

WJEC A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT PH2 OLD SPECIFICATION PAPERS

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Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A Level

1322/01 – **LEGACY**



S16-1322-01

PHYSICS – PH2 Waves and Particles

P.M. THURSDAY, 9 June 2016

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	18	
2.	10	
3.	13	
4.	9	
5.	11	
6.	10	
7.	9	
Total	80	

1322
010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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.

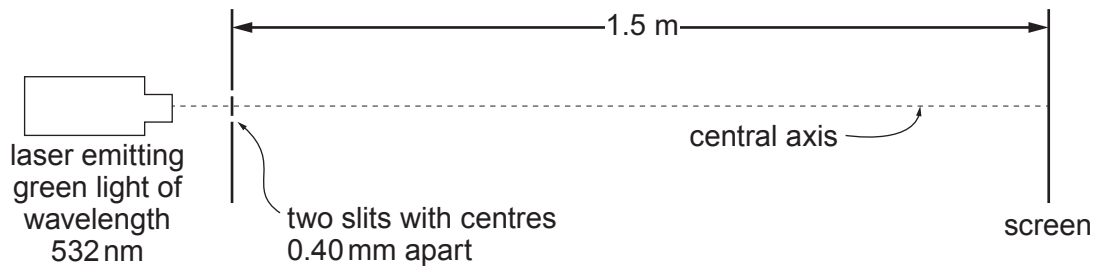
The number of marks is given in brackets at the end of each question or part-question.

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 modern version of Young's double slit experiment is set up as shown.



- (i) Calculate the fringe separation.

[2]

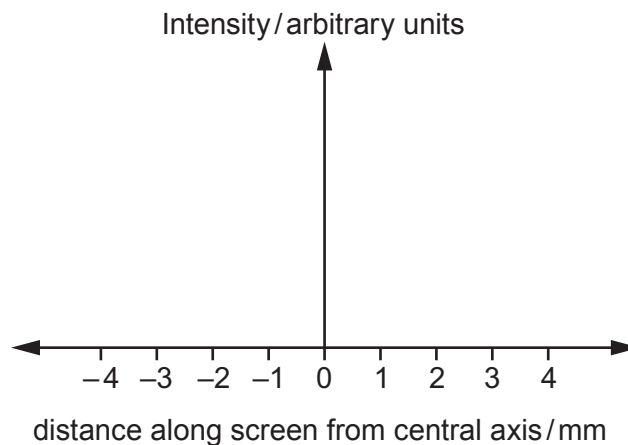
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- (ii) Assuming that there is a bright fringe on the central axis, sketch below a graph of light intensity against distance from the central axis.

[3]



- (iii) State **two** ways in which the pattern will change if the screen is brought closer to the slits.

[2]

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(iv) **Explain** what would happen if the following changes were made, individually.

I. A red laser is used instead of a green laser.

[1]

II. One of the slits is blocked up.

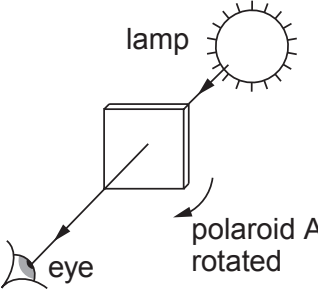
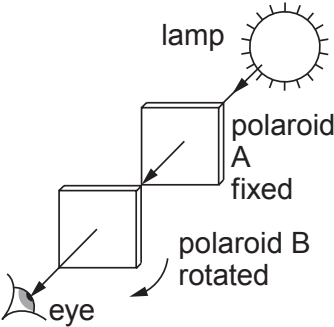
[2]

(b) Green light from the laser is now shone normally on to a diffraction grating. The centres of the slits are 1500 nm apart. **Second order** beams are observed at $45^\circ \pm 1^\circ$ to the normal. Calculate maximum and minimum values for the wavelength according to these readings.

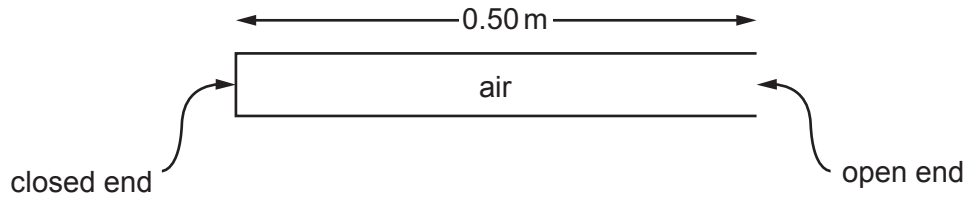
[3]

(c) Light from a filament lamp behaves like an *unpolarised, transverse* wave. This can be shown using polarising filters (*polaroids*). Two experiments are carried out as described briefly in the first column of the table below. In the second column state what is observed and, in the third column, give a brief explanation of what is observed.

[5]

What is done	What is observed	Explanation
		
		

2. (a) A stationary sound wave is set up in air in the tube shown in the diagram. The speed of sound in the air is 342 m s^{-1} .



- (i) There is an antinode of displacement at the open end of the tube, and a node at the closed end. Calculate the lowest frequency possible for the stationary wave. [2]

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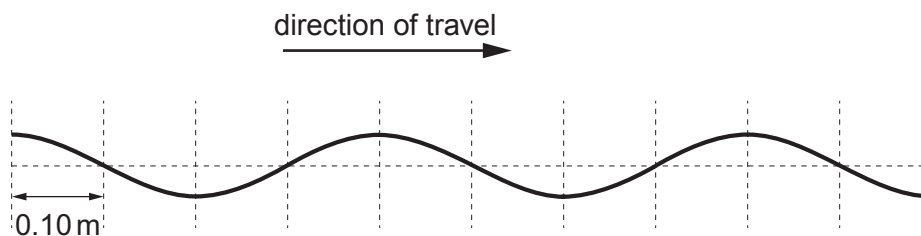
- (ii) The wave speed given above is for progressive waves. Explain how the stationary wave arises from progressive waves. [2]

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- (b) Waves are travelling to the right along a taut string at a speed of 5.0 m s^{-1} . The diagram shows part of the string at time $t = 0$.



- (i) **On the same diagram**, draw this part of the string at time $t = 0.10 \text{ s}$. [2]

- (ii) Calculate the frequency. [2]

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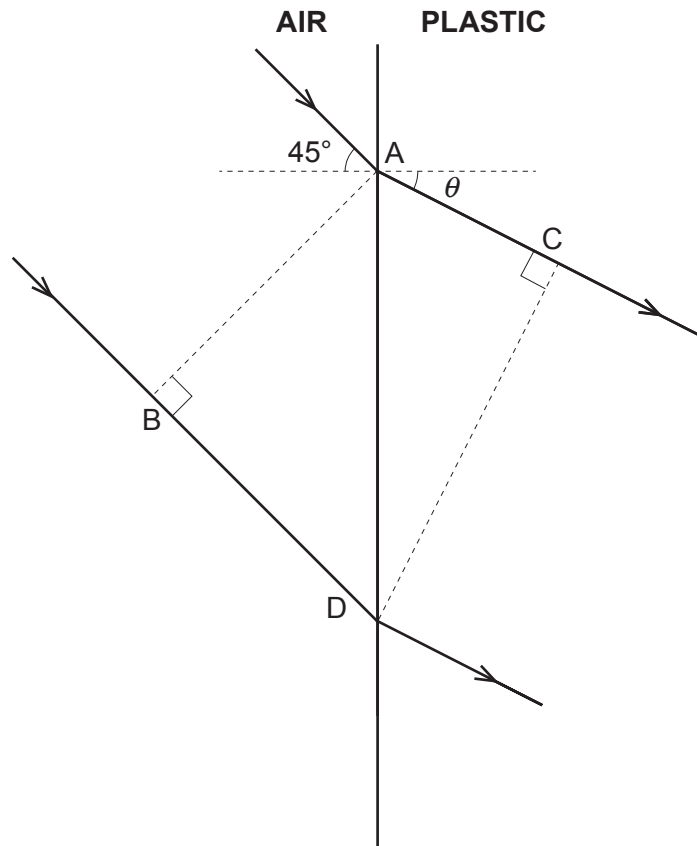
- (iii) The wave source (not shown) is now adjusted to increase the frequency. Explain the effect that this will have on the wavelength, stating any assumption that you make. [2]

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3. (a) The diagram, which is **actual size**, shows a beam of light travelling through air and entering transparent plastic. A wavefront moves from AB to CD as it enters the plastic.



