GCE AS/A level

1322/01

PHYSICS – PH2

Waves and Particles

P.M. THURSDAY, 4 June 2015

1 hour 30 minutes plus your additional time allowance

Surname ______________________________

Other Names ______________________________

Centre Number ______________________________

Candidate Number 2 ______________________________

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	12	
2.	7	
3.	8	
4.	14	
5.	10	
6.	12	
7.	9	
8	8	
Total	80	

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a DATA BOOKLET.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball-point pen or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.

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

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer is incorrect.

Answer ALL questions.

1(a) A student gives the following WRONG definition of wavelength.

"The wavelength of a progressive wave is the distance between two successive points which are oscillating WITH THE SAME AMPLITUDE."

(i) Write down the words which should replace the words in italics. [1]

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(ii) Explain why the student's original version does not make sense. [1]

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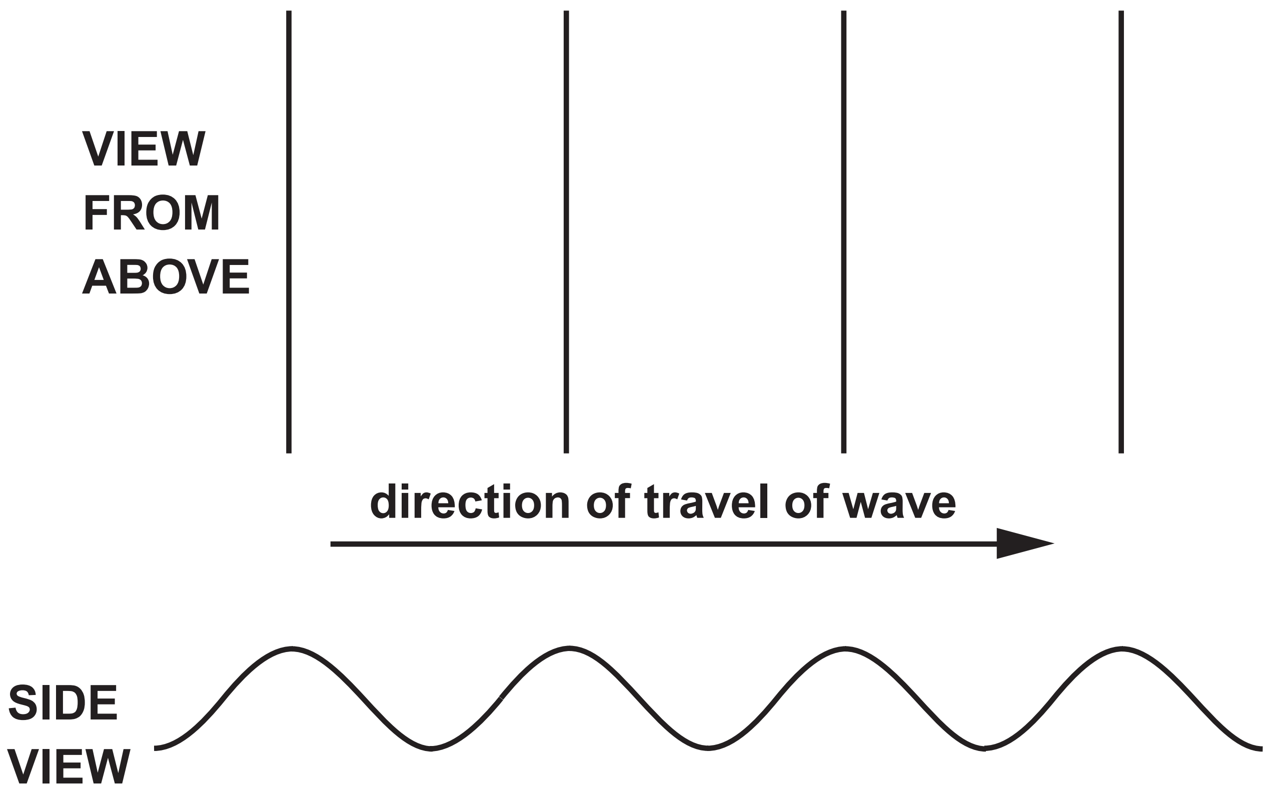
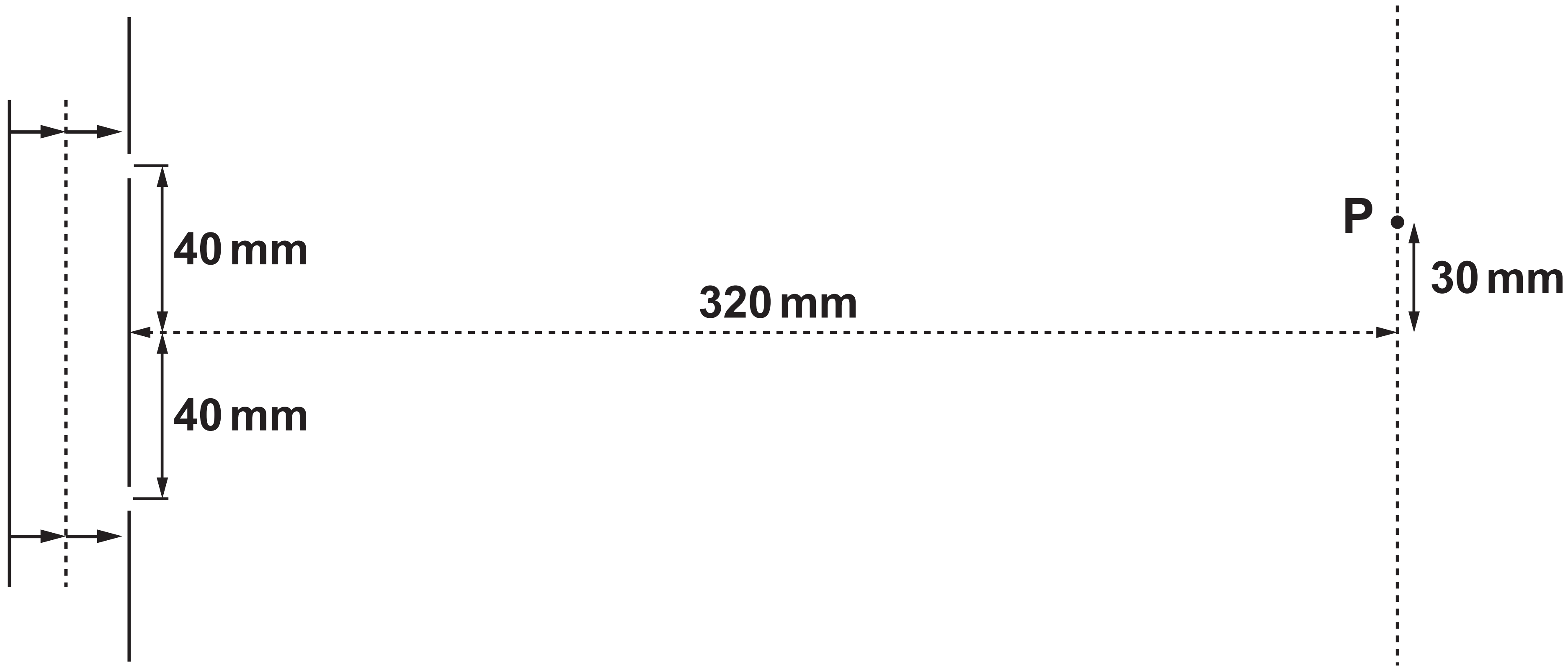

