

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

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CLASS

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TUTOR'S
NAME

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CENTRE
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INDEX
NUMBER

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PHYSICS

9749/03

Paper 3 Longer Structured Questions

20 September 2021

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use a HB pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A

Answer **all** questions.

Section B

Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/ 8
2	/ 10
3	/ 8
4	/ 10
5	/ 8
6	/ 7
7	/ 9
Section B	
8	/ 20
9	/ 20
Total	/ 80

This document consists of **22** printed pages.

Data

speed of light in free space

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$$

permittivity of free space

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$$

$$(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$$

elementary charge

$$e = 1.60 \times 10^{-19} \text{ C}$$

the Planck constant

$$h = 6.63 \times 10^{-34} \text{ J s}$$

unified atomic mass constant

$$u = 1.66 \times 10^{-27} \text{ kg}$$

rest mass of electron

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

rest mass of proton

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

molar gas constant

$$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

the Avogadro constant

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

the Boltzmann constant

$$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

gravitational constant

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

acceleration of free fall

$$g = 9.81 \text{ m s}^{-2}$$

Formulae

uniformly accelerated motion

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

work done on / by a gas

$$v^2 = u^2 + 2as$$

hydrostatic pressure

$$W = p\Delta V$$

gravitational potential

$$p = \rho gh$$

temperature

$$\phi = -Gm/r$$

pressure of an ideal gas

$$T / \text{K} = T / ^\circ\text{C} + 273.15$$

mean translational kinetic energy of an ideal molecule

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

displacement of particle in s.h.m.

$$E = \frac{3}{2}kT$$

velocity of particle in s.h.m.

$$x = x_0 \sin \omega t$$

electric current

$$v = v_0 \cos \omega t$$

resistors in series

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

resistors in parallel

$$I = Anvq$$

electric potential

$$R = R_1 + R_2 + \dots$$

alternating current/voltage

$$1/R = 1/R_1 + 1/R_2 + \dots$$

magnetic flux density due to a long straight wire

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

magnetic flux density due to a flat circular coil

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long solenoid

$$B = \frac{\mu_0 I}{2\pi d}$$

radioactive decay

$$B = \frac{\mu_0 NI}{2r}$$

decay constant

$$B = \mu_0 nI$$

$$x = x_0 \exp(-\lambda t)$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

Section A

Answer **all** the questions in the spaces provided.

- 1** The Poiseuille equation relating the volume flow rate $\frac{V}{t}$ of a fluid under laminar conditions through a horizontal tube of length L and internal radius r is

$$\frac{V}{t} = \frac{\pi p r^4}{8\eta L}$$

where p is the pressure difference between the two ends of the tube and η is the viscosity of the fluid.

- (a)** Show that the SI base units for η is $\text{kg m}^{-1} \text{s}^{-1}$.

[2]

- (b)** In an experiment to determine η for water, a student recorded the following measurements in SI units, as shown in Table 1.1.

Table 1.1

quantity	magnitude in SI units	percentage uncertainty / %
$\frac{V}{t}$	1.0×10^{-6}	3
p	500	2
L	0.20	0.5

The internal diameter of the tube was measured and recorded as (0.200 ± 0.002) cm.

- (i)** Calculate the percentage uncertainty in the internal radius r of the tube.

percentage uncertainty = % [1]

- (ii) Using the results in Table 1.1 and (b)(i), determine η with its associated uncertainty. Give your answer to an appropriate number of significant figures.

$$\eta = \dots\dots\dots \pm \dots\dots\dots \text{ kg m}^{-1} \text{ s}^{-1} [4]$$

- (iii) State and explain which measured quantity has the greatest contribution to the uncertainty of η .

.....

[1]

[Total: 8]

- 2 Two atoms X and Y, have masses $3m$ and $2m$ respectively. The 2 atoms move head-on towards each other with the same speed v as shown in Fig. 2.1.



Fig. 2.1

Fig. 2.2 comprises two velocity-time graphs A and B, which show how the velocity of each atom varies with time. The interaction between the atoms is elastic.

