NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	
CLASS	
TUTOR'S NAME	
CENTRE NUMBER	S
INDEX NUMBER	

PHYSICS 9749/02

Paper 2 Structured Questions

14 September 2023

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

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** 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	
1	/ 8
2	/ 9
3	/ 8
4	/ 7
5	/ 8
6	/ 8
7	/ 10
8	/ 22
Total	/ 80

This document consists of **20** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Fig. 1.1 shows the variation of velocity v with time t for a fuel-propelled model rocket travelling upwards.

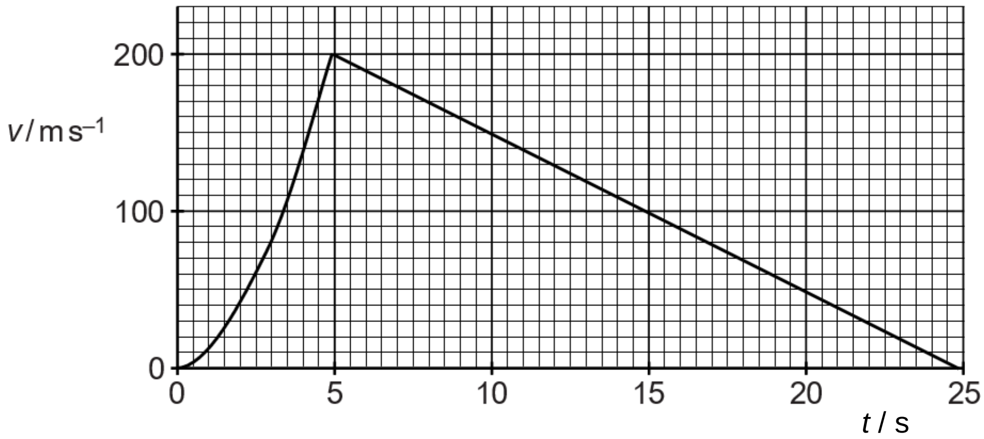

Fig. 1.1

(a) **(i)** Define *acceleration*.

.... [1]

(ii) State the time interval when the rocket has the greatest acceleration.

between t = ... s to t = ... s [1]

(iii) Explain why the acceleration of the rocket increases between t = 0 to t = 5.0 s.

....

....

.... [1]

(b) **(i)** Suggest a reason for the abrupt change in the motion of the rocket at t = 5.0 s.

....

.... [1]

(ii) Explain how it can be deduced from Fig. 1.1 that air resistance has a negligible effect on the motion of the rocket.

....

....

....

.... [2]

(c) Use Fig. 1.1 to determine the maximum height reached by the rocket.

height = ... m [2]

[Total: 8]

2 **(a)** State the *principle of moments*.

....

....[1]

(b) Fig. 2.1 shows part of a cable-stayed bridge. Each section of the bridge is supported by eight equally spaced cables that pass through a central supporting pillar.

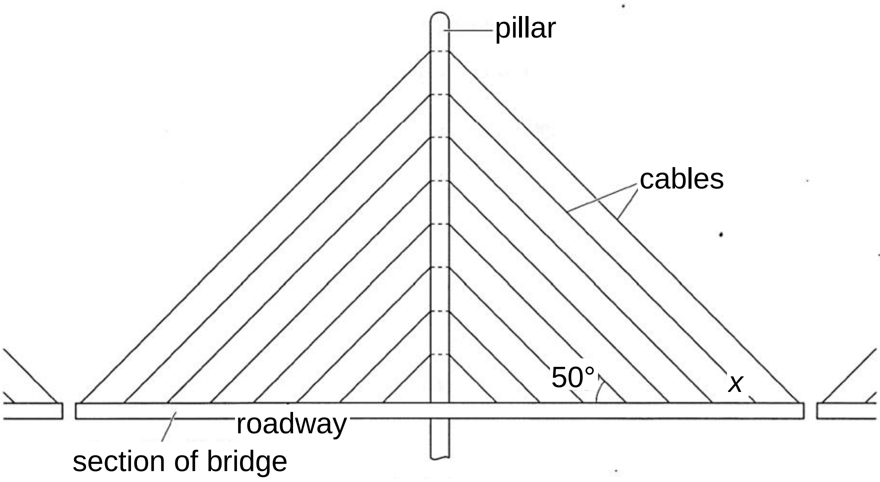

Fig. 2.1 (not to scale)

The cables are at an angle of 50° to the horizontal and the maximum tension allowed in each cable is 7.8×10^5 N.