VIEW
FROM
ABOVE
direction of travel of wave
SIDE
VIEW

1(b) The top diagram shown opposite is a plan (view from above) showing the positions of the crests of a progressive water wave at time $t = 0$. Underneath is a vertical section (side view) of the water surface at time $t = 0$.

(i) By the time $t = 0.12\,\text{s}$ the wave has travelled $60\,\text{mm}$. The wavelength is $15\,\text{mm}$. Calculate the frequency. [3]

1(b) (ii) On the top diagram opposite page 6 carefully draw in the positions of the crests at t = 0.010 s. [2]

Space for calculations if needed.



40 mm
40 mm
320 mm
P
30 mm

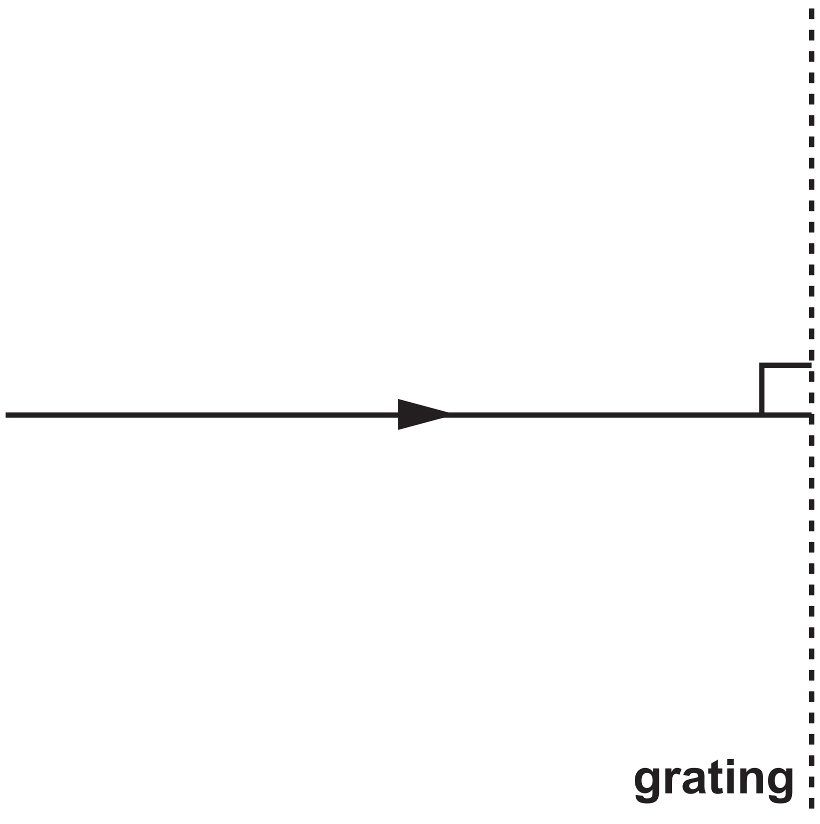
1(c) **See the diagram opposite. A barrier with two narrow slits is placed as shown in the path of water waves of wavelength 15 mm. An interference pattern is observed.**