- (i) By measuring **lengths** on the diagram show that the speed of light in the plastic is approximately $2 \times 10^8 \text{ m s}^{-1}$. [3]

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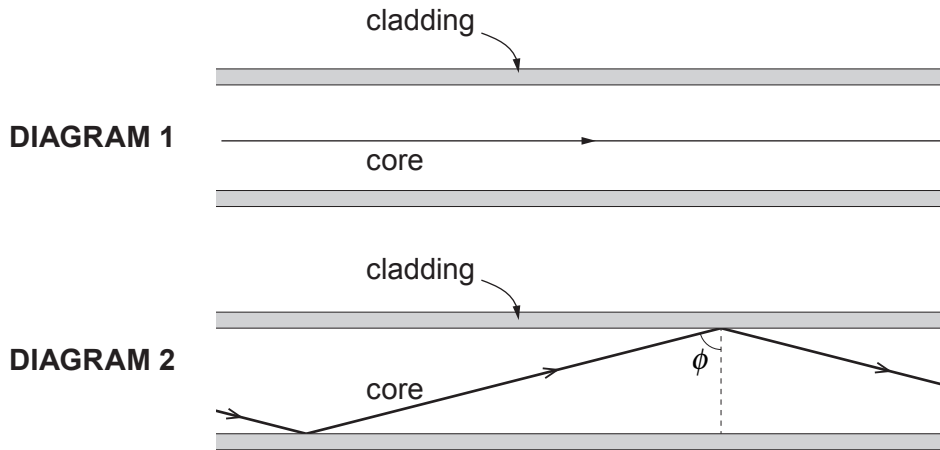
- (ii) Calculate θ , the angle of refraction, giving your working. Assume $n_{\text{air}} = 1$. [2]

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- (b) Light takes $1.86 \mu\text{s}$ to travel through 360 m of multimode fibre by the **quickest** route, as shown in diagram 1, and $1.91 \mu\text{s}$ to travel through the same fibre by the **slowest** route, as shown in diagram 2.



**DIAGRAMS
NOT
ACTUAL SIZE**

- (i) Calculate the refractive index of the core of the fibre.

[2]

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- (ii) Calculate the angle ϕ .

[2]

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- (iii) Explain why it is not possible to have slower routes than that shown in diagram 2.

[2]

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- (iv) Explain why multimode fibres are used for transmitting data over short distances only.

[2]

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4. (a) Einstein's photoelectric equation may be written:

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

In terms of *energy*, state the meanings of:

(i) hf [1]

(ii) ϕ [1]

- (b) The *work function* of sodium is 3.65×10^{-19} J. Light of various frequencies (see below) is shone on to a sodium surface. In each case calculate the **maximum** kinetic energy of the emitted electrons, or explain in terms of photons, with an appropriate calculation, why there is no emission.

(i) violet light of frequency 7.40×10^{14} Hz [2]

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(ii) a mixture of violet light of frequency 7.40×10^{14} Hz and blue light of 6.82×10^{14} Hz [1]

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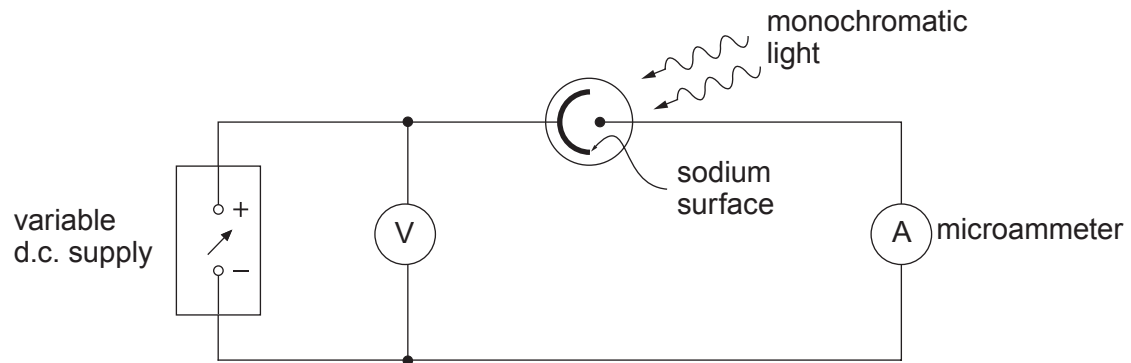
(iii) yellow light of frequency 5.22×10^{14} Hz [2]

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- (c) The diagram shows a circuit set up to determine the maximum kinetic energy, $E_{k \text{ max}}$, of electrons ejected from a sodium surface by light of a certain frequency.



Describe how you would use the apparatus to determine $E_{k \text{ max}}$.

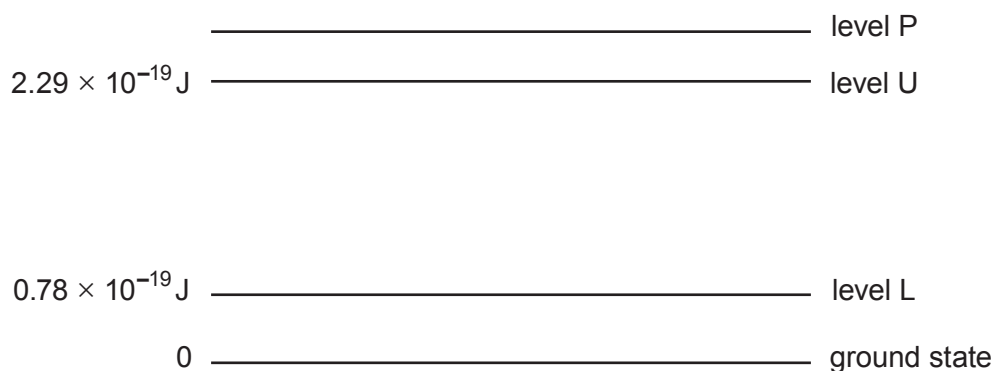
[2]

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5. A simplified energy level diagram is given for the amplifying medium in a four level laser, which is pumped using light. Stimulated emission involves levels U and L.



- (a) (i) Calculate the wavelength of the emitted radiation, and name the region of the electromagnetic spectrum in which it lies. [3]

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- (ii) The power supplied to the laser is 5.0W, and its efficiency is 0.70%. Calculate the number of photons of this wavelength emitted per second. [3]

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- (b) Explain **in terms of the energy level diagram** how a population inversion between levels U and L is brought about. [3]

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- (c) Explain how stimulated emission differs from spontaneous emission and why stimulated emission can give light amplification. [2]