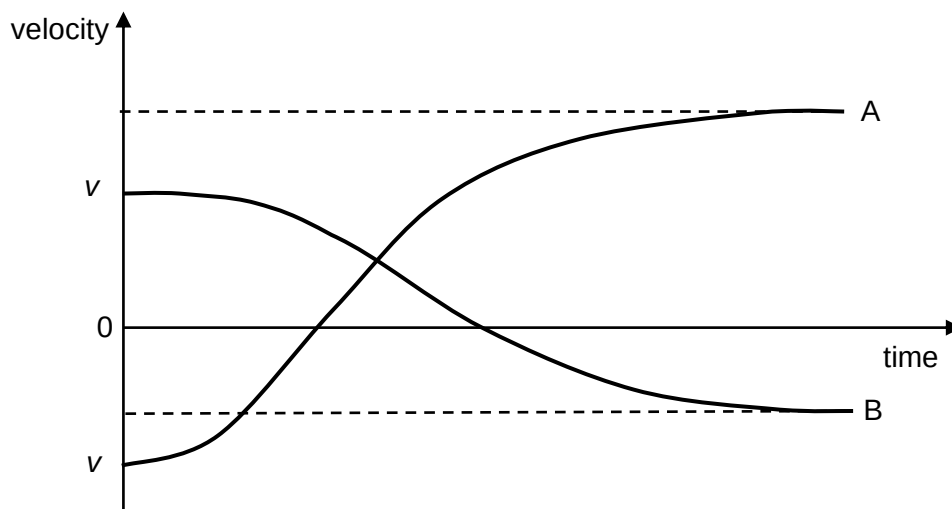


Fig. 2.2 (not to scale)

- (a) (i) Explain why it is not possible for the atoms to stop at the same instant.

.....

 [1]

- (ii) At one instant during the interaction between the atoms, they are both travelling in the same direction with the same speed. Calculate this speed, in terms of v .

speed = [2]

- (b) (i)** State and explain, which of the curves A or B is the velocity-time sketch for atom Y.

.....

.....

.....

.....

..... [3]

- (ii)** On Fig. 2.2, mark the instant in time at which the atoms are at their distance of closest approach. Label this point **T**. [1]

- (iii)** Determine the final speed of each atom in terms of v .

final speed of X =

final speed of Y = [3]

[Total: 10]

- 3 A 2.0 kg block on a track is released at A, 1.0 m above the ground as shown in Fig. 3.1. The track is frictionless except for the rough surface between B and C, which has a length of 2.0 m. The block travels down the track, hits the spring of force constant $k = 225 \text{ N m}^{-1}$ at D and compresses the spring by 0.20 m from its equilibrium position before coming to rest momentarily.

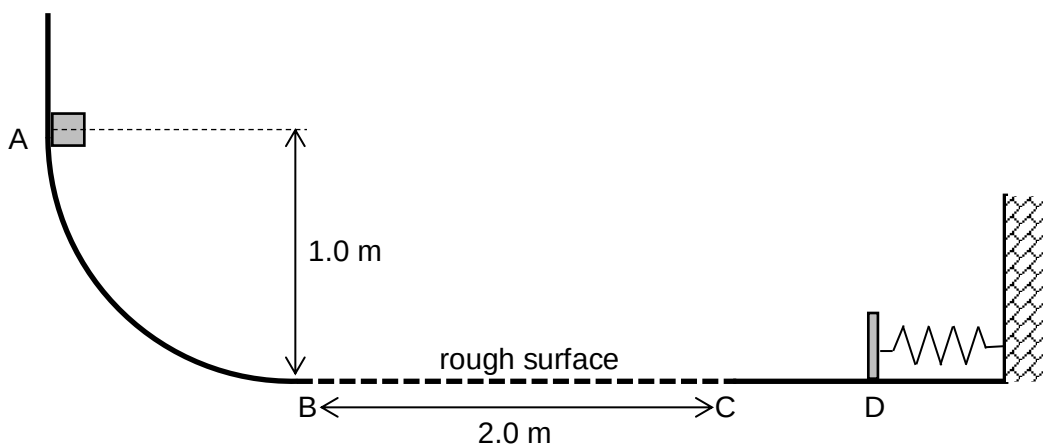


Fig. 3.1

- (a) (i) Determine the speed of the block at B.