Diagram not to scale.

(i) **Making use of the equation for double slit interference, determine whether there is constructive or destructive interference at point P. Give your reasoning. [3]**

1(c) (ii) Explain why DIFFRACTION is essential for the formation of the interference pattern.

[2]


grating

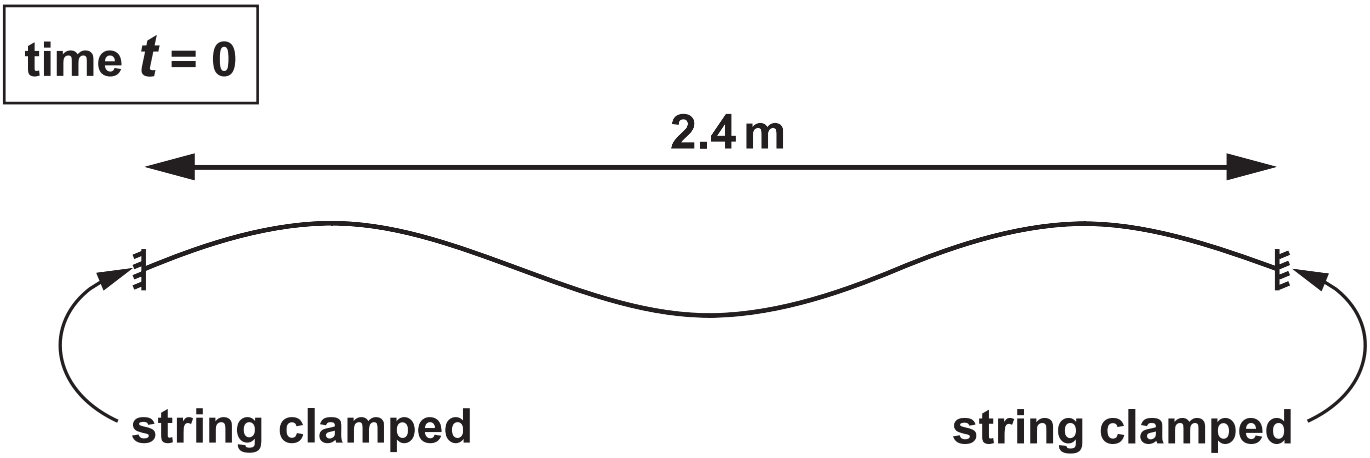
2(a) See the diagram opposite. A beam of light of wavelength 532 nm is shone normally (in the direction shown) on to a diffraction grating with slit spacing 1 200 nm (between centres of adjacent slits).

(i) Calculate all the angles at which bright beams emerge from the grating. [3]

2(a) (ii) **Draw all the emerging beams (representing each as a single line) ON THE DIAGRAM OPPOSITE PAGE 10. [You are not expected to use a protractor.] [2]**

(b) **Light of wavelength 650 nm is now used instead of the light of wavelength 532 nm. State the ways in which the pattern of emerging beams will change. [You may wish to make further calculations.] [2]**

3(a) **The diagram shows a STATIONARY wave on a stretched string at a time of maximum displacement (t = 0).**



(i) **Determine the wavelength. [1]**

(ii) **Determine the distances of all the ANTINODES from the left hand end of the string. [1]**

3(a) (iii) Time $t = t_1$ is the first time after $t = 0$ that the string is as shown below.

time $t = t_1$

(I) The frequency is 50 Hz.
Determine t_1. [2]