(i) The mass of the roadway in this section is 350 tonnes (1 tonne = 1000 kg).
Calculate the maximum mass of traffic that is allowed on this section of the roadway.

mass = ... kg [2]

(ii) Suggest a reason why the maximum tension allowed in each cable is well below the breaking tension.

....

....

....[1]

(c) Fig. 2.2 shows a suspension bridge. The cables of the bridge are anchored into large free-standing anchor blocks of concrete.

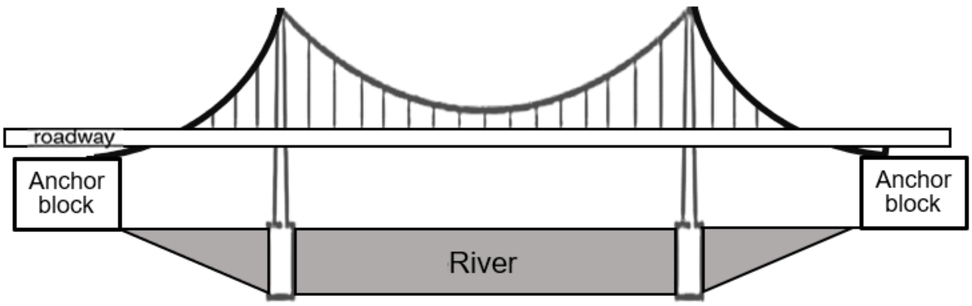

Fig. 2.2

The anchor block on the right is shown on a larger scale in Fig. 2.3. It has a length of 30.0 m and its cross-section and density are uniform.

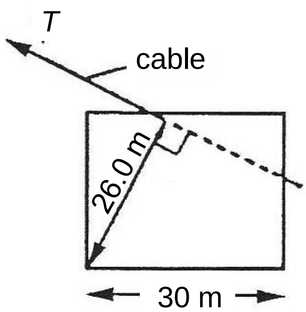

Fig. 2.3

This block is standing on the ground. The maximum force which the cables could exert on this block is 5.50×10^8 N for a particular bridge. This force acts in the direction shown so that its line of action is 26.0 m from the point about which the block might possibly rotate.

(i) Calculate the minimum mass of the block needed to prevent rotation, when the force exerted by the cable has its maximum value.

minimum mass = ... kg [2]

(ii) Draw on Fig. 2.4 the two other forces acting on the block under normal operating conditions (i.e. when the maximum force of the cable on the block is not at the maximum value). [3]

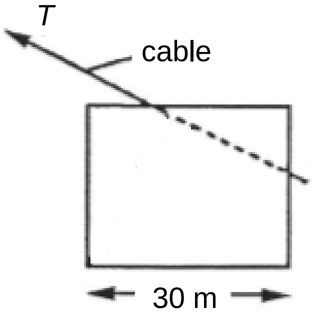

Fig. 2.4

[Total: 9]

3 (a) (i) By reference to the direction of propagation of energy, state how plane-polarised light differs from unpolarised light.

....

....

....[2]

(ii) Explain why sound waves cannot be polarised.

....

....[1]

(b) Light from a laser incident normally on an ideal polarising filter. The polarising filter is slowly rotated about a horizontal axis that is parallel to the incident light as shown in Fig. 3.1.

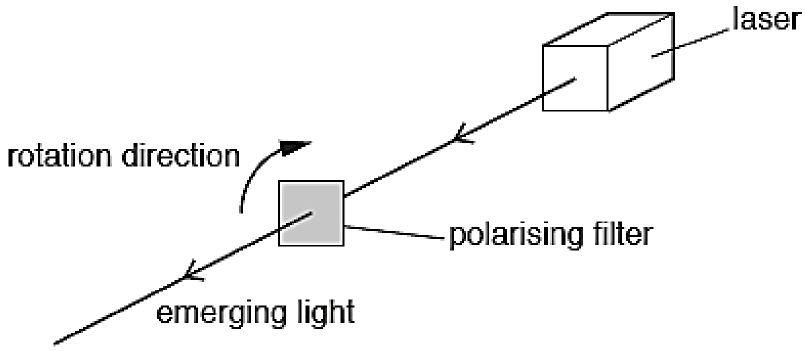

Fig. 3.1

It was observed that the intensity of the emerging light varies from I_o to 0.

(i) State what may be deduced from this observation.