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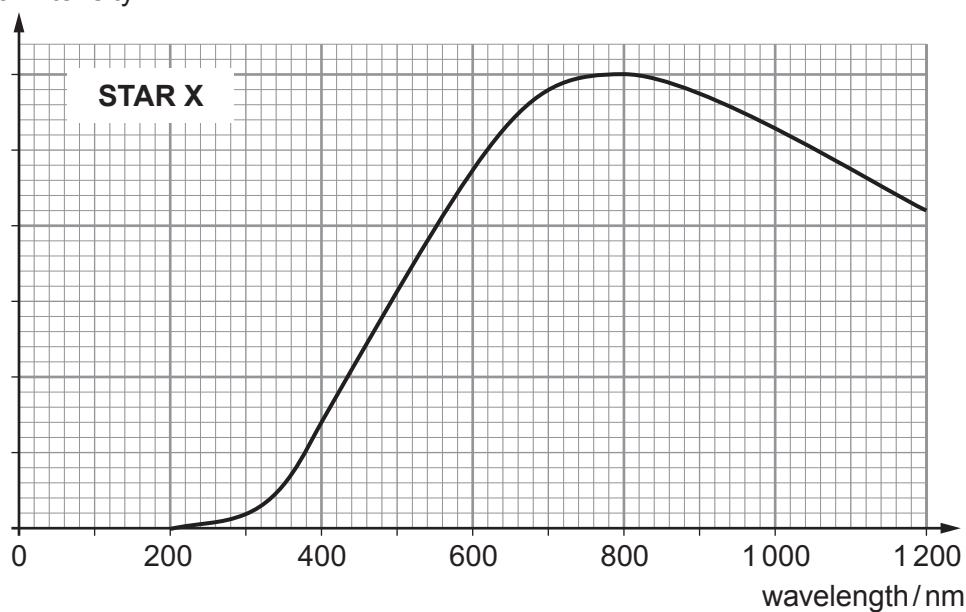
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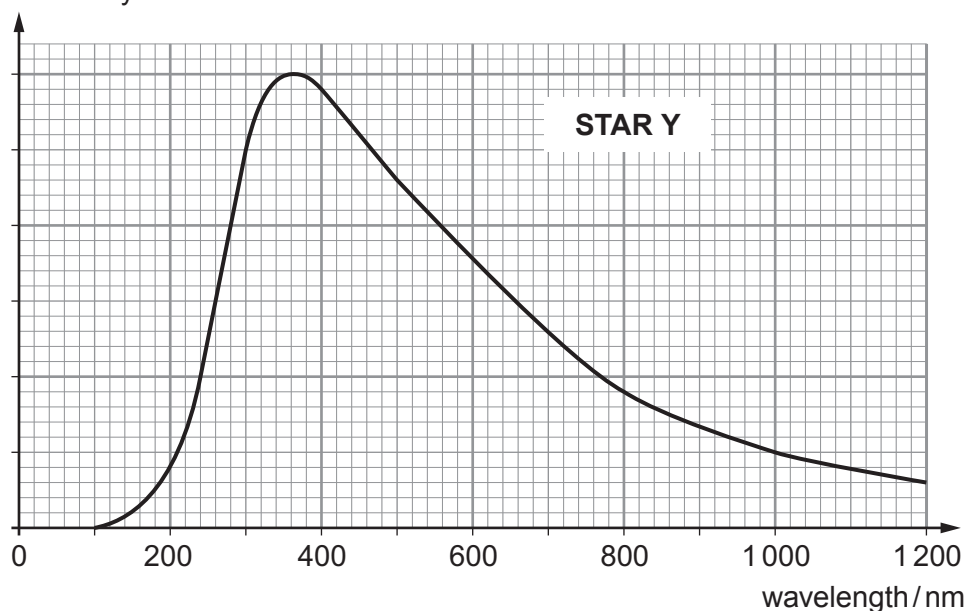
6. (a) Stars emit radiation as *black bodies*. State what is meant by a *black body*.

[1]

- (b) The spectra of two stars, X and Y, are given below. The vertical scales are arbitrary.
spectral intensity



spectral intensity



- (i) The range of visible wavelengths is roughly 400 nm-700 nm. Identify the likely *colours* of the two stars, giving your reasoning.

[2]

- (ii) Show clearly that the ratio:

$$\frac{\text{Kelvin temperature of surface of Y}}{\text{Kelvin temperature of surface of X}} \text{ is approximately 2,}$$

giving your own value for the ratio to two significant figures.

[3]

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- (iii) Calculate the ratio:

$$\frac{\text{Power of electromagnetic radiation emitted by Y per m}^2 \text{ of surface}}{\text{Power of electromagnetic radiation emitted by X per m}^2 \text{ of surface}}$$

[1]

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- (iv) Measurements show that:

$$\frac{\text{Total power of electromagnetic radiation emitted by Y}}{\text{Total power of electromagnetic radiation emitted by X}} = 9.0$$

The diameter of X is 1.5×10^9 m. Calculate the diameter of Y.

[3]

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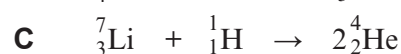
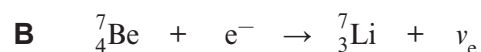
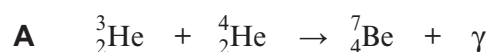
7. (a) The charge on a proton is e and the charge on a neutron is 0. Account for these values in terms of quarks. [2]

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- (b) **A**, **B** and **C** are three interactions which are from part of a sequence of interactions in a star such as the Sun. Symbols of the form ${}^A_Z\text{X}$ represent nuclei.



- (i) Baryon number (as well as energy and momentum) is conserved in all interactions. Name **two** other conserved quantities and explain how each is conserved in **B** above. [2]

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- (ii) In **B** there is only one change of nucleon type, and this can be traced to a single change of quark flavour. Identify the change in nucleon type and the change in quark flavour. [2]

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- (iii) Identify the change in **isotope** between the beginning and the end of the sequence **A**, **B**, **C** taken as a whole. [1]

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- (iv) Interaction **A** could be described both as a *fusion interaction* and as an interaction involving the electromagnetic force. Explain why both these descriptions are correct. [2]

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END OF PAPER

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GCE MARKING SCHEME

SUMMER 2016

**PHYSICS PH2 - (LEGACY)
1322/01**

INTRODUCTION

This marking scheme was used by WJEC for the 2016 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

**WJEC GCE PHYSICS PH2 - (LEGACY)
SUMMER 2016 MARK SCHEME**

Question				Marking details	Marks Available
1	(a)	(i)		$y = \frac{532 \times 10^{-9} \times 1.5}{0.0004}$ even if slips in powers of 10 (1) $y = 2.0 \text{ mm}$ (1) unit mark	2
		(ii)		Maxima on $-4, -2, 0, 2, 4 \text{ mm}$; minima on $-3, -1, 1, 3 \text{ mm}$ ecf (1) Reasonable attempt at smooth variation (1) Maxima lower further from centre or evidence of single slit diffraction envelope (1)	3
		(iii)		[Bright] fringes brighter (1) Fringes closer together (1) don't accept fringes are smaller	2
		(iv)	I	• No credit for “Fringes red instead of green” Fringes further apart because $\lambda_{\text{red}} > \lambda_{\text{green}}$	1
	(b)		II	• Bright fringes dimmer and / or dark fringes brighter or uniform brightness. [Accept “fringes disappear” or “no fringes” or single [broad] peak] (1) because no [destructive or constructive] interference or because we now have single slit diffraction (1)	2
				$1500 \text{ [nm]} \sin 44^\circ$ [or 46° or even 45°] = 2λ or equivalent (1) $\lambda_{\text{min}} = 521 \text{ [nm]}$ (1) $\lambda_{\text{max}} = 540 \text{ [nm]}$ or 539 [nm] (1)	3
		(c)		First experiment Observed: no change in brightness or equivalent (1) Explanation: oscillations in all directions [in plan of polariser] so equal absorption for all angles [of polaroid] (1) Accept equal absorption in all directions Second experiment Observed: Brightness changes as polaroid rotated (1) from bright to dark or vice versa every 90° or bright twice every revolution or any other correct quantitative remark (1) Explanation: extinctions [when absorbing axes of polaroids] are at right angles or crossed or equivalent (1)	5
Question 1 Total				[18]	

Question			Marking details	Marks Available
2	(a)	(i)	$\lambda = 2.0$ [m] or equivalent (1) $f = 171$ [Hz] (ecf on wrong value of λ) (1)	2
		(ii)	Progressive waves travelling in opposite directions <u>interfere</u> (accept superpose). (1) Waves in opposite directions arise from <u>reflections</u> [at ends of pipe] (1)	2
	(b)	(i)	Graph shifted one division (0.1 m) to the right (1) Whole string shown, and amplitude roughly same as before (1)	2
		(ii)	$\lambda = 0.40$ [m] or $T = 0.080$ [s] or by implication (1) $f = 12.5$ Hz unit mark (1)	2
		(iii)	[From $\lambda = \frac{v}{f}$] λ decreases (1) assuming v unchanged (or tension unchanged) (1)	2
		Question 2 total		[10]