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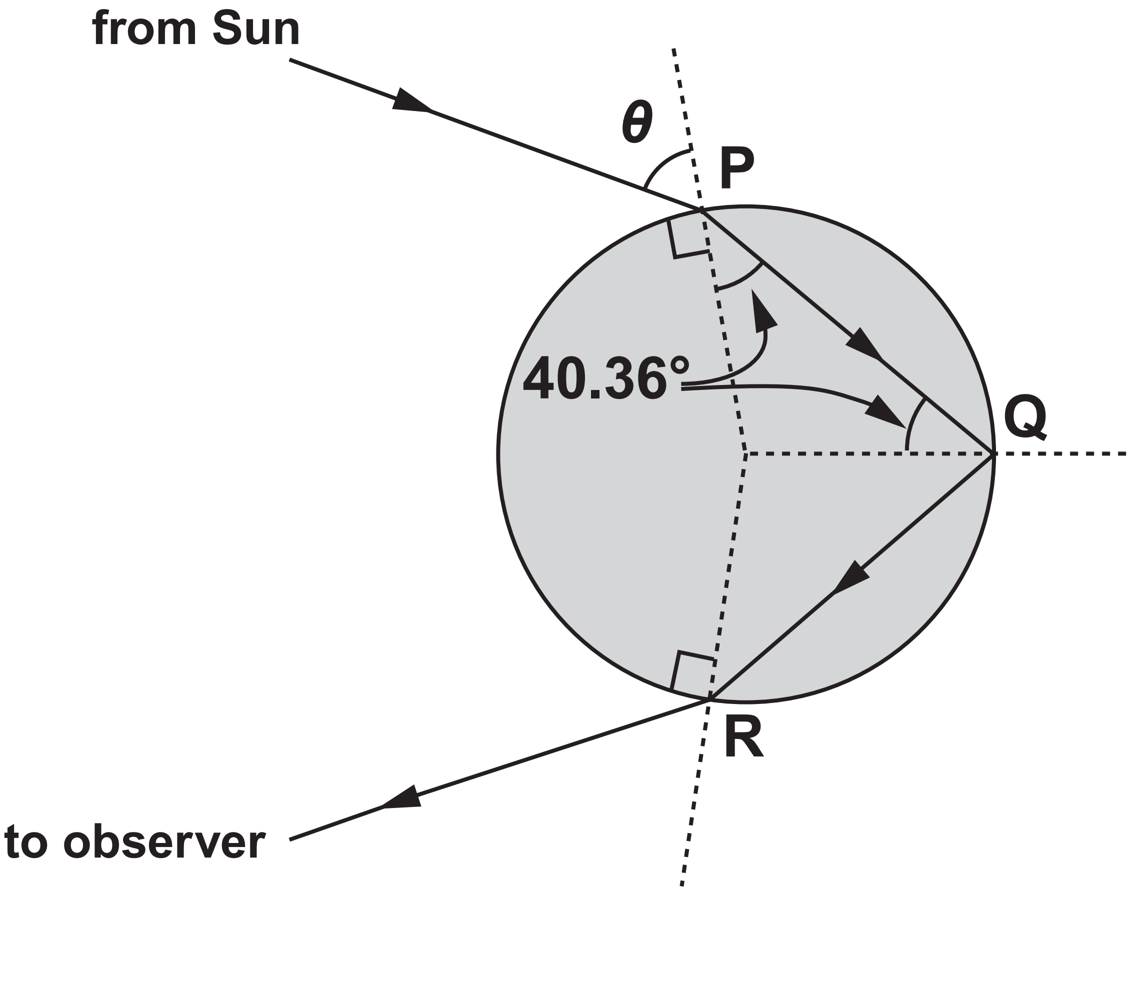
(II) ON THE DIAGRAM above for time $t = t_1$, draw vertical arrows at the approximate positions of the antinodes, to show the directions of motion of the string. [1]