....[1]

(ii) On Fig. 3.2, sketch a graph to show how the intensity of the emerging light may vary with the angle θ which the filter is rotated. [2]

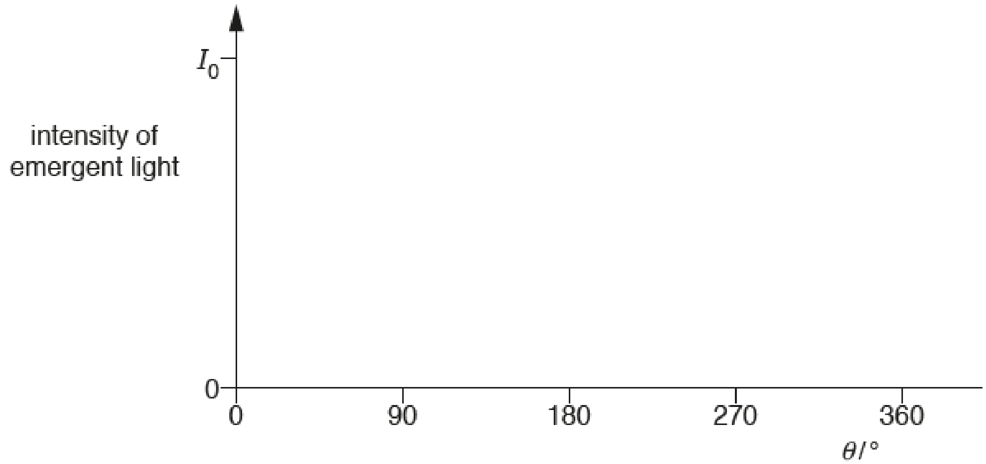

Fig. 3.2

(c) Fig. 3.3 shows a beam of sunlight that is reflected from a surface and passes through a vertical polarising filter.

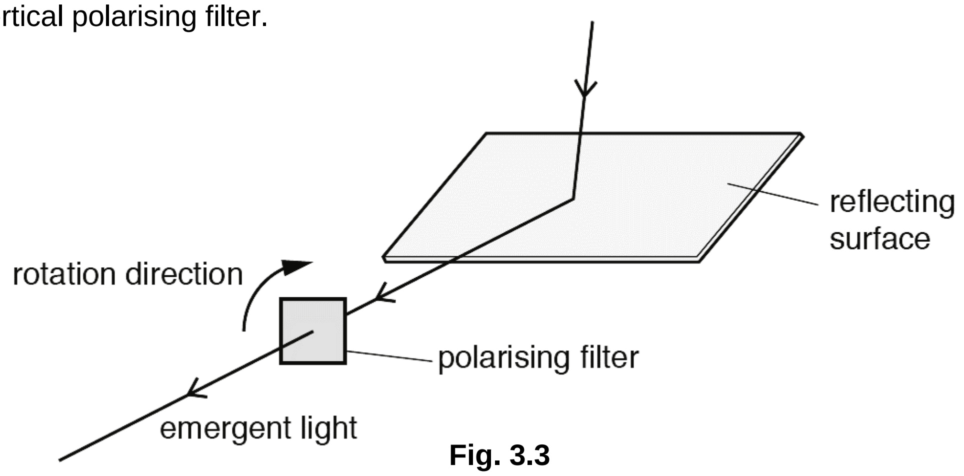

Fig. 3.3

The light that reflects from the surface is an unequal mixture of vertically polarised and horizontally polarised light.

When the polarising direction of the filter is vertical, the intensity of the emergent light is 0.262 I_o. When the polarising direction of the filter is horizontal, the intensity is 0.850 I_o.

Determine the intensity of the emergent light when the polarising direction of the filter is 30° from the vertical.

intensity = ... I_o [2]

[Total: 8]

4 **(a)** Explain what is meant by a *field of force*.

....

.... [1]

(b) State **one** similarity and **one** difference between the fields produced by an isolated point charge and by an isolated point mass.

similarity: ....

....

difference: ....

....

[2]

(c) An isolated solid metal sphere A of radius R has charge $+Q$, as illustrated in Fig. 4.1.

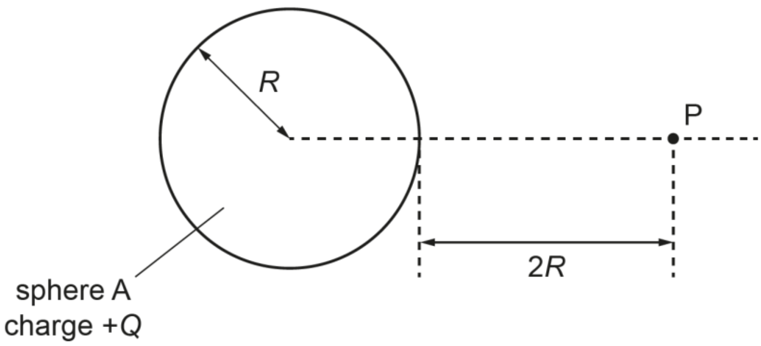

Fig. 4.1

A point P is distance $2R$ from the surface of the sphere.

