NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	

PHYSICS

9646/03

Paper 3 Longer Structured questions

23 September 2014

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

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	
2	
3	
4	
5	
Section B	
6	
7	
8	
deductions	
Total	**80**

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o{}^2 - x^2)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	=	exp(-2kd)
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{0.693}{t_{1/2}}$

For Examiner's Use

Section A

Answer **all** the questions in this section.

1 **(a)** **(i)** Define *gravitational potential*.

....

....

.... [2]

(ii) Explain why gravitational potential has a negative value.

....

....

....

.... [2]

(b) Values for the gravitational potential due to the Earth are given in the table below:

Distance from the Earth's surface/ m	Gravitational potential/ MJ kg^{-1}
0	-62.72
390 000	-59.12
400 000	-59.03
410 000	-58.94
infinity	0

(i) Calculate the loss in the potential energy of a satellite of mass 700 kg if it falls from a height of 400 000 m to the surface of the Earth.

loss in potential energy = ... J [2]

(ii) Deduce a value for the gravitational field strength of the Earth at a height of 400 000m.

gravitational field strength = ... N kg^{-1} [2]

2 **(a)** State the First Law of Thermodynamics.

....

....

.... [1]

Fig. 2.1 shows the variation with volume of the pressure of an ideal gas. The gas which is initially at state X, can be compressed to state Z either directly along the curve path XZ or indirectly from X to Y to Z.

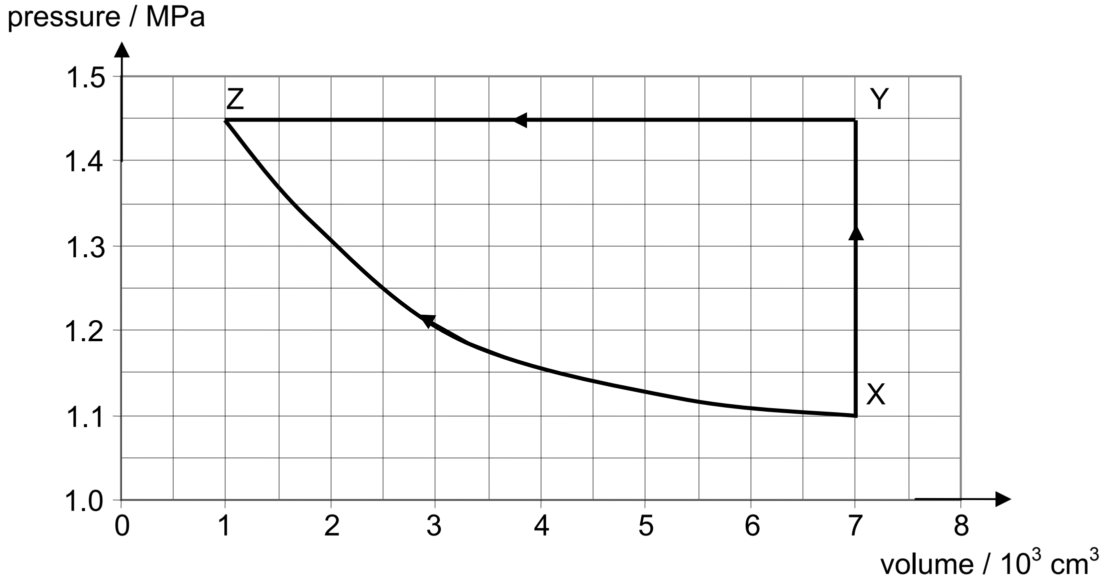

Fig. 2.1

(b) When the gas is compressed from X to Z along the curved path, 9000 J of heat energy is released to the surrounding.

(i) Using Fig. 2.1, estimate the work done on the gas.

work done on gas = ... J [2]

(ii) Hence, calculate the change in internal energy of the gas.

change in internal energy = ... J [1]

(c) When the gas is compressed from **X** to **Z** along the paths **XY** and **YZ**,

(i) determine the quantity of heat supplied to the gas.

heat supplied = ... J [2]

(ii) using the graph, explain whether the process from **Y** to **Z** is isothermal.

