length 70 cm is vibrating at a frequency of 200 Hz in its simplest standing wave pattern as indicated in the diagram. The string is shown at the instant when the centre of the string has its maximum positive displacement of 4 mm.

(i) Draw a sketch to show the displacement of the centre of the string as a function of time for two complete oscillations. Take $t = 0$ as the time when the displacement is maximum positive.
Show units for the displacement and time axes. (3)

(ii) Below the sketch for part (i) and with the same time scale, draw a sketch of the velocity of the centre of the string as a function of time for the same two oscillations.
Show units for the axes. (2)

(b) The original string of length 70 cm is now made to vibrate at its third harmonic, with an amplitude at the centre of the string of 3 mm.

(i) Calculate the period of oscillation of the third harmonic. (1)

(ii) Sketch the displacement of the string as a function of distance x along the string at the instant of time when the centre of the string has maximum positive displacement. (1)

(iii) On the same sketch as part (ii) draw a dashed line to show the displacement of the string as a function of distance along the string at a time 0.83 ms after the centre of the string has maximum positive displacement. (1)

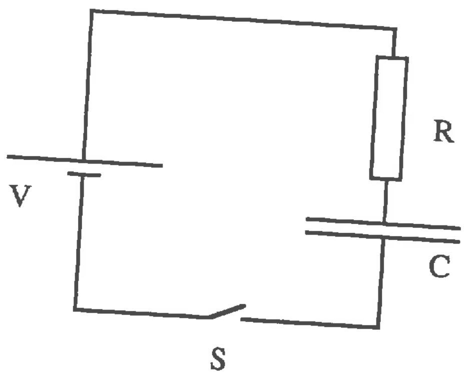
(iv) Calculate the maximum acceleration of the centre of the string. (1)

(c) A long length of the same guitar string is held at the same tension and struck so that a transverse pulse travels along the string.

Find the speed of travel of the pulse. (1)

Question 4

(a)



The circuit shows a capacitor and a resistor connected to a battery and a switch. When the switch S is closed a time dependent current i(t) flows where i(t) can be written

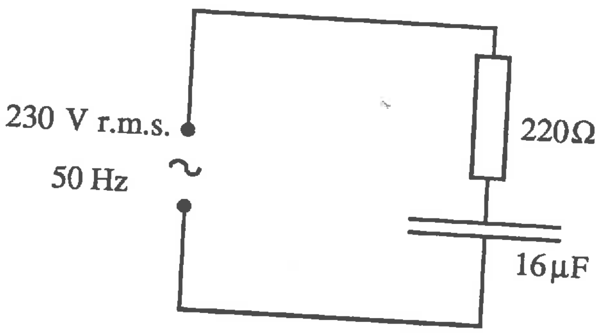
$$i(t) = i_0 e^{-\alpha t}$$

(i) Explain why the current i changes with time t. (2)

(ii) Obtain an expression for the voltage on the capacitor in terms of the parameters given. (1)

(iii) Find an expression for α in terms of the other parameters given. (3)

(b)



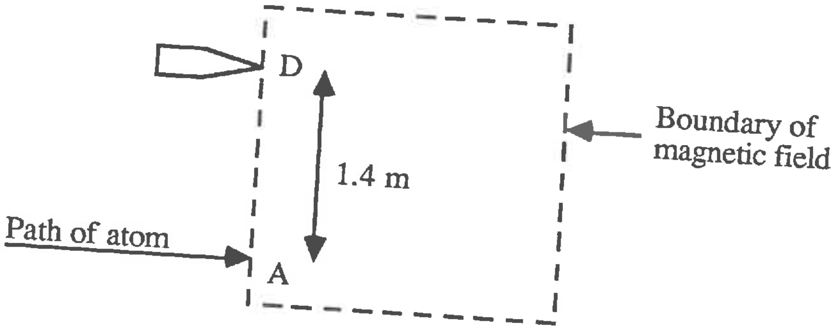
A resistor and a capacitor are connected to an AC voltage source of r.m.s voltage 230 volts and frequency 50 Hz as shown.

(i) Calculate the r.m.s. current in the circuit. (3)

(ii) Calculate the power dissipated by the resistor. (1)

Question 5

(a)