Determine an expression that includes the terms R and Q for the electric field strength E at point P.

E = ... [1]

(d) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance 6*R*, as shown in Fig. 4.2.

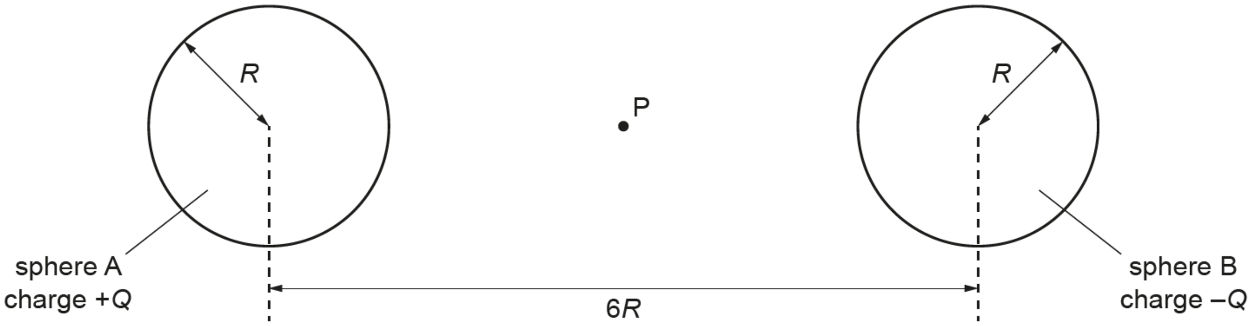

Fig. 4.2

Point P lies midway between spheres A and B.

Sphere B has charge –*Q*.

Explain why

(i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere.

....

....[1]

(ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to 2*E*, where *E* is the electric field strength determined in **(c)**.

....

....

....

....[2]

[Total: 7]

5 A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 5.1.

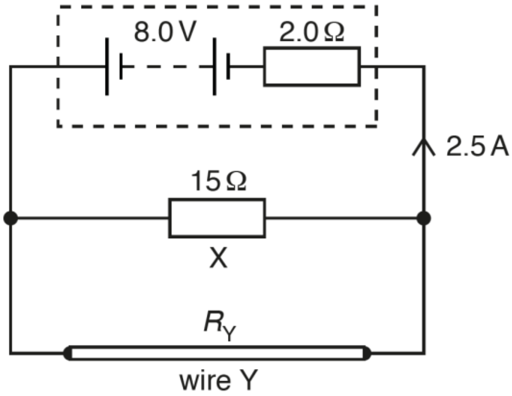

Fig. 5.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(a) Calculate

(i) the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ... J [2]

(ii) the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(b) Determine the resistance R_Y.

R_Y = ... Ω [3]

(c) Wire Y is replaced in the circuit by a new wire Z which has less resistance than wire Y. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

....

....

....[2]

[Total: 8]

6 **(a)** Define *magnetic flux*.

....

....

....[2]

(b) A solenoid has a coil C of wires wound tightly about its centre, as shown in Fig. 6.1.

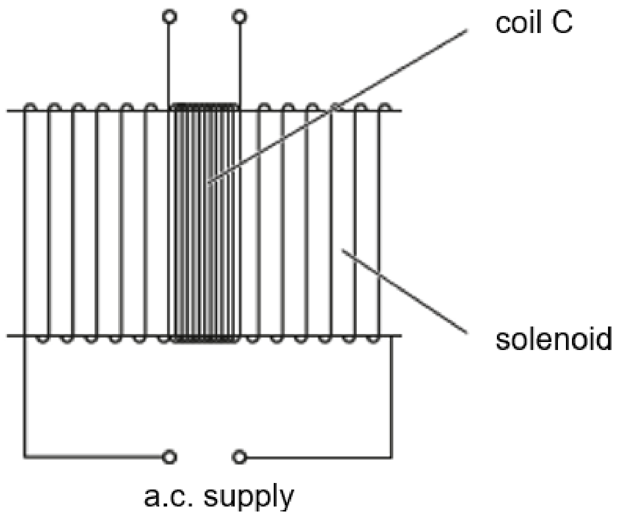

Fig. 6.1

Coil C has 86 turns.

The uniform magnetic flux Φ (in weber) in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current in the solenoid.

The variation with time t of the current I in the solenoid by the a.c. supply is shown in Fig. 6.2.