speed at B = m s^{-1} [2]

- (ii) Calculate the maximum elastic potential energy stored in the spring.

elastic potential energy = J [1]

- (iii) Using your answers to (a)(i) and (ii), determine the work done against friction when the block travels from B to C.

work done against friction = J [2]

- (b) The block subsequently rebounds and moves towards B after the spring un-compresses itself. Determine the distance along the track from C where the block finally stops.

distance from C = m [3]

[Total: 8]

- 4 A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 4.1.

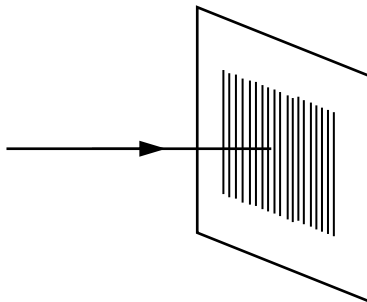


Fig. 4.1

- (a) Describe how diffraction of light takes place at the grating.

.....

 [1]

- (b) The diffraction pattern on the screen is shown in Fig. 4.2. The brightest spot is O. The two bright spots closest to O is 3.5 cm away from O.

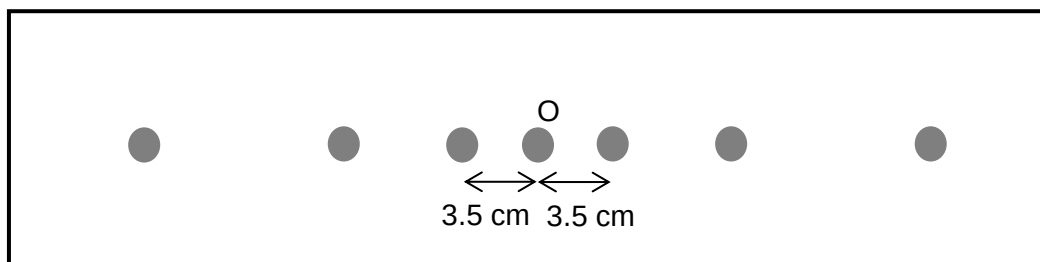


Fig. 4.2 (Not to scale)

The diffraction grating is placed 10 cm from the screen.

Determine the number of lines per metre on the grating.

number of lines per metre = [3]

- (c) A second laser is directed normally to another diffraction grating with the same number of lines as in (b).

Describe and explain how the new appearance of the diffraction grating pattern provide evidence for any changes to the following.

- (i) the wavelength of the second laser,

.....

 [2]

- (ii) the orientation of the diffraction grating.

.....

 [1]

- (d) The diffraction grating in (c) is added directly in front of the first grating such that the orientation of the two diffraction gratings are perpendicular to each other. The diffraction pattern in Fig. 4.3 is observed.