....

....

....

.... [2]

3 **(a)** Define *electric field strength* at a point in an electric field.

....

....

.... [1]

(b) Fig. 3.1 shows two isolated point charges **X** and **Y**. **X** carries a charge of $+3.2 \times 10^{-10}$ C, while **Y** carries a charge of -6.2×10^{-10} C. The two charges are 0.20 cm apart.

Sketch on Fig. 3.1, the resultant electric field lines due to the two charges.

Fig. 3.1

[3]

For Examiner's Use

(c) A test charge **T** of $+1.2 \times 10^{-10}$ C is placed 0.10 cm from **X** such that **XTY** forms a right angle as shown in Fig. 3.2.

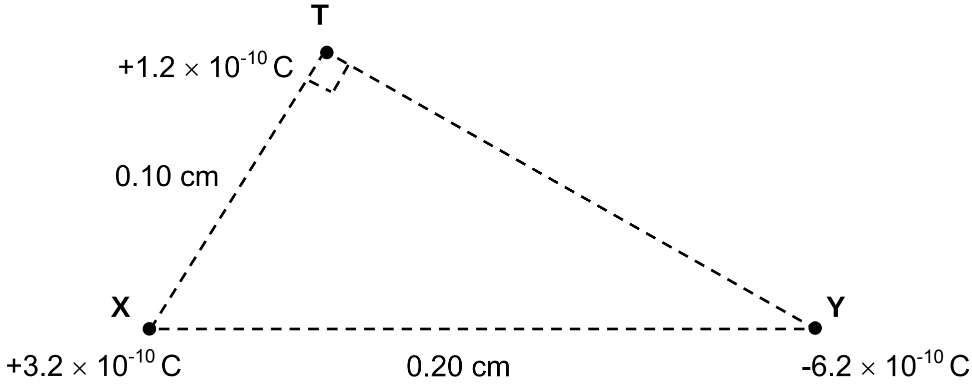

Fig. 3.2

(i) Calculate the magnitude of the net force, ***F***, acting on **T** and

magnitude of net force, ***F*** = ... N [3]

(ii) indicate its general direction in Fig. 3.2 (Exact calculation for the direction is not required.) [1]

4 A potential divider circuit consists of two resistors of resistances *A* and *B*, as shown in Fig. 4.1.

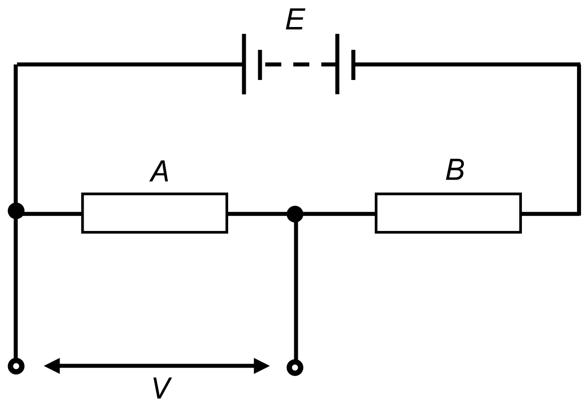

Fig. 4.1

The battery has e.m.f. *E* and negligible internal resistance.

For Examiner's Use

(a) Deduce that the potential difference V across the resistor of resistance A is given by the expression

$$V = \frac{A}{A+B}E$$

[2]

(b) The resistances A and B are 1500 Ω and 4000 Ω respectively.
A voltmeter is connected in parallel with the 1500 Ω resistor and a thermistor is connected in parallel with the 4000 Ω resistor, as shown in Fig. 4.2.

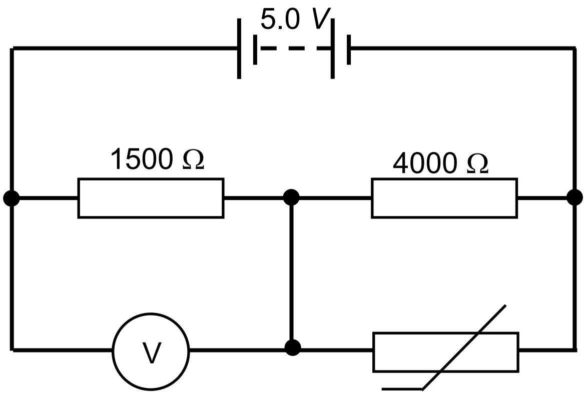

Fig. 4.2

The battery has e.m.f. 5.0 V. The voltmeter is ideal.