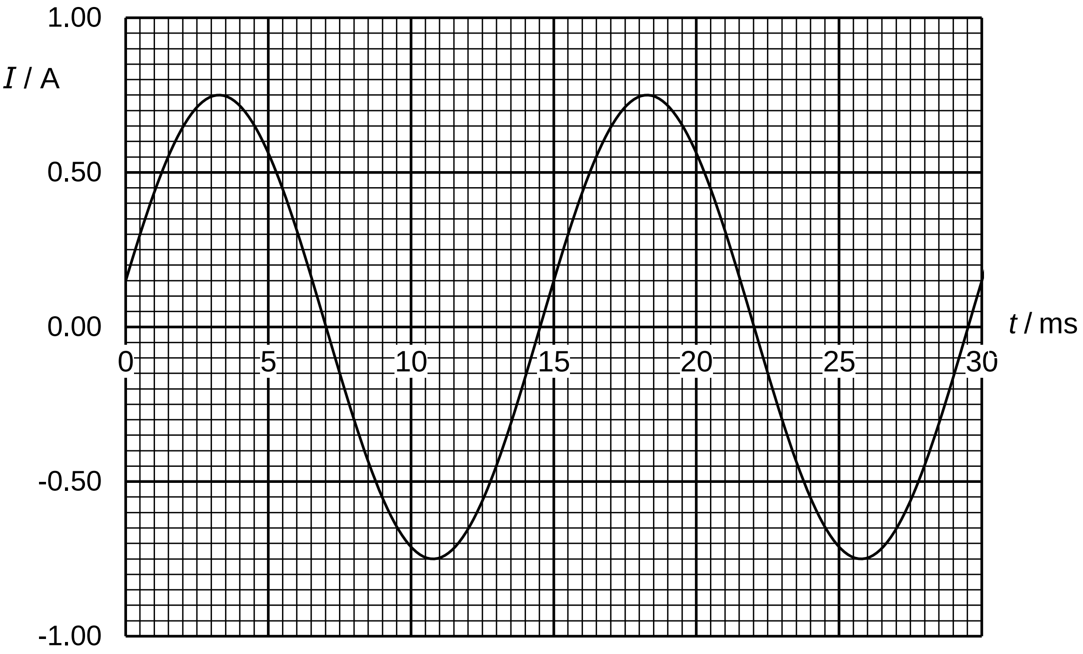

Fig. 6.2

(i) Explain how electromotive force (e.m.f.) is induced in coil C.

....

....

....

....[2]

(ii) Use Fig. 6.2 to determine the maximum e.m.f. induced in coil C.

e.m.f. = ... V [2]

(iii) The a.c supply is changed to a non-sinusoidal periodic wave as shown in Fig. 6.3.

On Fig. 6.3, draw the corresponding e.m.f. that is induced in coil C.

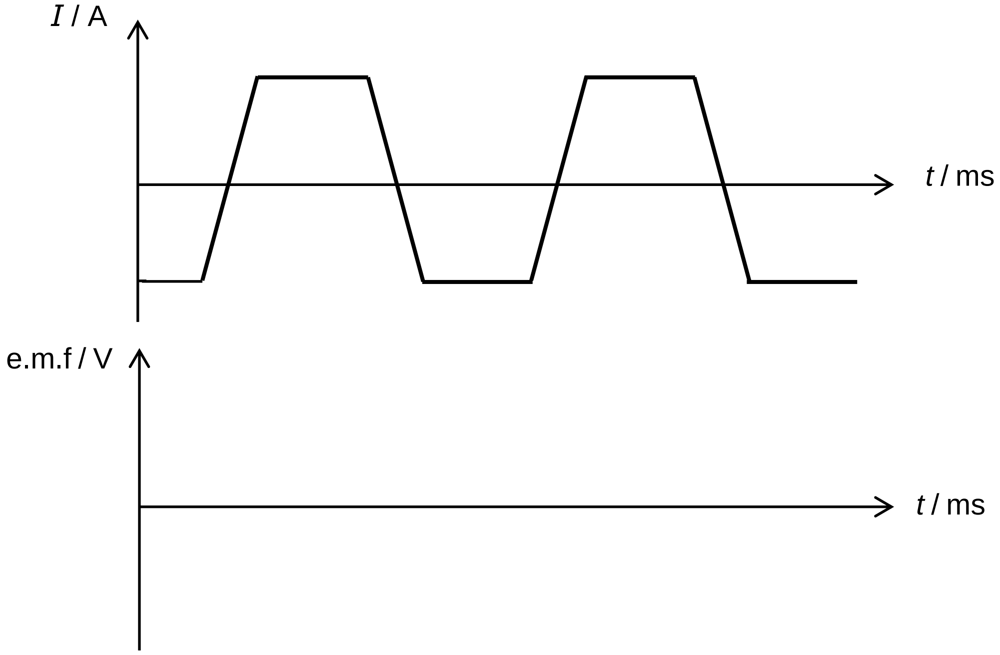

Fig. 6.3

[2]

[Total: 8]

7 **(a)** The radioactive isotope of Bismuth $^{210}_{83}\text{Bi}$ decays into Polonium (chemical symbol: Po) with the emission of a beta particle.