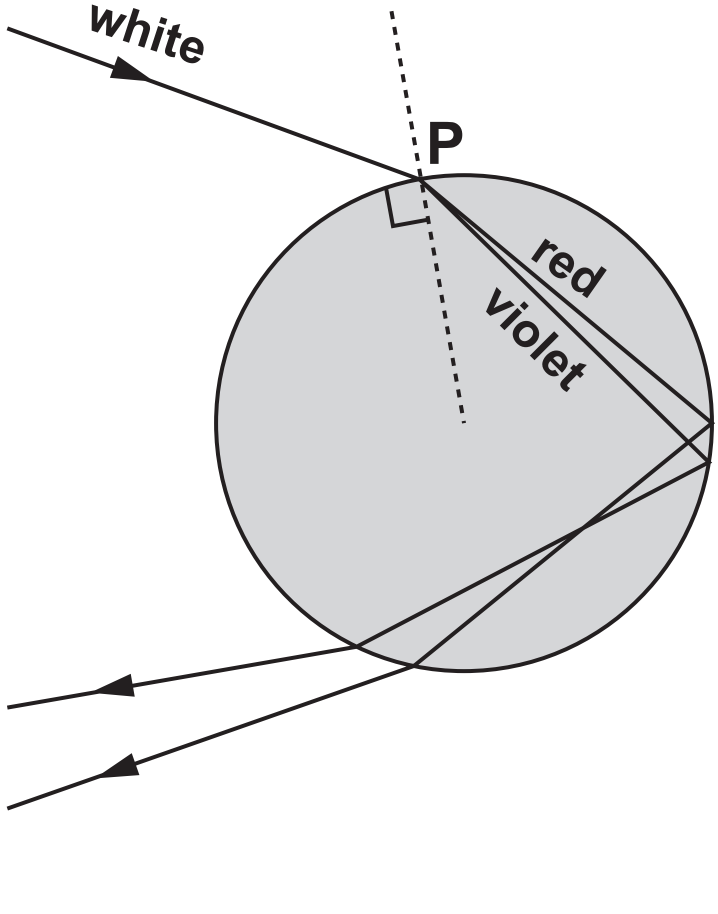
3(b) **Complete the diagram below to show the lowest frequency (fundamental) stationary wave on the string, at a time of maximum displacement, and CALCULATE ITS FREQUENCY. [3]**


from Sun
θ
P
40.36°
Q
R
to observer

4(a) Rainbows form when sunlight is refracted and reflected by raindrops. The diagram opposite shows the path of red light (of wavelength 700 nm) through a raindrop when a rainbow is observed.

(i) The refractive index of water (for light of this wavelength) is 1.331. Calculate the angle of incidence, θ, at P.
[Refractive index of air = 1.000.] [2]

4(a) (ii) **Is the internal reflection at Q a case of TOTAL internal reflection? Give your reasoning clearly. [2]**


white
P
red
violet

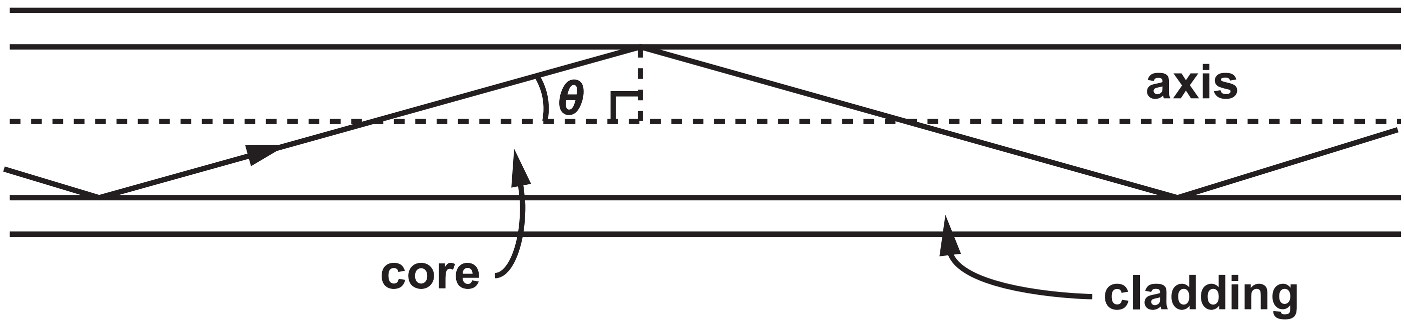
4(a) (iii) **The diagram opposite shows the paths (difference exaggerated) of violet and red light through the raindrop. The paths are different because different wavelengths of light travel through water at slightly different speeds.**

By comparing the refraction of the red and the violet light at P, explain which colour, violet or red, travels more slowly through water. [2]

4(b) **Light takes 1.75 μs to travel through 360 m of multimode fibre by the quickest route through the core.**

(i) **Show that the refractive index of the core is approximately 1.5, giving your own answer to 3 significant figures. [2]**

4(b) (ii) The greatest angle, θ, to the axis at which light can propagate with total internal reflection is 15°.



Calculate the refractive index of the CLADDING. [3]

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4(b) (iii) **Although total internal reflection occurs for any angle smaller than 15° to the axis, the accurate transmission of data encoded as a rapid stream of pulses is more likely if the paths are restricted to a maximum angle much lower than 15°. Explain why. [3]**

5(a) Einstein's photoelectric equation is

$$E_{k\,\mathrm{max}} = hf - \phi$$

State, in terms of ENERGY, the meaning of each term in the equation.