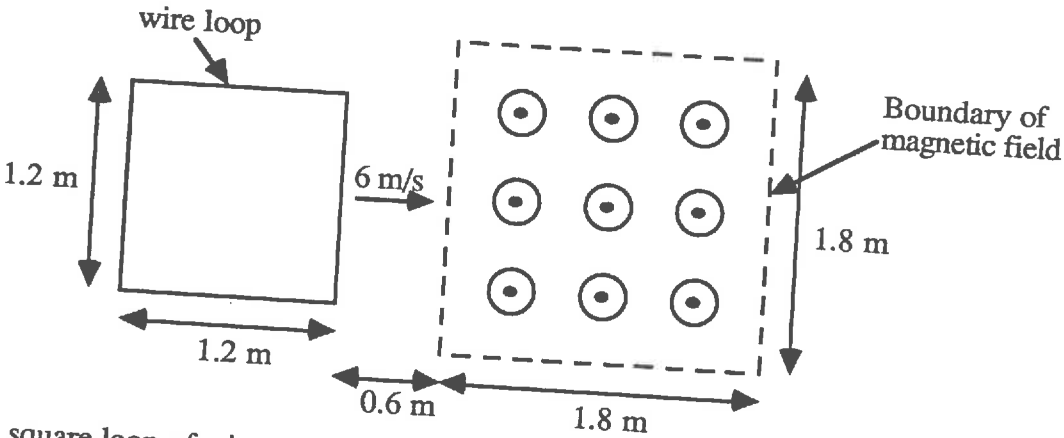
The diagram shows apparatus that can be used as a mass spectrometer. Charged atoms are first accelerated and then enter the uniform magnetic field as shown at point A and are deflected to enter the detector at point D. The distance AD is 1.4 m.

An atom of Tin (chemical symbol Sn) of mass 1.98×10^{-25} kg is ionised by the removal of one electron and then it is accelerated from rest by a potential difference of 2000 V.

(i) Calculate the speed of the Sn atom after it has been accelerated. (2)

(ii) Find the magnitude and direction of the magnetic field which is required to deflect the atom of Sn into the detector. (3)

(b)



A square loop of wire of total resistance 8 Ω passes through a uniform magnetic field of 3 tesla as shown. The square loop has sides of length 1.2 m. The magnetic field is out of the page and covers a square of side 1.8 m.

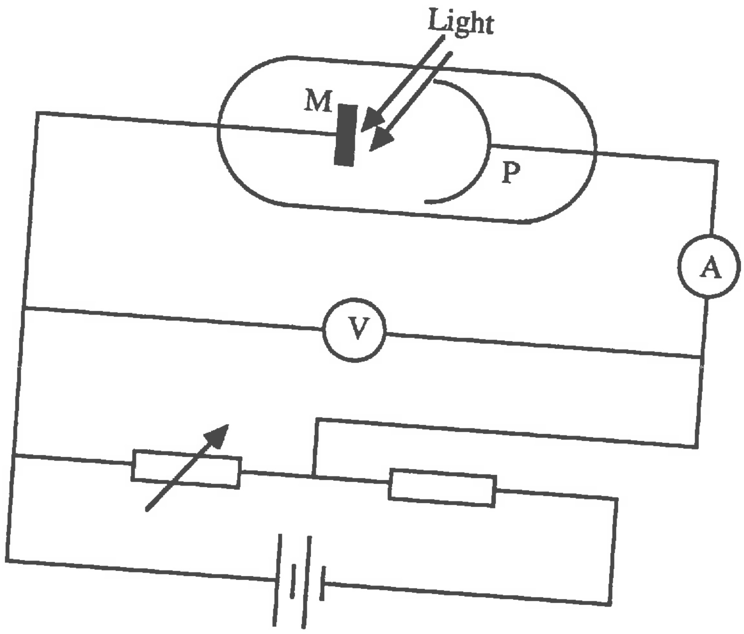
The wire loop is moving at a constant speed of 6 $m.s^{-1}$. At time t = 0 the edge of the loop is 0.6 m from the edge of the magnetic field as in the diagram.

(i) Find the magnetic flux throught the wire loop when the loop is entirely within the magnetic field. (1)

(ii) Find the maximum current in the loop as it passes through the magnetic field. (2)

(iii) Sketch the current in the loop as a function of time from time t = 0 to t = 0.7 s. Take the positive direction for current as clockwise. (2)

Question 6



The diagram shows apparatus which can be used to study the photoelectric effect.

Light of frequency ν falls on the metal plate M which is inside an evacuated chamber. Another metal plate P inside the chamber is connected to a voltmeter V and an ammeter A as shown. The voltage V can be varied by adjusting the value of the adjustable resistor.

(a) The voltage V is now set to zero and the ammeter shows that a current is flowing.

Explain how this current arises. (2)

(b) The voltage V is now slowly increased so that M is positive with respect to P.

Explain what happens to the current and why. (2)

(c) (i) Explain what happens if part (b) is repeated using light of a higher frequency. (1)

(ii) Give a mathematical equation relating the frequency of the light to appropriate values which can be measured with the above apparatus. Explain the meaning of any symbols you use. (2)

(d) Light is often described in terms of wave motion.

Identify two features of the photoelectric effect which cannot be explained in terms of light as a wave motion and show how they are explained in terms of quantum effects. (3)