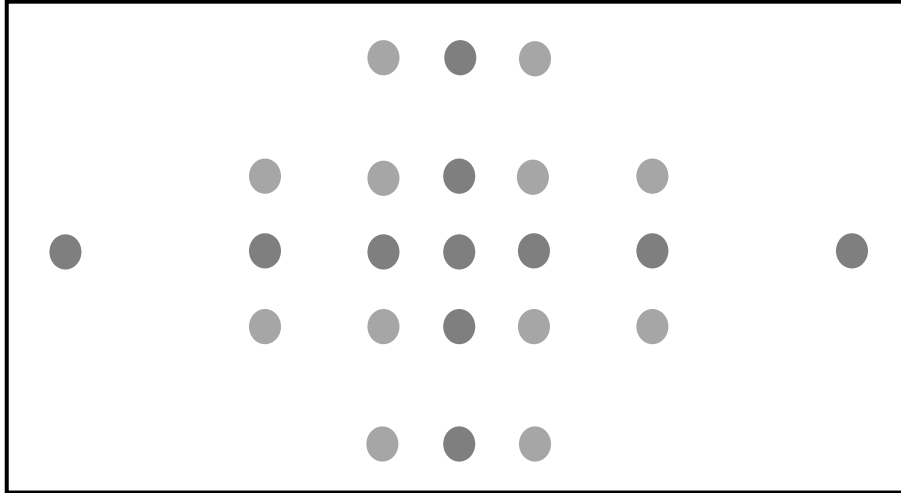


Fig. 4.3

Suggest how the pattern in Fig. 4.3 is formed.

.....

.....

.....

..... [2]

- (e) A student sets up the apparatus in Fig. 4.1 but rotates the diffraction grating by 45° such that the laser is no longer normal to the grating.

Suggest and explain whether the position of the brightest spot O in Fig. 4.2 will change.

.....

.....

..... [1]

[Total: 10]

- 5 Two stars A and B are separated by a distance of 1.2×10^{10} m as shown in Fig. 5.1. x is the distance from the centre of star A, in the direction toward the centre of star B.

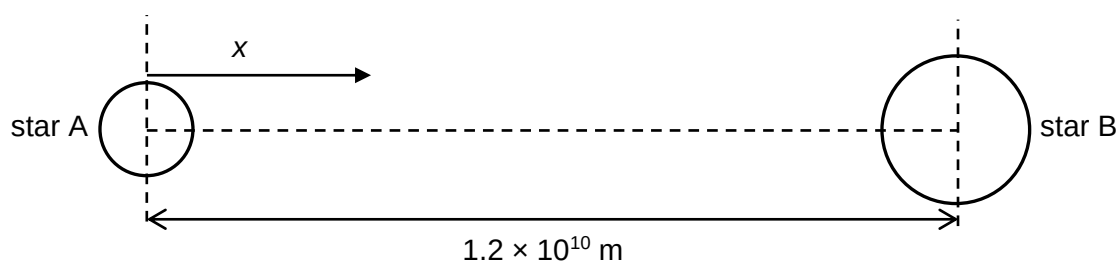


Fig. 5.1

The variation with x of the gravitational potential ϕ due to the two stars along the line joining their centres is shown in Fig. 5.2.