Question			Marking details	Marks Available
3	(a)	(i)	Method 1 AC= 27 mm [± 1 mm] BD = 42 mm [± 1 mm] (1) $v_{\text{plastic}} = \frac{AC}{BD} \times 3.00 \times 10^8 \text{ m s}^{-1} \text{ or equivalent (1)}$ $v_{\text{plastic}} = 1.9 \times 10^8 \text{ m s}^{-1} \text{ ecf on lengths (1)}$ Method 2 AC= 27 mm [± 1 mm] AD = 59.5 mm [± 1 mm]; (1) $\sin \theta = \frac{AC}{AD} = [0.453] \text{ so } v_{\text{plastic}} = 3.00 \times 10^8 \text{ m s}^{-1} \times \frac{AC}{\sin 45^\circ} \text{ (1)}$ $v_{\text{plastic}} = 1.9 \times 10^8 \text{ m s}^{-1} \text{ ecf on lengths (1)}$	3
		(ii)	$\sin \theta = \frac{\sin 45^\circ}{\frac{BD}{AC}} \text{ or equivalent (1)}$ $\theta = 27^\circ [\pm 2^\circ] \text{ ecf on lengths and arithmetical slips (1)}$	2
	(b)	(i)	$v = \frac{360}{1.86 \times 10^{-6}} [= 1.94 \times 10^8 \text{ m s}^{-1}] \text{ or by implication (1)}$ $n = 1.55 \text{ (1) [1 mark for } n = 1.59 \text{ from using zigzag time]}$	2
		(ii)	$\sin \phi = \frac{1.86}{1.91} [= 0.974] \text{ or equivalent or by implication (1)}$ $\phi = 77^\circ \text{ (1)}$	2
		(iii)	$[\phi \text{ is for slowest route, so } \phi \text{ is critical angle or equivalent (1)}$ Slower paths would imply smaller angles of incidence, for which light would escape [into cladding] (1)	2
		(iv)	Pulses broadened [in time] or can overlap because of different possible routes [<i>accept</i> by multipath dispersion] (1) The shorter the fibre the less the broadening or the less chance of pulses overlapping [or equivalent] (1)	2
			Question 3 Total	[13]

Question			Marking details	Marks Available
4	(a)	(i)	Energy of photon [of frequency f]	1
		(ii)	[Minimum] energy needed to eject an electron [not “electrons”] from a surface [or a metal or a solid, not an atom].	1
	(b)	(i)	$hf = 7.40 \times 10^{14} \times 6.63 \times 10^{-34} - 3.65 \times 10^{-19}$ seen or by implic (1) $E_{k \max} = 1.26 \times 10^{-19}$ [J] (1)	2
		(ii)	$E_{k \max} = 1.26 \times 10^{-19}$ [J] ecf or same as for violet alone or equivalent	1
		(iii)	No emission because <u>photon</u> energy too small (1) $hf = 3.46 \times 10^{-19}$ J, which is less than ϕ , $hf - \phi = -1.9 \times 10^{-20}$ J with attention drawn to minus sign or equivalent (1)	2
	(c)		Increase voltage from zero until microammeter reads zero (accept until current is zero) or equivalent (1) $E_{k \max} = e \times \text{‘cut-off voltage’}$ accept $E_{k \max}$ in eV = cut-off voltage (1)	2
			Question 4 Total	[9]

Question			Marking details	Marks Available
5	(a)	(i)	$\Delta E = 1.51 \times 10^{-19} \text{ J}$ [or $hf = \Delta E$ and $\lambda = \frac{c}{f}$ or $\lambda = \frac{hc}{\Delta E}$ or by imp] (1) $\lambda = 1.32 \text{ }\mu\text{m}$ (1) Infra-red (1)	3
		(ii)	Correct handling of efficiency output power 0.035 W or by implic (1) Division of power by photon energy ($1.51 \times 10^{-19} \text{ J}$) attempted (1) $2.3 \times 10^{17} \text{ s}^{-1}$ photons per unit time [ecf on $2.29 \times 10^{-19} \text{ J}$ from (i)] (1)	3
	(b)		Electrons raised [or pumped] from ground to P and drop to U [or shown on diagram] (1) Electrons [spontaneously] drop from L to ground (accept L is self-emptying) (1) Any × 1 from: • P short-lived • U long-lived [metastable] • L short-lived • L not reliant on pumping to deplete	3
	(c)		Stimulated emission requires a [passing] photon [of energy $E_U - E_L$]; [spontaneous emission doesn't] (1) Two photons after stimulated emission event; one before (1)	2
			Question 5 Total	[11]

Question			Marking details	Marks Available
6	(a)		An object [or surface] that absorbs all [e-m] radiation falling on it or that emits more radiation [per second per unit area at each wavelength] than any other object [or surface] at the same temperature	1
	(b)	(i)	X peaks in infra-red or close to red or close to 700 nm or equivalent and is red [or yellow] (1) Y peaks in ultraviolet or close to blue or close to 400nm or equivalent and is blue [or white or violet] (1)	2
		(ii)	X peaks at 800 nm [± 20 nm], Y at 360 nm [± 10 nm] or by implication (1) $T_X = 3625$ K, $T_Y = 8056$ K or $\frac{T_Y}{T_X} = \frac{800}{360}$ or equivalent or inverse proportionality between T and λ mentioned (1) $\frac{T_Y}{T_X} = 2.2$ must be to 2 sig figs [ecf on numerical slips including wrong peak λs, but only if comment made if answer doesn't round to 2] (1)	3
		(iii)	24 or 23 [or 16 if $\frac{T_Y}{T_X}$ taken as 2] ecf	1
		(iv)	$24 \frac{A_Y}{A_X} = 9.0$ [ecf on 24] or equivalent or by implication (1) $\frac{d_Y}{d_X} = \sqrt{\frac{9}{24}}$ or equivalent, ecf on $\frac{9}{24}$, or by implication (1) $d_Y = 9.2 \times 10^8$ [m] or 9.4×10^8 [m] or 1.1×10^9 [m] ecf on (iii) (1) Alternative: $P_X = 6.92 \times 10^{25}$ [W] or equivalent (1) $9.0 P_X = \sigma A_Y \times 8056^4$ or equivalent (1) $d_Y = 9.2 \times 10^8$ [m] or 9.4×10^8 [m] or 1.1×10^9 [m] ecf on (iii) (1)	3
		Question 6 Total		

Question			Marking details	Marks Available
7	(a)		proton: uud , charge = $\frac{2}{3} + \frac{2}{3} + -\frac{1}{3} = 1.0$ [units of e] (1) neutron: udd , charge = $\frac{2}{3} + -\frac{1}{3} + -\frac{1}{3} = 0$ (1) [Accept alternative presentations in which quark constitutions of p and n are clear, and charges of u and d are clear.]	2
	(b)	(i)	Charge LHS: $4p, 1e^-$ [overall charge $3e$]; RHS: $3p, \nu_e$ has no charge [overall charge $3e$] Accept $4-1 \rightarrow 3+0$ (1) Lepton number LHS: $e^-: 1$ Be: 0; RHS: $\nu_e: 1$ Li: 0 Accept $0+1 \rightarrow 0+1$ (1)	2
		(ii)	Proton lost, neutron gained [or proton changes to neutron] (1) u lost, d gained [or u changes to d] (1)	2
		(iii)	${}^3_2\text{He}$ lost, ${}^4_2\text{He}$ gained [or ${}^3_2\text{He}$ changed to ${}^4_2\text{He}$]	1
		(iv)	Fusion: [smaller or lighter] <u>nuclei</u> combine (1) E-m interaction: shown by γ or photon released (1)	2
			Question 7 Total	[9]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01



S15-1322-01

PHYSICS – PH2

Waves and Particles

P.M. THURSDAY, 4 June 2015

1 hour 30 minutes

For Examiner's use only		
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1.	12	
2.	7	
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7.	9	
8	8	
Total	80	

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010001

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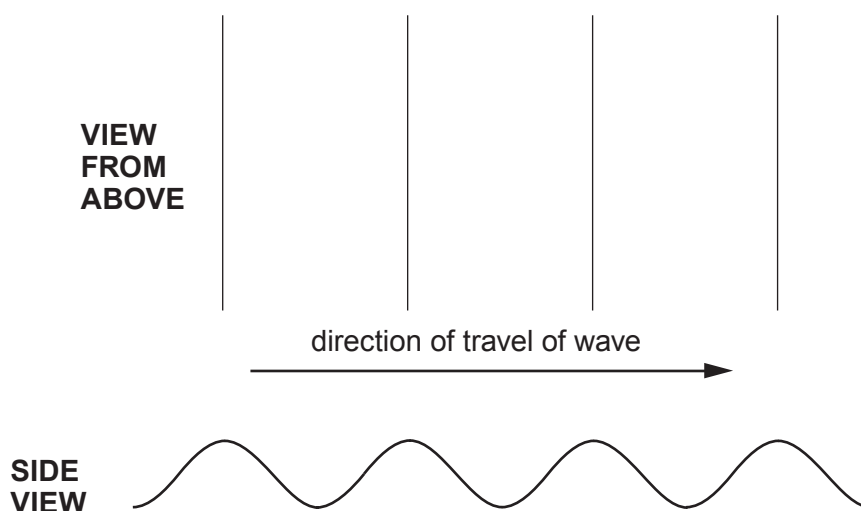
1. (a) A student gives the following **wrong** definition of wavelength.