(i) $E_{k\,\mathrm{max}}$ ______________________________

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[1]

(ii) hf ______________________________

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[1]

(iii) ϕ ______________________________

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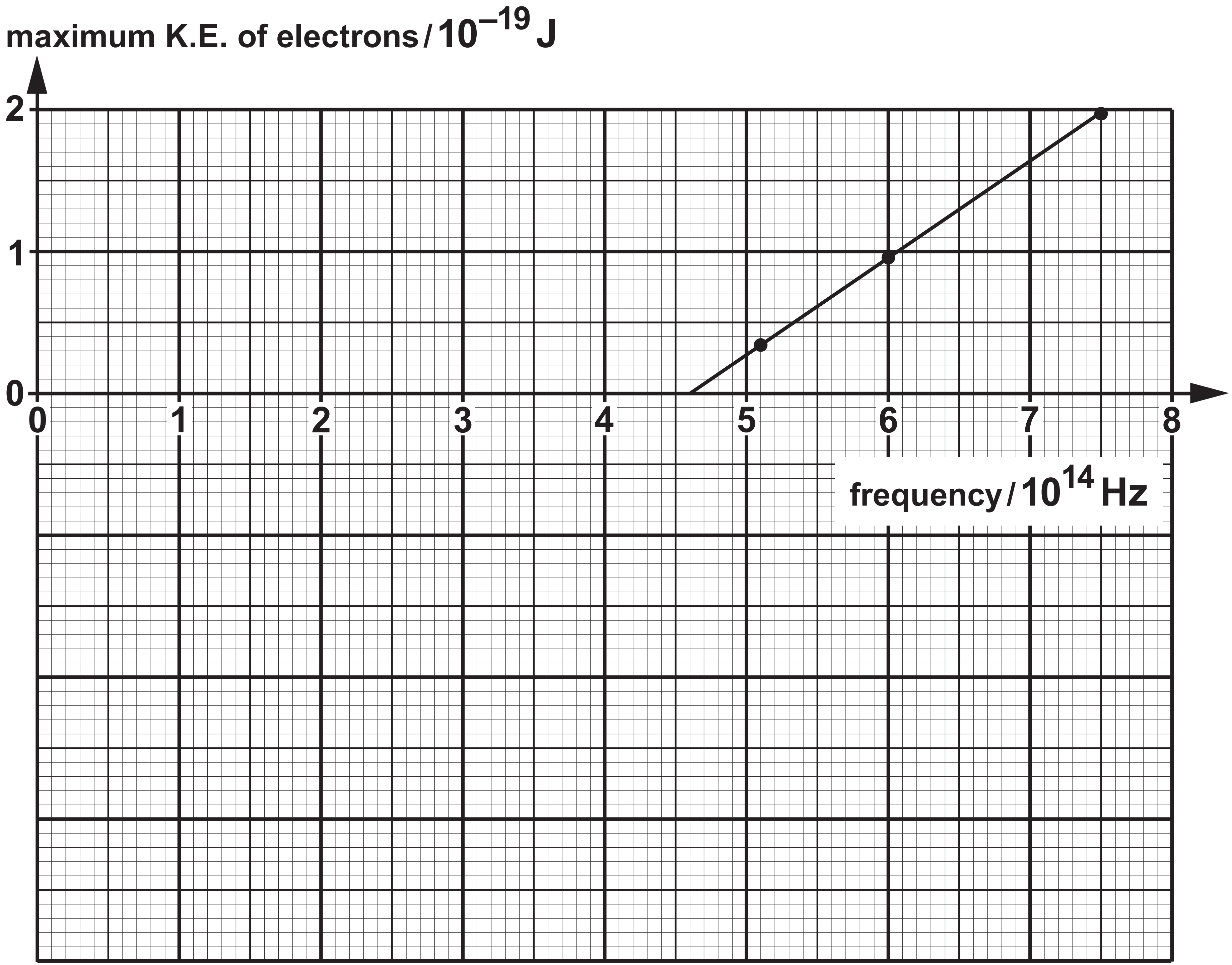
[1]

5(b) The minimum frequency of radiation which will eject electrons from a surface is f_0. Determine, as a multiple of f_0, the frequency of radiation which will eject electrons with maximum kinetic energy 2ϕ from the same surface. [2]



maximum K.E. of electrons / 10^{-19} J
2
1
0
0
1
2
3
4
5
6
7
8
frequency / 10^{14} Hz

5(c) A student determines the maximum kinetic energy of electrons ejected from a caesium surface by incident light of three frequencies, and plots the straight line graph shown opposite.