(i) State the origin of the beta particle.

....

....[1]

(ii) Write down the equation representing the beta decay of $^{210}_{83}\text{Bi}$.

....[1]

(iii) State two quantities that are conserved in any radioactive decay process.

1. ....

2. ....

[2]

(iv) The mass of a $^{210}_{83}Bi$ nucleus is 209.939 *u*. Show that its mass defect is 1.767 *u*. (mass of proton, m_p = 1.00729 *u*; mass of neutron, m_n = 1.00867 *u*)

[2]

(v) Calculate the binding energy per nucleon, in MeV, of $^{210}_{83}Bi$.

binding energy per nucleon = ... MeV [2]

(b) Fig. 7.1 shows the energy spectrum for beta particles emitted during the decay of $^{210}_{83}Bi$. The intensity indicates the number of beta particles emitted with each particular kinetic energy.

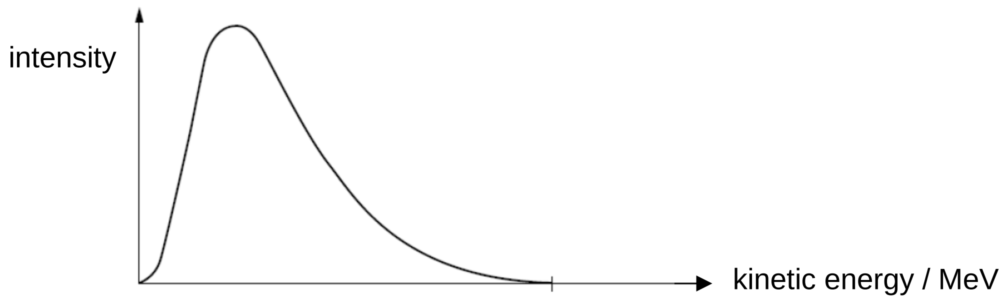

Fig. 7.1

Explain how a consideration of this kinetic energy spectrum provide evidence for the prediction of the existence of the antineutrino.

....

....

....

....

....[2]

[Total: 10]

8 Read the passage below and answer the questions that follow.

Stars

Stars are formed from the gravitational collapse of gas clouds called nebulae. Gravitational potential energy is converted to internal energy of hot gases which emit electromagnetic radiation. Thus, the search for new stars usually involves the use of infra-red telescopes in space.

Once the core of a young star is hot enough to initiate hydrogen fusion, it is called a main sequence star. Such stars are stable, lasting for millions or billions of years. One example is our Sun, which produces energy when hydrogen nuclei fuse into stable helium nuclei in the stellar core. The temperature at the core is very high, typically 10^8 K or greater! Here, a process known as the proton-proton cycle begins, releasing energy. This three-stage process can be summarised in a single equation:

$$4\,{}^1_1\text{H} \rightarrow {}^4_2\text{He} + 2\,{}^0_1\text{e} + 2\upsilon + \text{energy}\,.$$

Our Sun is 1.51×10^{11} m from Earth, and it radiates energy uniformly through space with a mean intensity of radiation reaching the Earth's atmosphere of 1.34 kW m^{-2}. Hence, the Sun radiates a power of 3.8×10^{26} W. This is also equal to its luminosity, which is defined as the total power radiated by a star.

While hydrogen fusion supplies the energy stars require to maintain energy balance over its life span, this has little effect to the change in mass of the star. Even after five billion years, the Sun is very nearly the same mass as it is now!

We can estimate the surface temperature of a star from its colour. A body that is at a higher temperature than its surroundings emit electromagnetic radiation. The variation of intensity of the emitted radiation with wavelength λ is shown in Fig. 8.1.