“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]

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

- (b) The top diagram 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 mm. The wavelength is 15 mm. Calculate the frequency. [3]

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- (ii) On the **top** diagram carefully draw in the positions of the crests at $t = 0.010\text{ s}$. [2]
Space for calculations if needed.

- (c) 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]

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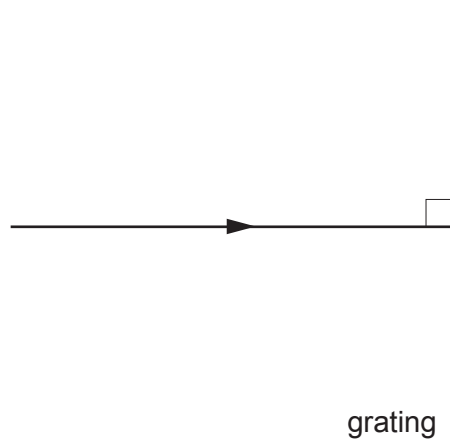
- (ii) Explain why *diffraction* is essential for the formation of the interference pattern. [2]

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2. (a) A beam of light of wavelength 532 nm is shone normally (in the direction shown) on to a diffraction grating with slit spacing $1\,200\text{ nm}$ (between centres of adjacent slits).



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

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- (ii) Draw all the emerging beams (representing each as a single line) **on the diagram above**. [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]

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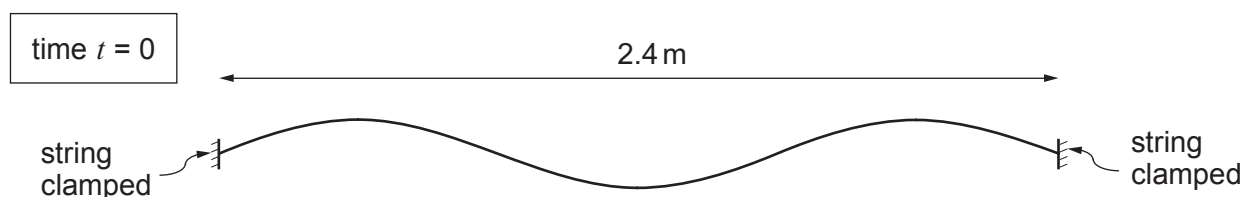
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3. (a) The diagram shows a **stationary** wave on a stretched string at a time of maximum displacement ($t = 0$).



- (i) Determine the wavelength. [1]

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

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



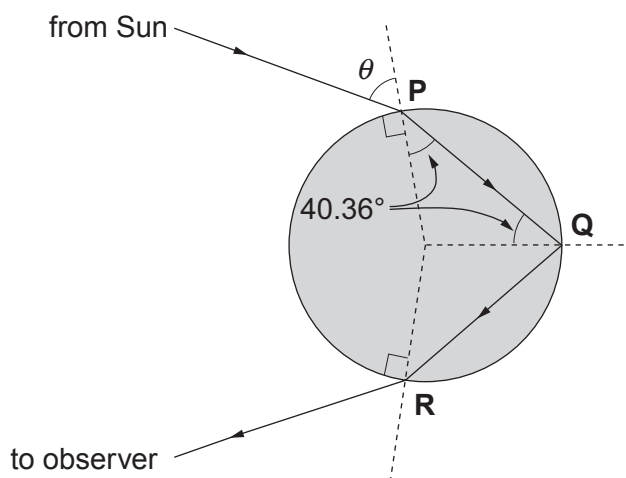
- (I) The frequency is 50 Hz. Determine t_1 . [2]

- (II) **On the diagram** 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]

- (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]



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



- (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]

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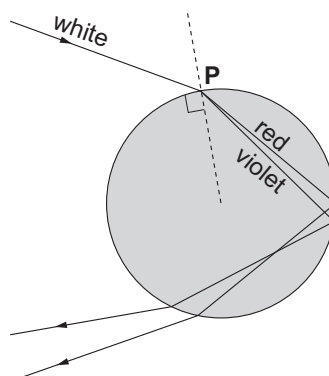
- (ii) Is the internal reflection at **Q** a case of *total* internal reflection? Give your reasoning clearly. [2]

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- (iii) The diagram below 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]

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- (b) Light takes $1.75\ \mu\text{s}$ 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]

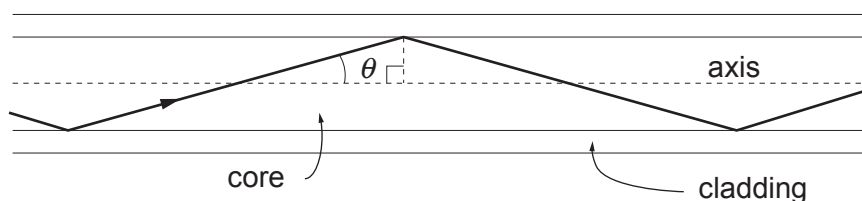
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- (ii) The greatest angle, θ , to the axis at which light can propagate with total internal reflection is 15° .



Calculate the refractive index of the **cladding**.

[3]

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- (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]

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5. (a) Einstein's photoelectric equation is $E_{k \max} = hf - \phi$

State, in terms of *energy*, the meaning of each term in the equation.

(i) $E_{k \max}$ [1]

(ii) hf [1]

(iii) ϕ [1]

- (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]

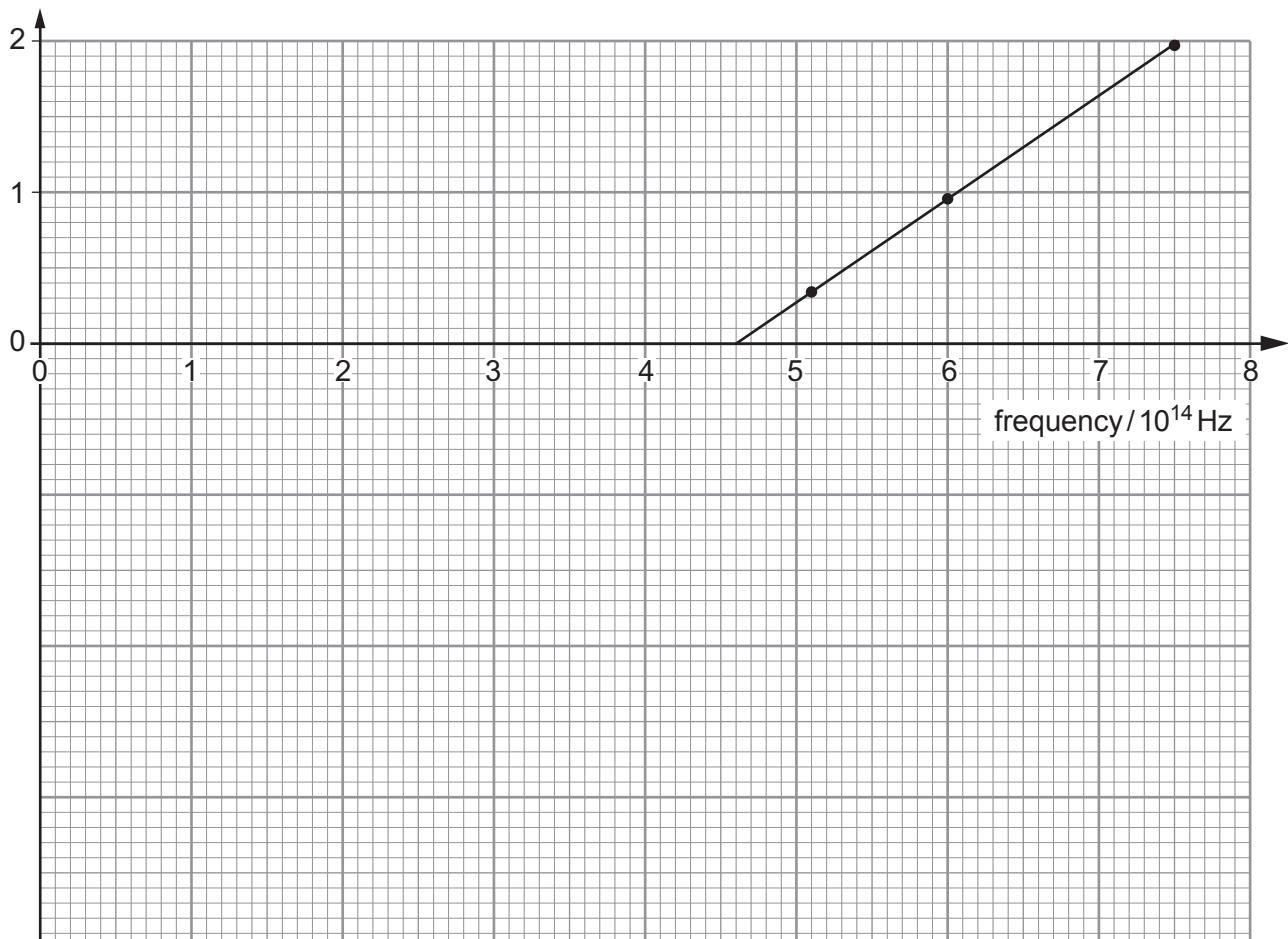
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- (c) A student determines the maximum kinetic energy of electrons ejected from a caesium surface by incident light of three frequencies, and plots the straight line graph shown.