(i) Determine from the graph values for:

(I) the Planck constant; [2]

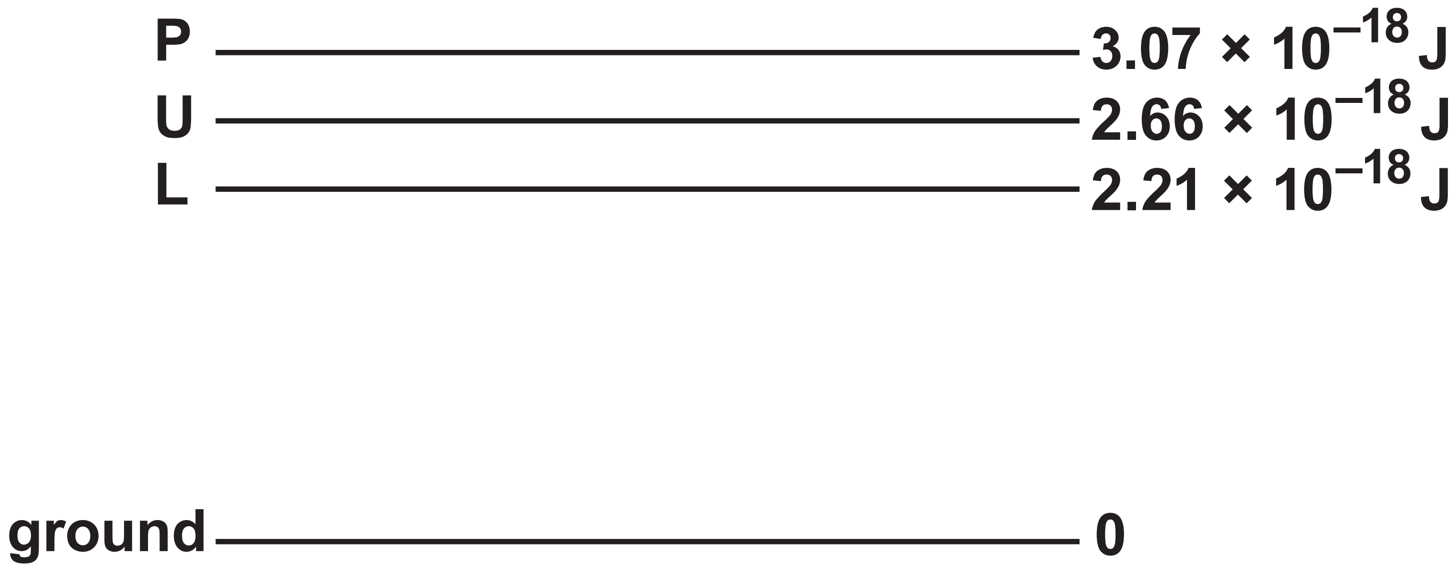
(II) the work function of caesium. [1]

5(c) (ii) The student starts to repeat the process for a sodium surface, but runs out of time after obtaining data for one graph point:

$$f = 6.0 \times 10^{14}\ \text{Hz}, \qquad E_{k\,\text{max}} = 0.32 \times 10^{-19}\ \text{J}$$

Obtain a value for the work function of sodium, showing your reasoning. [2]

6. A simplified energy level diagram is given for a four level laser system.



(a) Calculate:

(i) the wavelength of radiation emitted by stimulated emission; [3]

6(a) (ii) **the number of photons of this radiation emitted per second if the output power of the laser is 15 mW; [2]**

6(a) (iii) the energy of a photon emitted in a stimulated emission event as a PERCENTAGE of the energy needed for a pumping event. [2]

6(b) As light goes from one end of the laser cavity to the other, its intensity increases.

(i) Referring to the energy level diagram, explain in terms of photons how the increase in intensity takes place. [Assume that a population inversion has already been set up.] [3]

6(b) (ii) **The pumping rate is now increased, making the population inversion greater. Suggest why this makes the output power greater than before. [2]**