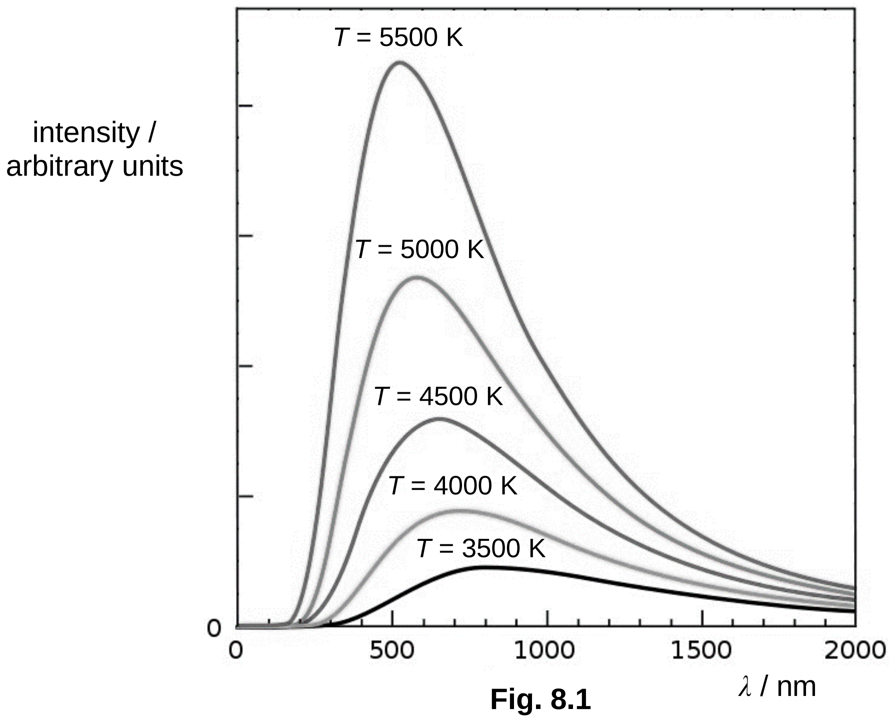

Fig. 8.1

The intensity distribution is different at different surface temperatures. At any temperature T, there is a peak corresponding to a wavelength λ_{max} for maximum intensity.
Theory states that

$$\lambda_{max} T = \text{constant}\,.$$

For example, at $T = 3500$ K, the intensity distribution spans the visible and infra-red wavelengths, with λ_{max} occurring at the red end of the visible spectrum. Since our eyes can only see in the visible spectrum, the object appears red-hot.

As the temperature of a body increases, the total emitted power also increases. It is known that the luminosity L of a star is related to its surface area A and its temperature T (in kelvins) as follows:

$$L \propto AT^4 .$$

When observing stars, astronomers rely on a phenomenon called the Doppler effect of light. The Doppler effect is more relatable to us with sound waves. Whenever there is relative motion between a wave source and an observer, the frequency noted by the observer is different from the actual frequency of the waves. We would have experienced the Doppler effect, such as when the frequency of the sirens change from higher pitch to lower pitch as an ambulance passes by. The higher pitch heard in front of the moving source is due to the 'bunching up' of wave crests as shown in Fig. 8.2. The reverse occurs for the observer behind the source.

Fig. 8.2

When light emitted from a distant star is passed through a diffraction grating, it is found that each line in the absorption spectrum from hydrogen gas occurs at a different wavelength from that of the corresponding line in the spectrum obtained in the laboratory. The Doppler effect is evident in Fig. 8.3. With some stars, all the spectral lines are shifted to longer wavelengths (red shifted), while with other stars, the lines are shifted to shorter wavelengths (blue shifted). Thus, hydrogen spectral lines provide important information about the motion of a star.

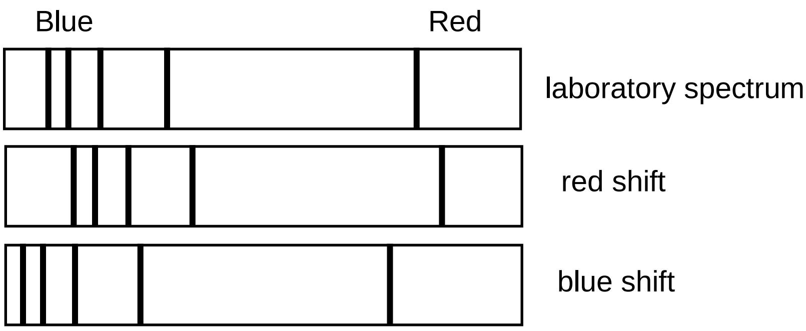

Fig. 8.3

Using the Doppler effect together with the hydrogen spectral lines is extremely important in the detection of binary stars. This method of detection is known as spectroscopic binary. Over four-fifths of the single spots of light we see in the night sky are two or more stars revolving around each other. Binary stars, which consist of only two stars, are the most common star systems. An example would be Sirius-A and Sirius-B. However, when two stars are close together, they appear visually as a single star when viewed with a telescope.

Since binary stars rotate about their common centre of mass, when one star is approaching Earth, the other must be moving away. Analysis of the spectral lines could reveal information that there are, in fact, two stars.

(a) Suggest one advantage of placing telescopes in space to observe new stars.