(i) State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised.

....

....

....

.... [3]

(ii) The voltmeter reads 2.4 V when the temperature of the thermistor is 20 °C. Calculate the resistance of the thermistor at 20 °C.

resistance = ... Ω [3]

For Examiner's Use

5 Fig. 5.1 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

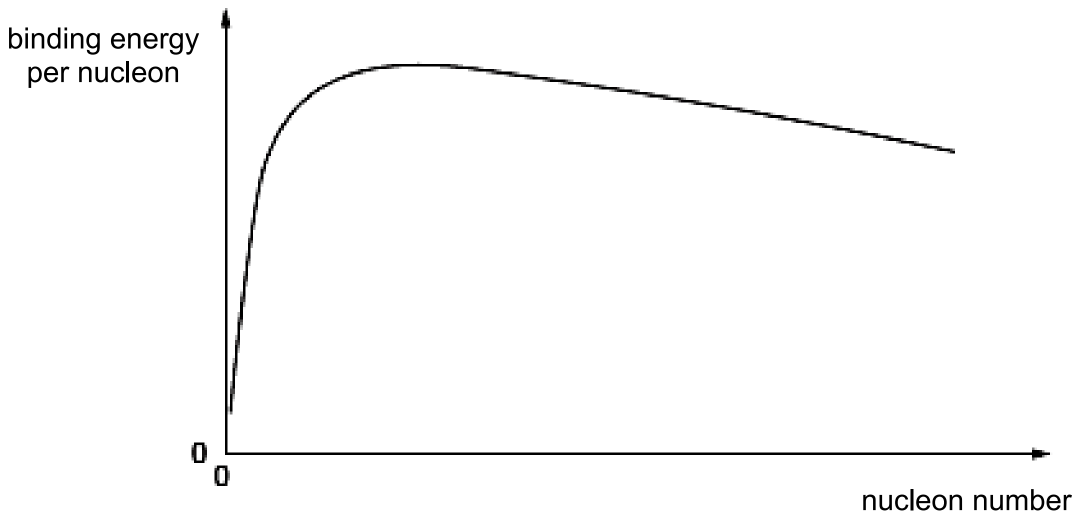

Fig. 5.1

(a) On Fig. 5.1, mark with the letter S the position of the nucleus with the greatest stability. [1]

(b) One possible fission reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n$$

(i) On Fig. 5.1, mark possible positions for

1 the Uranium-235 nucleus and label this position U, [1]

2 the Krypton-90 nucleus and label this position Kr. [1]

For Examiner's Use

(ii) The binding energy per nucleon of each nucleus is as follows:

$^{235}_{92}$U: 1.2191×10^{-12} J

$^{144}_{56}$Ba: 1.3341×10^{-12} J

$^{90}_{36}$Kr: 1.3864×10^{-12} J

Use these data to calculate

1 the energy released in this fission reaction, giving your answer to three significant figures.

energy released = ... J [3]

2 the mass equivalent of this energy.

mass = ... kg [1]

(iii) Suggest why the neutrons were not considered in your calculation in **(ii)**.

....

.... [1]

Section B

Answer **two** questions in this section.

6 **(a)** A structure consists of a sphere of mass 0.500 kg, attached firmly to one end of a light rod. The other end of the rod is pivoted freely at point O. The distance between the centre of gravity of the sphere to O is 0.400 m. The structure is held in a position such that the rod is at an angle of 5.00° from the vertical, as shown in Fig. 6.1.