7. A website gives the following data for the star Aldebaran:

radius = $44.2\ R_{\odot}$ luminosity = $518\ L_{\odot}$

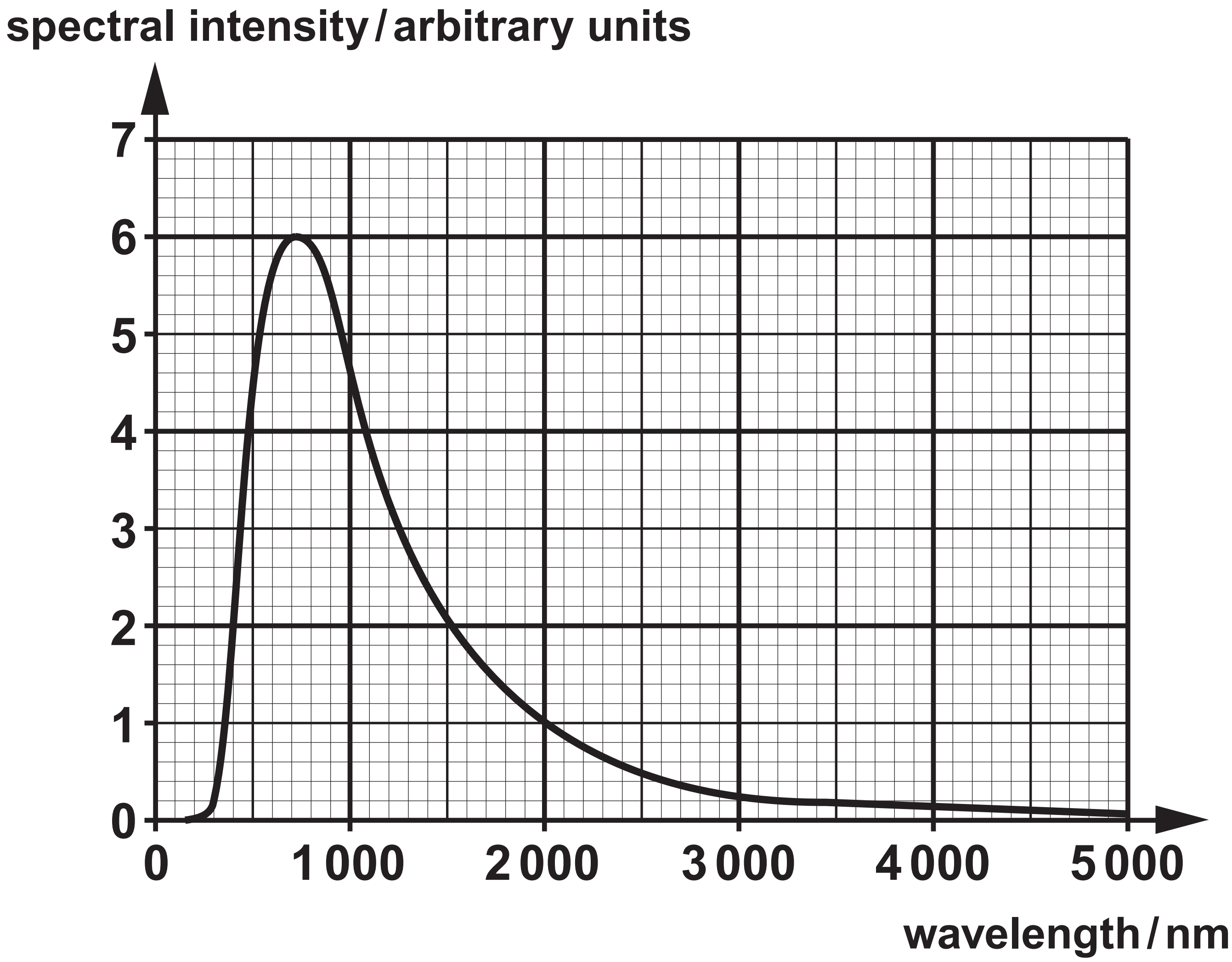
in which

$R_{\odot}$ = radius of Sun = 6.96×10^{8} m

and

$L_{\odot}$ = luminosity of Sun = 3.85×10^{26} W

(a) Use Stefan's law to calculate a value for the surface temperature of Aldebaran. [4]



spectral intensity / arbitrary units
7
6
5
4
3
2
1
0
0
1000
2000
3000
4000
5000
wavelength / nm

7(b) The continuous spectrum of Aldebaran is given opposite.

Determine a value for the temperature of Aldebaran without using Stefan's law giving your working. [2]

7(c) Agreement between the temperatures found in (a) and (b) would help to confirm that Aldebaran is emitting as a black body. What is a black body? [1]

(d) Explain, using the data in this question, why 'red giant' is an appropriate description of Aldebaran. [2]

8(a) The positive pion, π^+, is a meson.

(i) Distinguish, in terms of quark make-up, between a meson and a baryon. [1]

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(ii) Show that the charge of the π^+ fits with it having the quark make-up $u\bar{d}$. [1]

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8(b) The π^+ sometimes decays (typically in a time of 26 ns) in this way:

$$\pi^+ \rightarrow e^+ + \nu_e$$

(i) Show how lepton number is conserved in this decay. [1]

(ii) Identify the type of interaction, giving a reason for your answer. [1]

8(c) The following interaction has been observed.

$$\pi^+ + {}^2_1H^+ \rightarrow p + p$$

[The ${}^2_1H^+$ is a deuterium (heavy hydrogen) nucleus.]

(i) Show how u quark number is conserved. [1]

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8(c) (ii) **Before the interaction the π^+ and the $^2_1H^+$ are a few millimetres apart. The interaction will take place only if these charged particles are sent towards each other at high speeds. Explain why this is so. [3]**

END OF PAPER