....

....[1]

(b) Explain why very high temperatures are necessary for fusion reactions to occur in stars.

....

....

....[2]

(c) **(i)** Show that the total power radiated by the Sun is 3.8×10^{26} W.

[1]

(ii) Use the data below to calculate the number of fusion reactions occurring in the Sun each second. Assume all the radiated energy from the Sun comes from the fusion reaction.

mass of electron = 0.000549 *u*

mass of proton = 1.007276 *u*

mass of helium-4 nucleus = 4.001506 *u*

number of reactions per second = ... [3]

(iii) The present mass of the Sun is 2.0×10^{30} kg. In about another five billion years, the core of the Sun will be depleted of hydrogen.

Calculate the percentage decrease in the mass of the Sun when the core is depleted of hydrogen. Justify whether your calculation agrees with the claim in the passage.

percentage decrease = ... %

....

....[2]

(d) Fig. 8.4 shows some data about our Sun and Sirius-A, one of the binary stars mentioned.

	Sun	Sirius-A
Radius / m	R	$1.7R$
Luminosity / W	L	$25L$
Surface temperature / K	5800	
Wavelength λ_{max} at maximum intensity / nm	500	

Fig. 8.4

(i) Calculate the surface temperature T of Sirius-A.

T = ... K [2]

(ii) Use data from Fig. 8.1 to verify the theory that

$$\lambda_{max} T = \text{constant}.$$

[2]

(iii) Use information from Fig. 8.4 and your answer in **(d)(i)** to determine the wavelength λ_{max} for which maximum intensity occurs from Sirius-A.

λ_{max} = ... nm [2]

(iv) By considering your answer in **(d)(iii)**, suggest why Sirius-A appears as a bluish star to an astronomer using an optical telescope.

....

....[1]

(e) Fig. 8.5 shows the visible part of the absorption spectrum from hydrogen gas in a laboratory on the Earth and the same part of the absorption spectrum observed in light from a star in a distant galaxy. The numbers indicate the wavelengths in nanometres (nm).

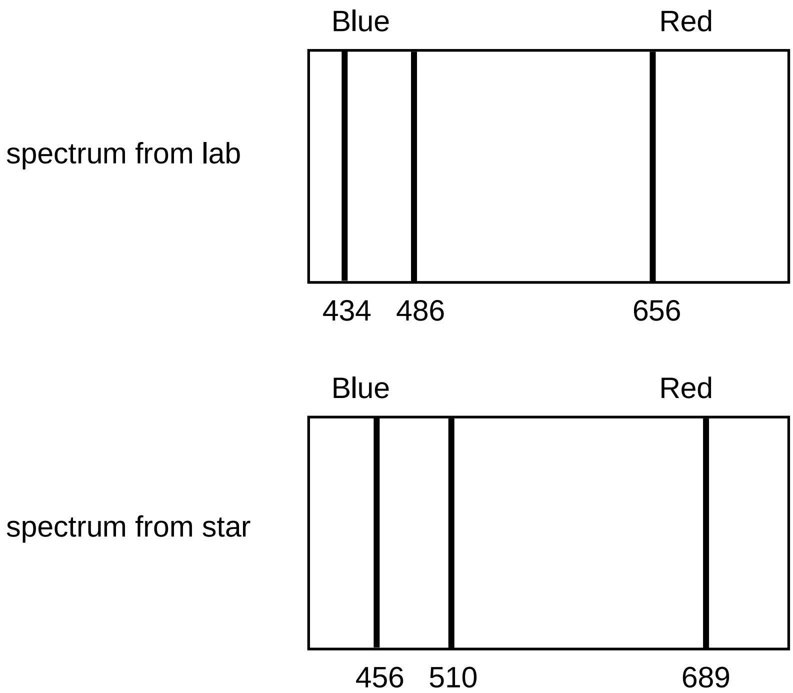

Fig. 8.5 (not to scale)

(i) Compare the line spectra and state what this shows about the motion of the star.

....

....

....[2]

(ii) Use Fig. 8.5 to calculate the percentage change in the wavelength of a spectral line observed with light from the star compared with a corresponding spectral line observed in the laboratory.

percentage change = ... % [1]

(f) **(i)** Apart from two binary stars being too close together, use Rayleigh's criterion to state another reason why the stars could appear as a single image as seen with a telescope.

....

....[1]

(ii) Suggest how hydrogen spectral lines might provide astronomers with information that a star is part of a binary star system.

Assume that the observed star has similar brightness as its binary counterpart and viewed from Earth in the plane of their orbits.

....

....

....

....[2]

[Total: 22]

End of Paper