maximum K.E. of electrons / 10^{-19} J



(i) Determine from the graph values for:

(I) the Planck constant;

[2]

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(II) the work function of caesium.

[1]

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

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

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

[2]

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

P	_____	$3.07 \times 10^{-18} \text{ J}$
U	_____	$2.66 \times 10^{-18} \text{ J}$
L	_____	$2.21 \times 10^{-18} \text{ J}$

ground _____ 0

(a) Calculate:

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

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

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

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(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]

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

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

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

in which $R_{\odot}$ = radius of Sun $= 6.96 \times 10^8 \text{ m}$

and $L_{\odot}$ = luminosity of Sun $= 3.85 \times 10^{26} \text{ W}$

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

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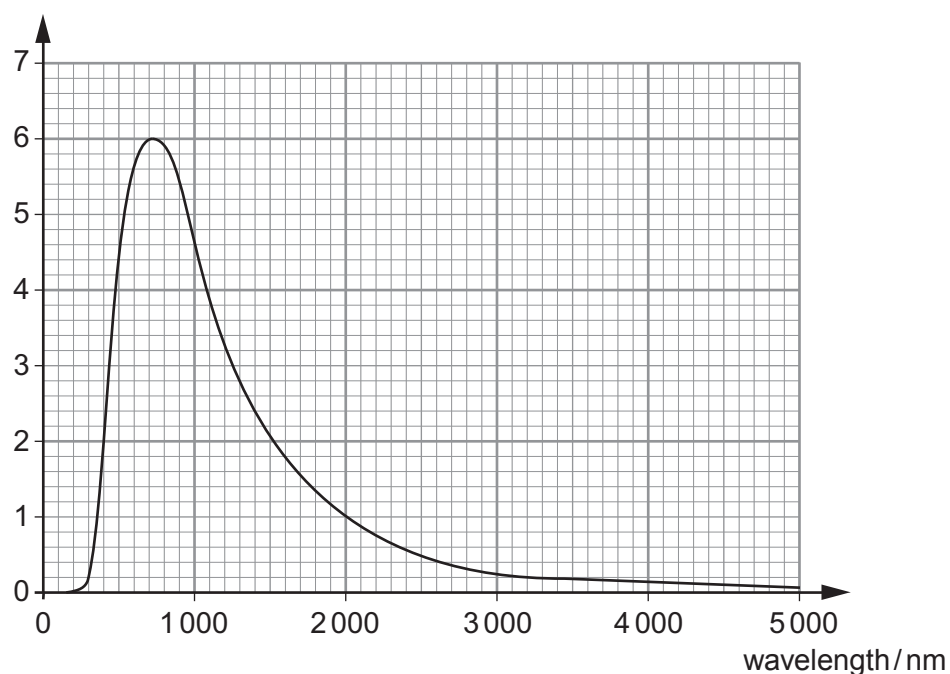
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- (b) The continuous spectrum of Aldebaran is given.

spectral intensity / arbitrary units



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

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- (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]

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

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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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(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]

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

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(c) The following interaction has been observed.

$$\pi^+ + {}^2_1\text{H}^+ \rightarrow \text{p} + \text{p}$$

[The ${}^2_1\text{H}^+$ is a deuterium (heavy hydrogen) nucleus.]

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

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(ii) Before the interaction the π^+ and the ${}^2_1\text{H}^+$ 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]

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END OF PAPER

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GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2015

INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2015 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

	Page
PH1	1
PH2	7
PH3	12
PH4	17
PH5	24
PH6	39

Question			Marking details	Marks Available
1	(a)	(i)	In phase [Accept: in step.]	1
		(ii)	Same amplitude everywhere [Accept: amplitude gets less and less.]	1
	(b)	(i)	$v = 500 \text{ mm s}^{-1}$ or 0.5 m s^{-1} or $T = 0.03 \text{ s}$. Accept without units. (1) Attempted use of $f = \frac{v}{\lambda}$ not $c = 3 \times 10^8 \text{ m s}^{-1}$) or $f = \frac{1}{T}$ or by implication (1) 33 [Hz] (1)	3
		(ii)	Working shows crests have moved $\frac{\lambda}{3}$ or 5 mm or by implic (1) Positions convincing by eye (1) Accept at 5 mm or third distance between crests. Fewer than 3 lines shown award 1 mark only .	2
	(c)	(i)	80 mm, 320 mm and 15 mm correctly put in double slit equation (1) states or implies that first const int is at 60 mm from axis. (1) concludes that there is dest int at P (1) • Give 1 mark if candidate claims first const int at 120 mm, having put in 40 mm instead of 80 mm for slit separation, and another mark if goes on to conclude that neither dest not const at P. • If equation used ‘backwards’, putting in 30 mm and finding 7.5 mm for λ award 1 mark and 2 nd mark if also states that dest int at P. For the 3 rd mark it must be carefully explained why destructive interference at P for $\lambda = 15 \text{ mm}$ Alternative solution: Path difference = $7.7 \pm 0.1 \text{ mm}$ (1) This is equal to / approximately equal to $\frac{\lambda}{2}$ (1) Hence destructive interference will occur (1)	3
		(ii)	Diffraction is spreading of waves <u>at slits</u> (1) Without which waves wouldn’t overlap (or superpose) (1)	2
Question 1 total				[12]

Question			Marking details	Marks Available
2	(a)	(i)	λ and d correctly inserted (nm is fine) in equation or by implic (1) 26° (1) 62° (1)	3
		(ii)	Beams drawn at 0° and at two different angles one side of normal (1) 2 beams either side of normal with some regard for symmetry (1) ecf on 1 angle found in (i)	2
	(b)		Only 3 beams emerge (this must be stated in words) [Accept: no second order beams.] (1) First order beams at greater angle to zeroth (a calculation is acceptable) or equivalent (1) Reference to colours is irrelevant	2
			Question 2 total	[7]