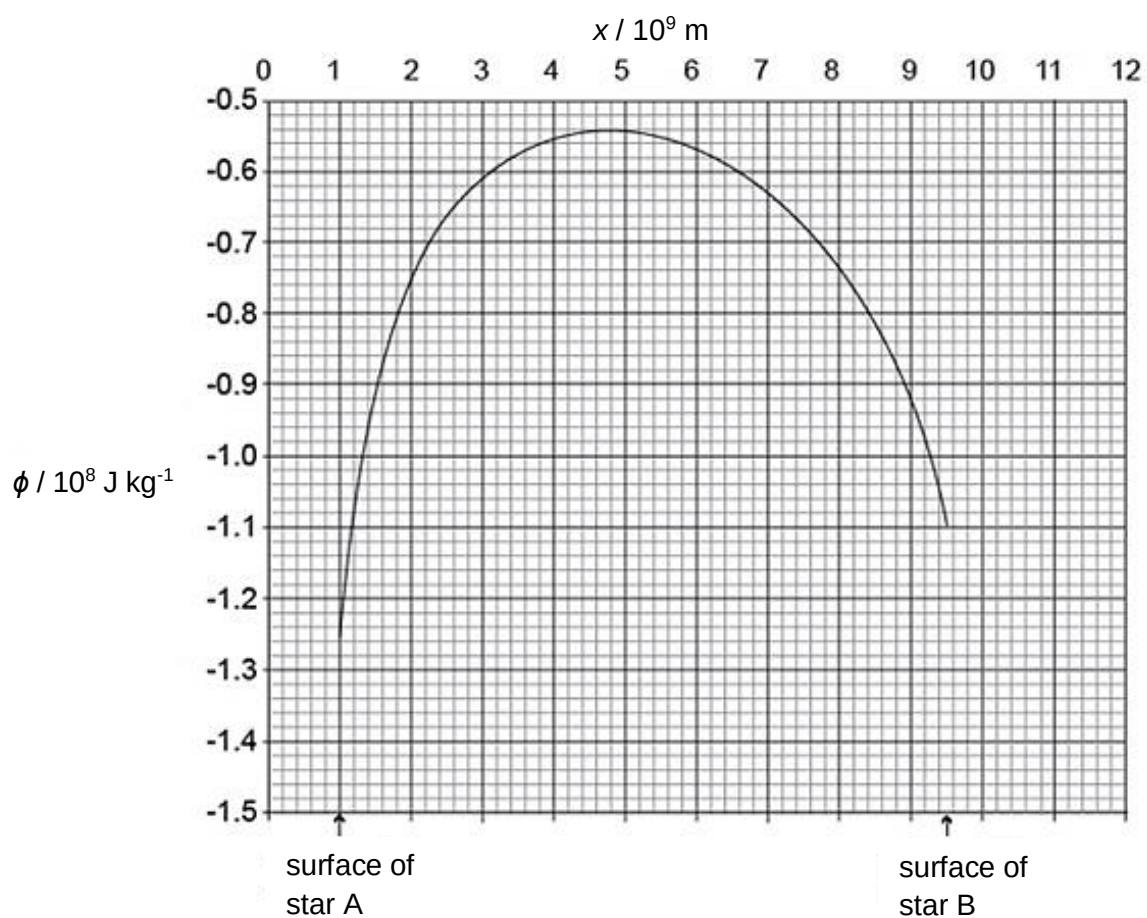


Fig. 5.2

A body is launched with kinetic energy E_K from the surface of star B.

The body then arrives at the surface of the star A.

- (a) Define *gravitational potential* at a point.

.....
[1]

- (b) Use Fig. 5.2 to explain whether the kinetic energy of the body when it arrives at the surface of star A is less than, equal to, or larger than E_k .

.....

[2]

- (c) State and explain the distance x at which the resultant gravitational field strength due to the two stars is zero.

.....

[2]

- (d) Determine the ratio $\frac{\text{average density of star A}}{\text{average density of star B}}$.

ratio = [3]

[Total: 8]

- 6 A power supply is connected across a load as shown in Fig. 6.1.

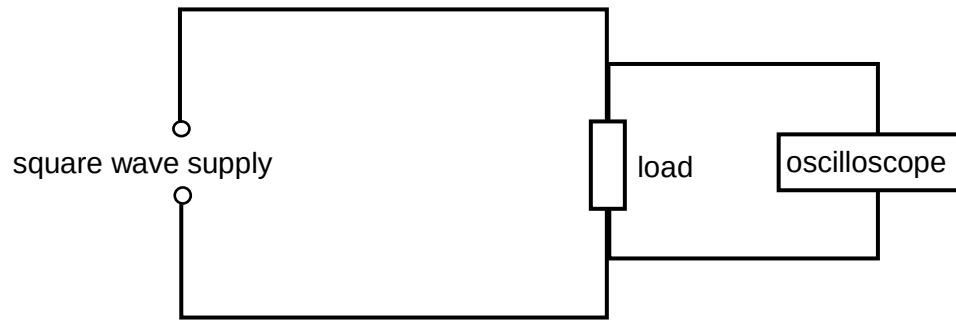


Fig. 6.1

The power supply provides a square wave voltage that cycles between $+7.0\text{ V}$ and -7.0 V as shown on the oscilloscope display in Fig. 6.2.