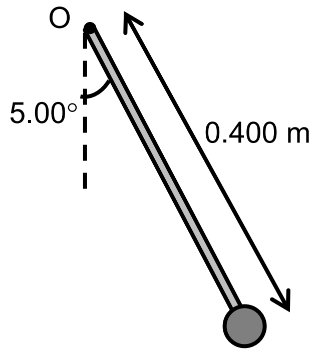

Fig. 6.1

The structure is then released from rest and oscillates in simple harmonic motion. At one instant during the oscillation, the sphere is directly below O, as shown in Fig. 6.2.

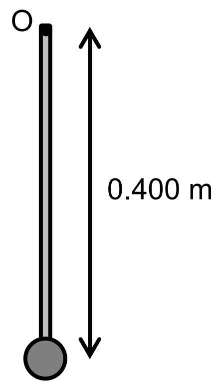

Fig. 6.2

(i) On Fig. 6.2, indicate the forces acting on the structure. [2]

(ii) Show that the linear speed of the sphere at the instant in Fig. 6.2 is 0.173 m s^{-1}.

[2]

For Examiner's Use

(iii) Determine the force exerted on the pivot by the structure in Fig. 6.2.

force = ... N [3]

(iv) With the aid of a diagram, discuss whether the force exerted by the pivot on the structure is *always upward* throughout the oscillation.

....

....

....

.... [3]

(b) A horizontal turntable is connected to a motor such that it rotates at exactly 47 revolutions per minute. A peg is fixed vertically on the turntable. A horizontal beam of light casts a shadow of the peg onto a screen in front of which is suspended the structure mentioned in **(a)**, as shown in Fig. 6.3.

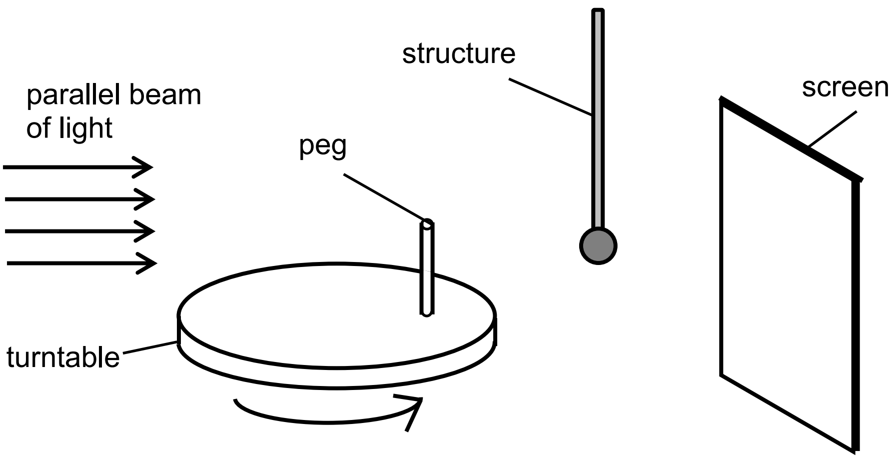

Fig. 6.3

The length of the structure is adjusted such that the shadows of the peg and the structure move in phase on the screen.

For Examiner's Use

(i) Explain what is meant by *in phase* in this context.

....

.... [1]

The angular speed of the turntable suddenly increases to $47\frac{1}{3}$ revolutions per minute.

(ii) Define *angular speed*.

....

.... [1]

(iii) Briefly describe what will be observed on the screen.

....

....

....

.... [2]

(iv) Determine the time taken before the two shadows are next in phase.

time taken = ... s [2]

(v) Calculate the number of oscillations made by the *peg* before the shadows are next in phase.

number of oscillations = ... [2]

(vi) State two assumptions that were made in the calculations of **(b)(iv)** and **(b)(v).**

....

....

....

.... [2]

For Examiner's Use

7 **(a)** **(i)** State the *principle of superposition*.

....

....

.... [1]

(ii) Explain what is meant when two sources are *coherent*.

....

....

.... [1]

(b) Two sources S_1 and S_2 of sound are situated 80 cm apart in air, as shown in Fig. 7.1.