Question				Marking details	Marks Available
3	(a)	(i)		1.6 [m]	1
		(ii)		0.4 [m], 1.2 [m], 2.0 [m]	1
		(iii)	I	$t_1 = \frac{T}{4}$ or $T = 0.02$ [s] (1) $t_1 = 0.005$ s (1) UNIT mark	2
			II	down, up, down	1
	(b)			half sinusoid: up, down or both (1) $c = 80$ [m s ⁻¹] and $\lambda = 4.8$ [m] or frequency of fundamental = third frequency of 3 rd harmonic or by implication (1) $f = 17$ [Hz] (1)	3
Question 3 Total					[8]
4	(a)	(i)		$\sin \theta = 1.331 \sin 40.36^\circ$ or by implication (1) 60° (1) Accept 59.5 °	2
		(ii)		Not total + attempt at justification even if not worth next mark (1) For the 2nd mark either: Light got in at P or gets out at R, so can get out at Q [as angles in water the same] or $1.331 \sin 40.36$ reshow to be < 1 or $C = 49^\circ$	2
		(iii)		$v_{\text{violet}} < v_{\text{red}}$ + attempt at justification even if not worth next mark e.g. violet bends more (1) For the 2nd mark either: Violet must have larger n therefore smaller v or bending caused by light travelling more slowly in water than in air, so violet must travel most slowly.	2
	(b)	(i)		Speed in glass = $\frac{360}{1.75 \times 10^{-6}}$ [= 2.06×10^8 m s ⁻¹] or by implication (1) $n = 1.46$ (1) must be to 3 sig figs	2
		(ii)		$C = 75^\circ$ or by implication (1) $1.46 \sin 75^\circ = n_{\text{clad}} [\sin 90^\circ]$ [Accept 1.5 for 1.46] or by implic (1) $n_{\text{clad}} = 1.41$ [1.45 if n_{core} taken as 1.50] (1) Award 1 mark only for: $1.46 \sin 15^\circ = n_{\text{clad}} [\sin 90^\circ]$	3
		(iii)		Larger angles give longer propagation times. [Accept longer dists.](1) So each pulse spread out over time on arrival or each pulse is less spread out if the angles are restricted (1) So pulses might overlap (Accept pulses muddled) or overlap/muddling of pulses less likely if angles restricted. (1) Award 1 mark only for less multimode dispersion	3
				Question 4 Total	[14]

Question				Marking details	Marks Available	
5	(a)	(i)		[Maximum] kinetic energy of <u>emitted electron</u> [s]	1	
		(ii)		Photon energy	1	
		(iii)		[Minimum] energy needed to release [or eject] <u>electron</u> from surface [or metal or solid]	1	
	(b)			$\phi = hf_0$ or by implication (1) $f = 3 f_0$ (1)	2	
	(c)	(i)	I	attempt at gradient calculation even if slips, e.g. in 10^n (1) $h = 6.8 [\pm 0.2] \times 10^{-34}$ [J s] (1)	2	
			II	$\phi = 3.1 [\pm 0.1] \times 10^{-19}$ [J] Don't accept a negative ϕ	1	
		(ii)		$\phi_{\text{sodium}} = \phi_{\text{caesium}} + 0.6$ [or 0.7] $\times 10^{-19}$ J or parallel line or use of equation (1) $\phi_{\text{sodium}} = 3.7 [\pm 0.3] \times 10^{-19}$ [J] ecf (1)	2	
Question 5 Total					[10]	
6	(a)	(i)		$\Delta E = 2.66 - 2.21 \times 10^{-18}$ J [=0.45 $\times 10^{-18}$ J] (1) Use of $[\Delta]E = hf$ and $f = \frac{c}{\lambda}$ or $[\Delta]E = \frac{hc}{\lambda}$ (1) 440 n[m] No ecf except on arithmetical slip in ΔE (1)	3	
			(ii)	$\frac{15\text{mW}}{\Delta E}$ ecf [attempted] (1) 3.3×10^{16} [s ⁻¹] ecf (1)	2	
		(iii)		Pumping energy taken as 3.07×10^{-18} J (1) 15 % Accept 14 % (1) ecf on photon energy	2	
	(b)	(i)		Passing photon causes drop from U to L (1) With emission of another photon (1) Don't accept absorption of incident photon and emission of 2. Process happens repeatedly and increases photon number (unless already made clear for single event). (1)	3	
			(ii)	Stimulated emission events more probable (or equivalent) (1) Absorption events less probable (1)	2	
		Question 6 Total				

Question			Marking details	Marks Available
7	(a)		$r = 3.07 \times 10^{10} \text{ m}$ and $L = 1.99 \times 10^{29} \text{ W}$ or by implication (1) $L = \sigma 4\pi^2 T^4$ (1) Correct algebra including fourth-rooting (1) $T = 4150 \text{ K}$ UNIT mark (1) [Take 5865 K arising from $A = \pi^2$ as ecf] If only Sun considered $T = 5776 \text{ K}$ award 3 marks only	4
	(b)		Attempted use of $\lambda_{\text{max}} = 700 - 750 \text{ [nm]}$ in Wien's Law (1) $3867 - 4140 \text{ [K]}$ (1)	2
	(c)		Black body absorbs all [electromagnetic] radiation (accept light) falling on it. [Accept: Black body emits more radiation per second [or equivalent] [at every wavelength] than any other body at same temperature. Don't accept it is a perfect emitter.	1
	(d)		Spectrum peaks in red or equivalent. Accept infra-red. (1) $r = 44.2 R_{\odot}$ is sufficient. Must compare with the Sun. (1) Question 7 Total	2 [9]
8	(a)	(i)	A meson is a quark-antiquark combi; (don't accept 2 quark combination) a baryon is a 3 quark combi	1
		(ii)	Charge = $+(\frac{2}{3})[e] + (\frac{1}{3})[e] = +1[e]$ or equivalent	1
	(b)	(i)	$0 = -1 + 1$ or equivalent (which does not include $0 = +1 + -1$)	1
		(ii)	Weak; suggested by long decay time or Weak; indicated by neutrino involvement or Weak; indicated by change of quark flavour Don't accept: No quark involvement / (only) lepton involvement	1
	(c)	(i)	$1 + 2 + 1 = 2 + 2$ or equivalent (e.g. $1 + 3 = 2 + 2$)	1
		(ii)	2 × (1) from: • Mesons decay • Strong force is short-range • π^+ and H repel • Large energy needed to regroup groups For the 3rd mark: The relevance of one of the above points must be argued Question 8 Total	3 [8]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

PHYSICS – PH2

Waves and Particles

A.M. MONDAY, 9 June 2014

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	9	
2.	8	
3.	9	
4.	14	
5.	8	
6.	11	
7.	12	
8	9	
Total	80	

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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 string is stretched between fixed points **A** and **B**.



A stationary wave is set up on the string. The nodes are at the points marked by dots.

- (i) At one instant the string is straight, as shown. Point **P** is moving upwards. **Add to the diagram** a sketch of the string a quarter of a cycle later. [1]
- (ii) Compare the phases and amplitudes of the wave at points **P** and **Q**. [2]

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- (iii) Compare the phases and amplitudes of the wave at points **Q** and **R** (which are equal distances either side of a node). [2]

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- (iv) The string is 0.60 m long and vibrates at a frequency of 240 Hz. Calculate the wave speed, giving your reasoning. [2]

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- (b) A new stationary wave with a different frequency is set up on the same string. The nodes are as shown.



Calculate the new wave frequency, showing your working.

[2]

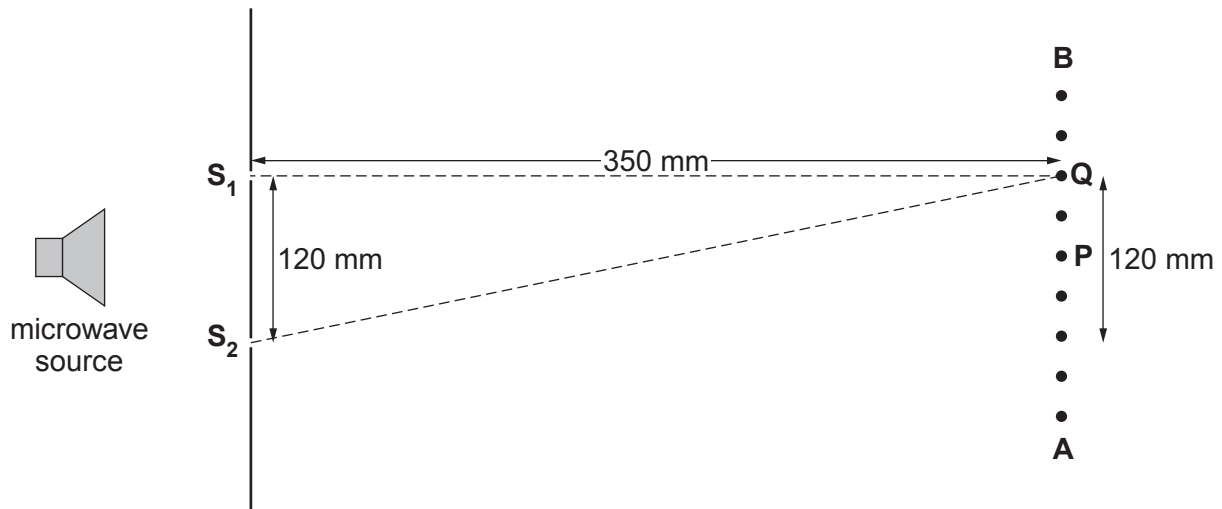
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2. (a) A microwave source is placed to the left of two narrow slits, S_1 and S_2 , so that these slits act as in-phase sources.