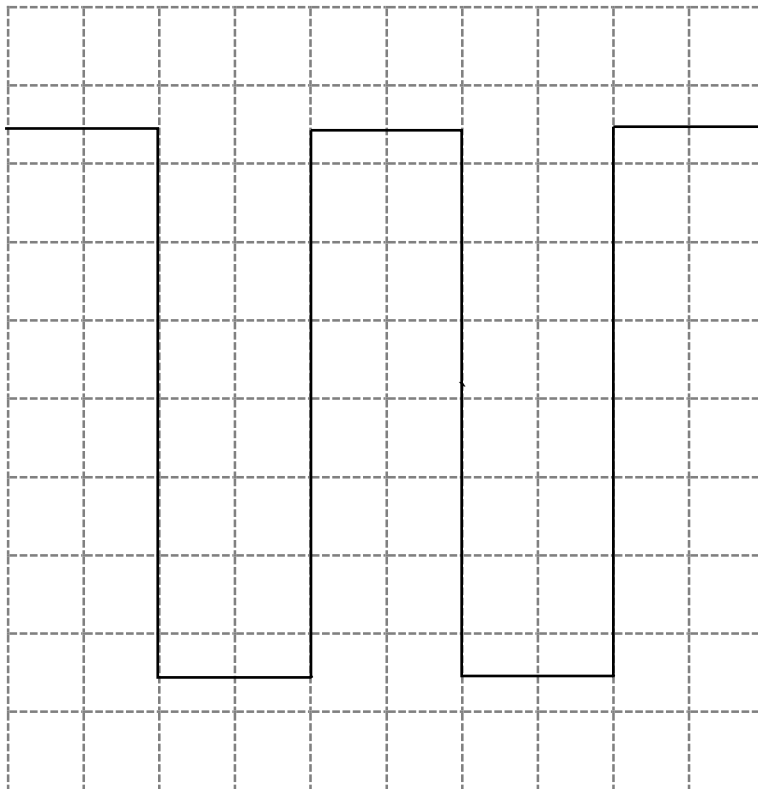


Fig. 6.2

- (a) Determine the Y-gain for the oscilloscope based on the waveform shown in Fig. 6.2

Y-gain = V / div [2]

- (b) Determine the frequency of the square wave given that the time base is 5.0 ms / div.

frequency of square wave = Hz [1]

- (c) The root-mean-square value for the square wave in Fig. 6.2 is 7.0 V. Explain the significance of this value.

.....

 [1]

- (d) A diode is used to achieve rectification of the square wave.

On Fig. 6.3, sketch the new waveform. The original waveform in Fig. 6.2 has been reproduced as the grey line shown. [1]