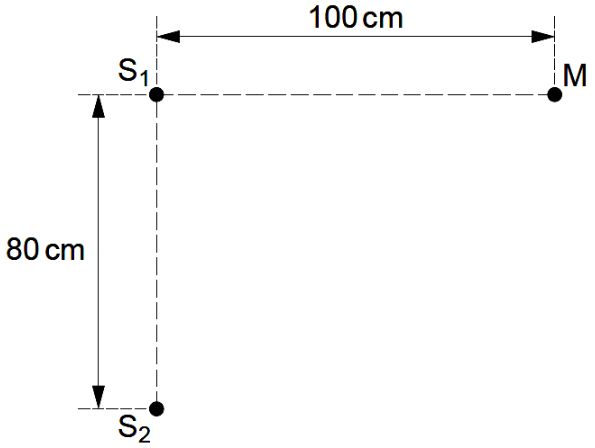

Fig. 7.1

The frequency of vibration can be varied. The two sources always vibrate in phase but have different amplitudes of vibration.

A microphone M is situated a distance 100 cm from S_1 along a line that is normal to S_1S_2.

As the frequency of S_1 and S_2 is gradually increased, the microphone M detects maxima and minima of intensity of sound.

(i) State the two conditions that must be satisfied for the intensity of sound at M to be zero.

1. ....

....

2. ....

.... [2]

(ii) The speed of sound in air is 330 m s^{-1}.

The frequency of sound from S_1 and S_2 is increased. Determine the number of minima that will be detected at M as the frequency is increased from 1.0 kHz to 4.0 kHz.

number of minima = ... [4]

(iii) The variation with time of the displacement x of the sound waves arriving at M from S_1 and S_2 are as shown in Fig. 7.2a and Fig. 7.2b respectively.