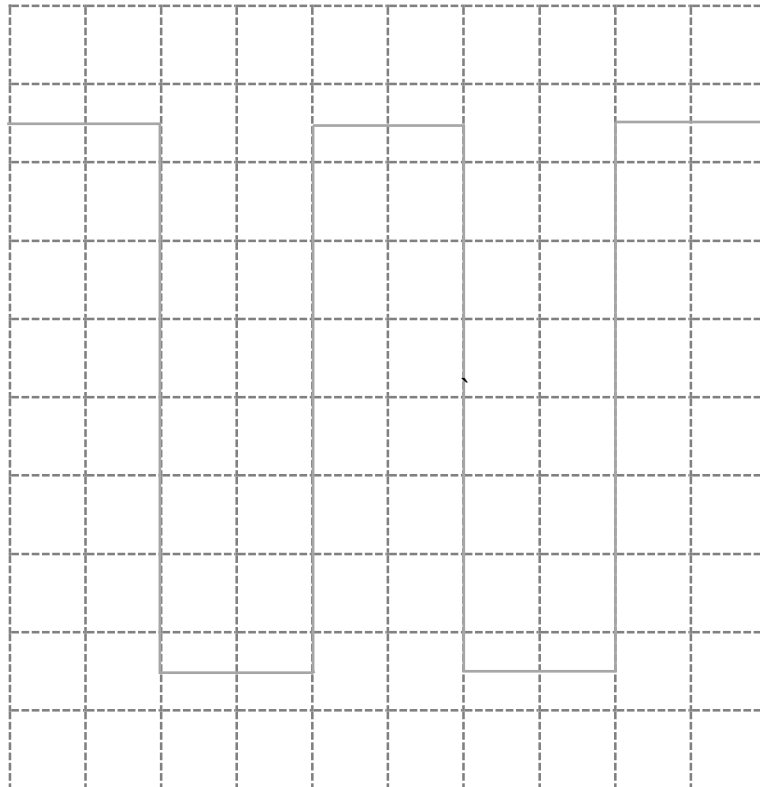


Fig. 6.3

- (e) With the diode still in place, the power supply is replaced by another one which is sinusoidal. Determine the value of the peak voltage such that the average power dissipated in the load remains the same as the value given in (c).

peak voltage = V [2]

[Total: 7]

- 7 (a) X-rays are produced in an X-ray tube when high-speed electrons are accelerated toward and hit a metal target. Fig. 7.1 shows the variation with wavelength of the intensity of X-ray radiation emitted.

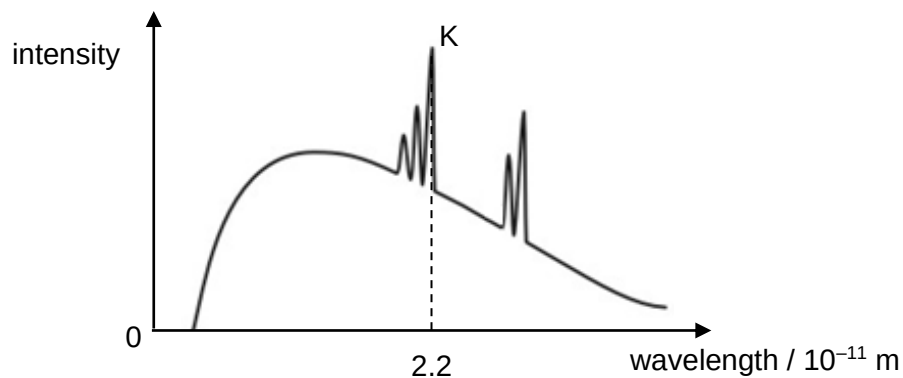


Fig. 7.1

- (i) Explain why there is a continuous distribution of wavelengths.

.....

.....

.....

.....

.....

..... [2]

- (ii) A series of characteristic lines shown by the high intensity peaks, such as K, are observed in Fig. 7.1.
1. Calculate the energy difference, in keV, associated with the characteristic line K.

energy difference = keV [2]

2. Suggest why there are other series of characteristic lines produced at wavelengths longer than K.

.....

.....

.....

.....

..... [2]

Question 7 continues on the following page.

- (b) A simple model of an atom with one electron can be represented by the electron as a stationary wave confined in a box of length 1.0×10^{-10} m equal to the diameter of the atom, as shown in Fig. 7.2.

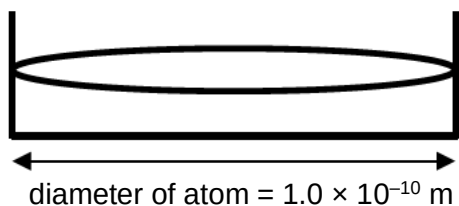


Fig. 7.2

- (i) State the uncertainty in locating the position of the electron.

uncertainty in position = m [1]

- (ii) Calculate the uncertainty in the velocity of the electron.

uncertainty in velocity = m s^{-1} [1]

- (iii) The diameter of a nucleus is 10^4 times smaller than the diameter of an atom.
Using the model above, suggest why an electron cannot be found inside the nucleus.

.....

[1]

[Total: 9]

Section B

Answer **one** question from this Section in the spaces provided.

- 8** This question is on the common last topic of Nuclear Physics and will not be assessed.

- 9 A cycle of changes in pressure, volume and temperature of gas inside a cylinder of a petrol engine is illustrated in Fig. 9.1. The gas is assumed to be ideal.