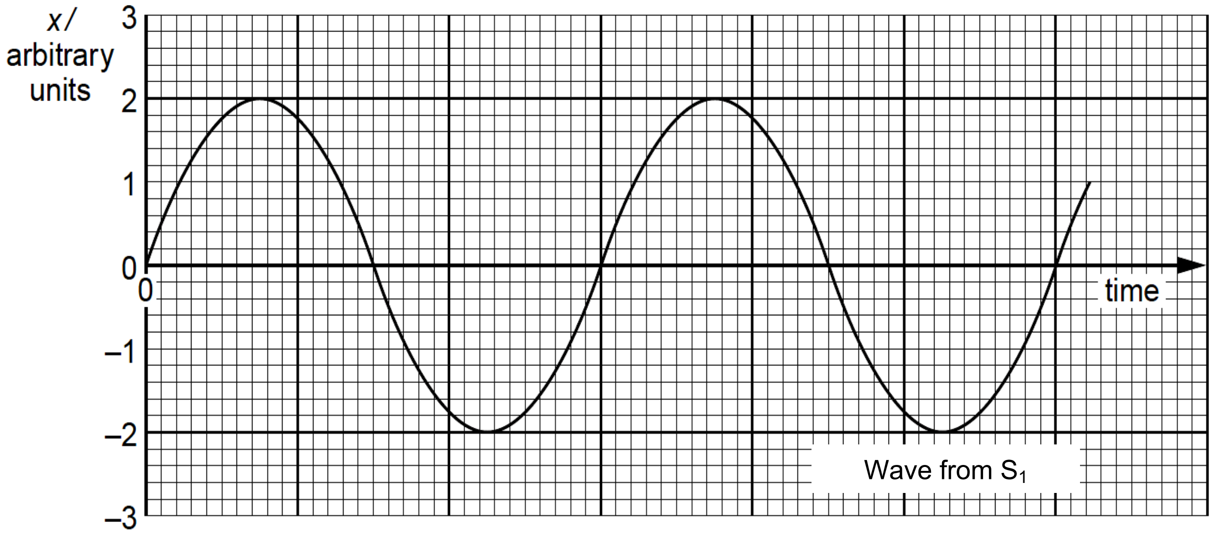

Fig. 7.2a

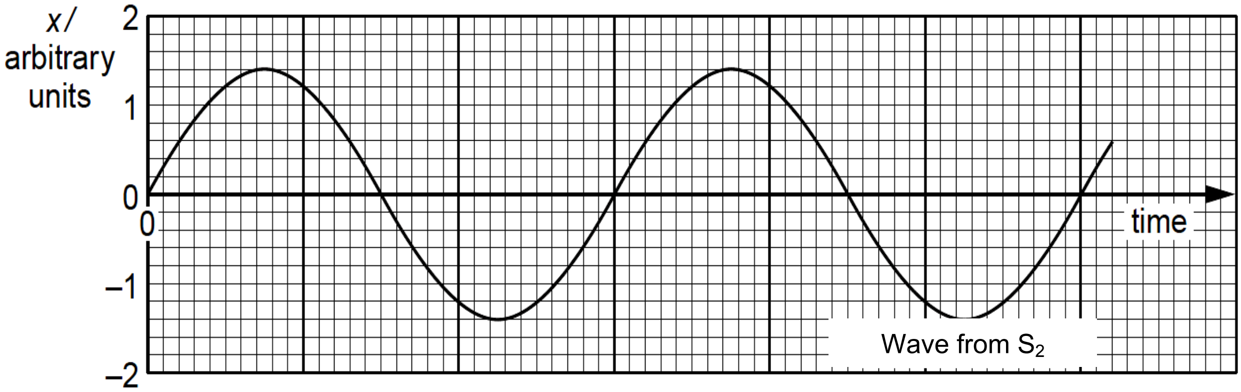

Fig. 7.2b

For Examiner's Use

Determine the ratio of

$$\frac{\text{intensity of sound when a maxima is detected at M}}{\text{intensity of sound when a minima is detected at M}}$$

ratio = ... [3]

(c) Laser beam of red light of wavelength 644 nm is incident normally on a diffraction grating having 550 lines per millimetre, as illustrated in Fig. 7.3.

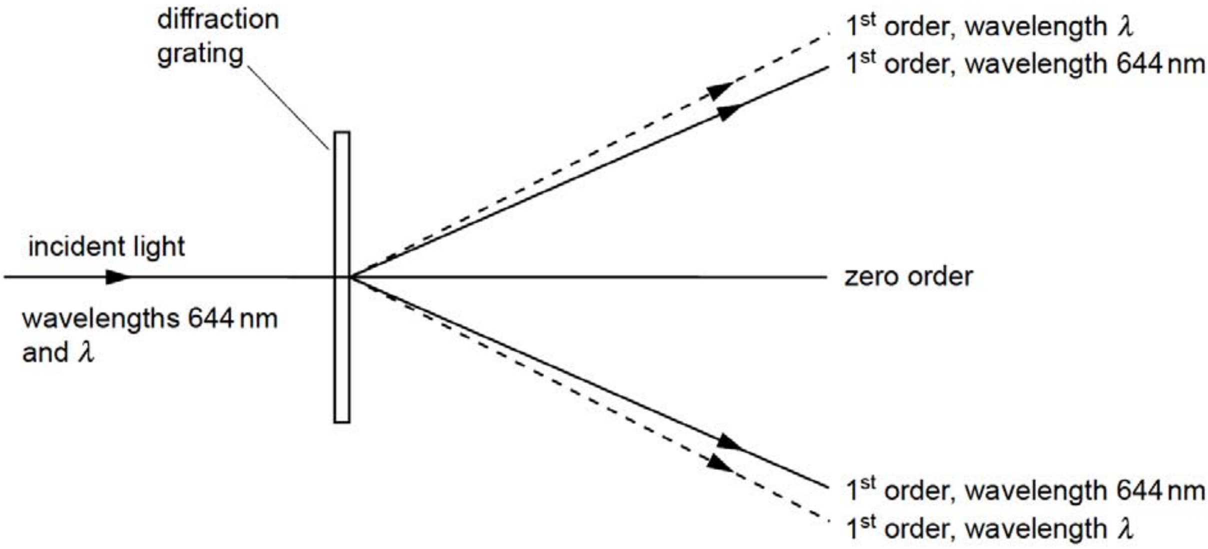

Fig. 7.3

Red light of wavelength λ is also incident normally on the grating. The first order diffracted light of both wavelengths is illustrated in Fig. 7.3.