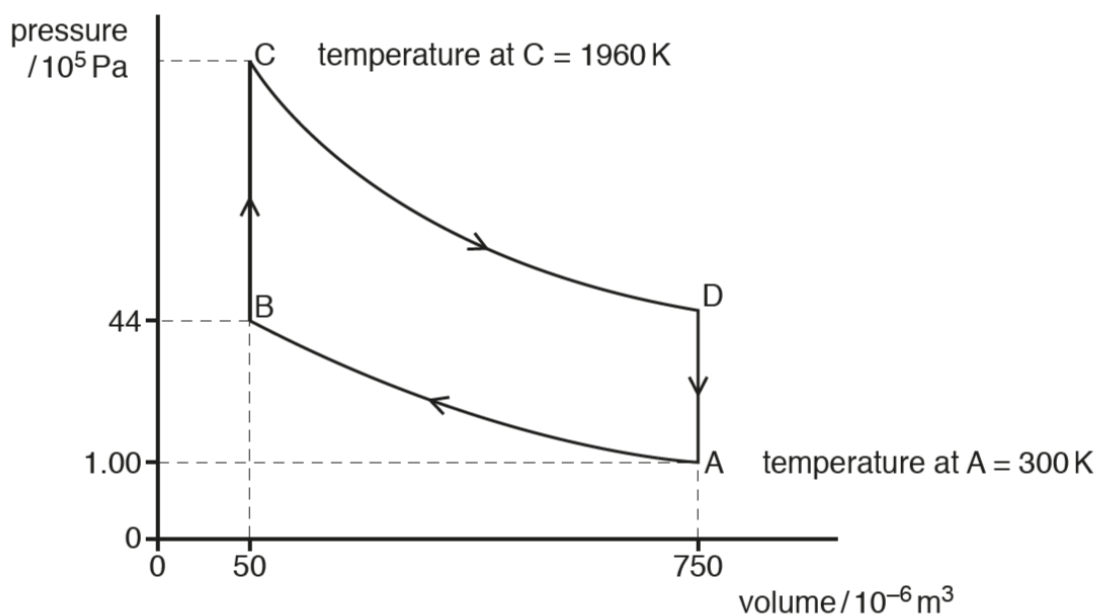


Fig. 9.1 (not to scale)

There are four stages in the cycle.

stage	description
A to B	Rapid compression of the gaseous petrol/air mixture with the temperature rising from 300 K at A. The pressure at B is 44×10^5 Pa.
B to C	The petrol/air mixture is exploded, resulting in an almost instant rise in pressure. At C the temperature is 1960 K.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the initial state of the cycle.

- (a) (i) Using appropriate values from Fig. 9.1, determine the number of moles present in the gases in the cycle.

number of moles = mol [2]

(ii) Calculate the temperature of the gas at B.

temperature =K [2]

(iii) Calculate the pressure of the gas at C.

pressure =Pa [2]

(iv) State

1. the numerical value of work done by the gas from B to C,

..... [1]

2. what is represented by the area ABCD enclosed by the graph.

.....
 [2]

(b) Complete Table 9.1, which shows the work done on the gas, the heat supplied to the gas and the increase in internal energy of the gas, during the four stages in the cycle.

Table 9.1

stage	work done on gas /J	heat supplied to gas /J	increase in internal energy of gas /J
A to B	+ 360	0	
B to C		+ 670	
C to D		0	– 810
D to A			

[4]

- (c) The efficiency of this engine is the ratio of the net work done by the gas to the heat supplied to the gas. Calculate the efficiency of this cycle.

efficiency = % [1]

- (d) Using the First Law of Thermodynamics, explain whether the r.m.s. speed of the molecules of the gas will increase, decrease or remains the same when the gas expands rapidly from C to D.

.....

 [2]

- (e) Explain, in terms of the collision of the molecules of the gas with the walls of the container, why an expansion results in a change in the kinetic energy of the molecules from C to D.

.....

 [2]

- (f) Calculate the total kinetic energy of the molecules of the gas at C.

total kinetic energy = J [2]

[Total: 20]

End of Paper