(i) Determine the total number of bright spots of wavelength 644 nm that are visible.

total number of bright spots = ... [3]

(ii) State and explain

1 whether λ is greater or smaller than 644 nm,

....

.... [1]

2 in which order of diffracted light there is the greatest separation of the two wavelengths.

....

.... [2]

(iii) The diffraction grating is now rotated 90° about an axis parallel to the incident laser beam, as shown in Fig. 7.4.

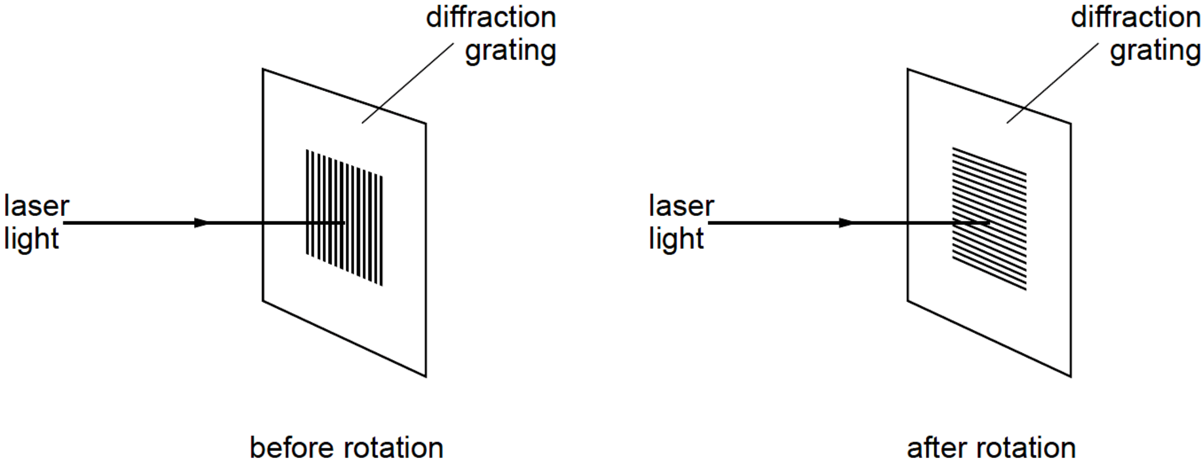

Fig. 7.4

State what effect, if any, this rotation will have on the diffraction pattern that is observed.

....

....

....

.... [2]

(iv) In another experiment using the same apparatus, a student notices that the angular separation between the zero order maxima and the two 1st order maxima are not equal.

Suggest a reason for this difference.

....

....

.... [1]

For Examiner's Use

8 **(a)** 'X-rays are used to investigate the atomic structure of solids.' Deduce from this statement the wavelength of the X-rays used.

....

.... [1]

(b) 'Sometimes, for example, in the case of rubber, electrons with a de Broglie wavelength of about 0.11 nm are used instead of X-rays.'
Determine the momentum of each electron.

momentum = ... N s [2]

(c) An X-ray tube operates with a potential difference of 100 kV between the anode and cathode. Fig. 8.1 is a sketch of the X-ray spectrum produced by this tube for a particular metal target. Fig. 8.2 shows a sketch of the energy level of target material and how the K_α line is formed. The tube voltage is 100 kV and the current is 20 mA.

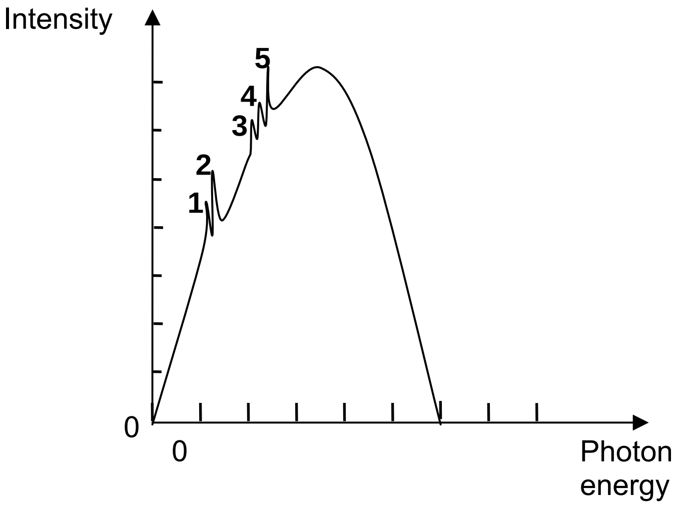

Fig. 8.1

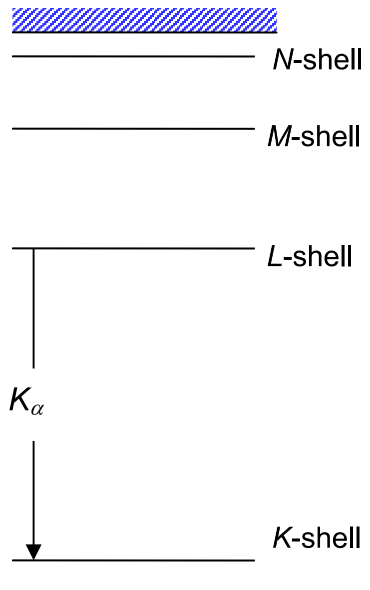

Fig. 8.2

(i) Calculate the maximum energy of an X-ray photon produced, explain your working.

maximum energy = ... J [2]

(ii) With reference to Fig. 8.1, write down the numbers that represent the spectrum lines K_α and L_β .

K_α: .... L_β: .... [2]

(iii) Sketch on Fig. 8.1 a spectrum for X-ray from the tube if the tube voltage is reduced to 50 kV, the current at 10 mA. Label this spectrum A. [2]

(d) Explain how the characteristic and continuous parts of the spectrum are formed.

(i) Formation of characteristic parts of X-ray spectrum:

....

....

....

.... [2]

(ii) Formation of continuous parts of X-ray spectrum:

....

....

....

.... [2]

(e) The energy required to remove an electron from the various shells of the nickel atom is:

K shell 1.36×10^{-15} J
L shell 0.16×10^{-15} J
M shell 0.08×10^{-15} J

An X-ray tube with a nickel target emits the X-ray K_α radiation of nickel.

Determine

(i) the minimum potential difference across the tube,

potential difference = ... V [2]

(ii) the energy of the X-ray quantum of longest wavelength in the K-spectrum of nickel.

energy = ... J [2]

(f) A beam of electrons moving in the x-axis in an X-ray tube with momentum 4×10^{-23} kg m s^{-1} in the x-axis passes through a 3 mm slit in an anode before it hits the target as shown in Fig. 8.3. The uncertainty of the y-position of the electrons can be considered in the order of the size of the slit. Use uncertainty principle to estimate the possible angular spread θ of the electron beam after passing through the slit.

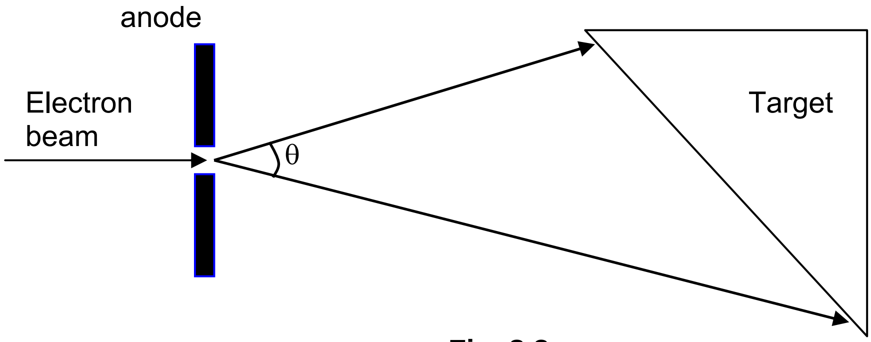

Fig. 8.3

θ = ... rad [3]