A microwave sensor which is moved along the line **AB** detects maxima at the points shown as dots. One of these points, **Q**, is directly in front of S_1 .

- (i) By considering the right angled triangle S_1S_2Q , show that the path difference, $S_2Q - S_1Q = 20 \text{ mm}$. [2]

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- (ii) **Hence** determine the wavelength of the microwaves, giving your reasoning. Note that point **P** is equidistant from S_1 and S_2 . [2]

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- (iii) Check your answer to (a)(ii) using the equation for double-slit interference, showing your working clearly. [2]

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- (b) Describe briefly how you would show that microwaves from this source are polarised.

[2]

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3. (a) Describe a diffraction grating.

[2]

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(b) A diffraction grating has 400 000 slits per metre of its width.

(i) Show that the distance between the centres of neighbouring slits is $2.5\text{ }\mu\text{m}$.

[1]

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(ii) A laser beam is shone normally at the grating. The **second** order beams leave the grating at angles of 25.2° either side of the grating normal. Calculate the wavelength of the laser light.

[3]

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(iii) Calculate the angle (to the grating normal) of the **third** order beams.

[2]

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(iv) The beams of different orders are spaced much further apart than the fringes in a typical Young's slits set-up using the same laser. Why is this so?

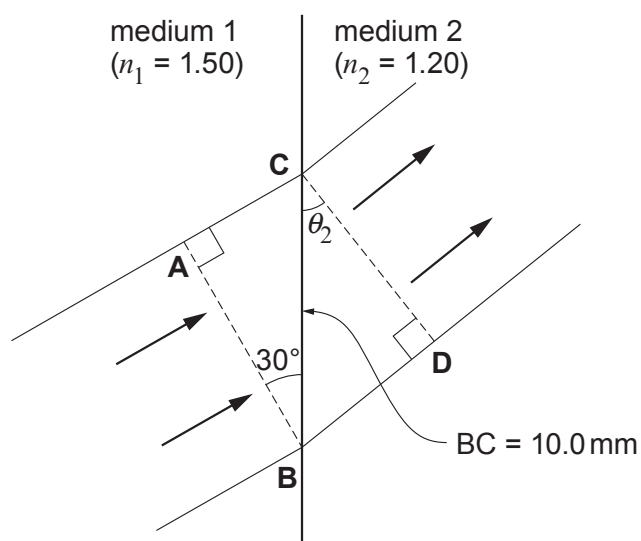
[1]

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4. (a) A beam of light passes from medium 1, of refractive index $n_1 = 1.50$, into medium 2, of refractive index $n_2 = 1.20$.



- (i) Calculate the speeds of light in the two media. [1]

medium 1

medium 2

- (ii) Show clearly that the end, **A**, of wavefront **AB** will take $2.5 \times 10^{-11} \text{ s}$ to reach the boundary at **C**. [Note that distance $BC = 10.0 \text{ mm}$.] [2]

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- (iii) While **A** is travelling to **C**, the end, **B**, of wavefront **AB** travels to **D**, through medium 2. Calculate the distance **BD** and hence the angle θ_2 . [2]

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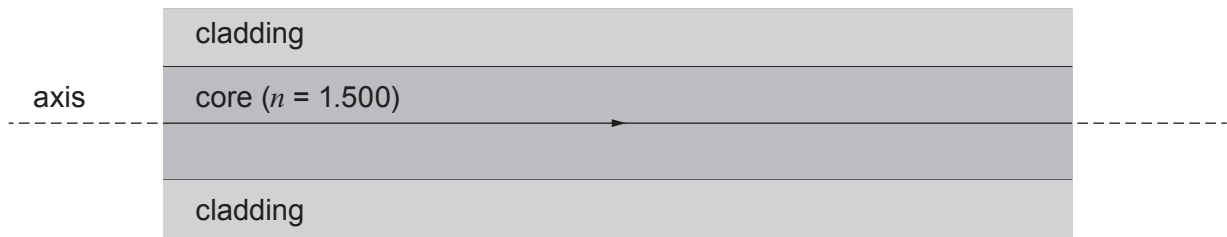
- (iv) Check your value of θ_2 using a refraction equation involving n_1 and n_2 . [2]

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- (b) A diagram of an optical fibre is given.



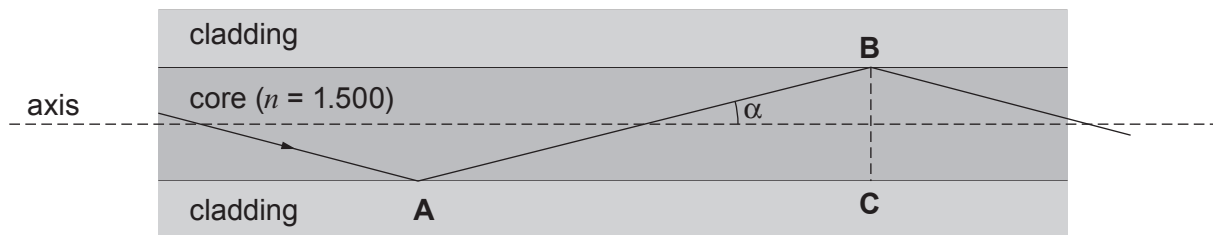
- (i) Show clearly that a light pulse travelling along the axis of the fibre takes $8.0\mu\text{s}$ to travel through 1.6 km of fibre. [2]

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- (ii) The greatest angle, α , **to the axis** at which light can travel through the core without escaping is 14° . Calculate the refractive index of the cladding. [3]



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- (iii) Calculate the **difference** in times taken for a pulse to travel through 1.6 km of fibre by the routes in (b)(i) and (b)(ii). [2]

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5. (a) Magnesium has a *work function* of 5.9×10^{-19} J. What does this statement mean? [1]

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- (b) Calculate the maximum kinetic energy of electrons ejected from a magnesium surface by ultraviolet radiation of frequency 1.16×10^{15} Hz. [2]

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- (c) Explain in physical terms why electrons are not emitted when radiation of frequency 8.21×10^{14} Hz (instead of the original frequency) falls on a magnesium surface. Support your answer with a calculation. [2]

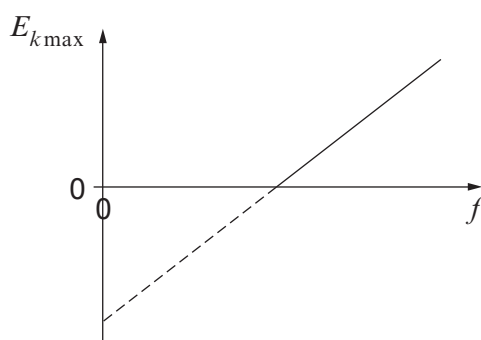
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- (d) The graph shows how the maximum kinetic energy, $E_{k\max}$ of electrons ejected from a magnesium surface varies with the frequency, f , of ultraviolet radiation falling on the surface.



State the physical quantities represented by:

- (i) the gradient; [1]

- (ii) the intercept on the $E_{k\max}$ axis; [1]

- (iii) the intercept on the f axis. [1]

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6. (a) A laser emits 25 W of coherent infra-red radiation of wavelength 1 064 nm.

(i) Explain what 'coherent' means in this sentence.

[2]

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(ii) Calculate the photon energy.

[2]

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(iii) Calculate the number of these photons leaving the laser per second.

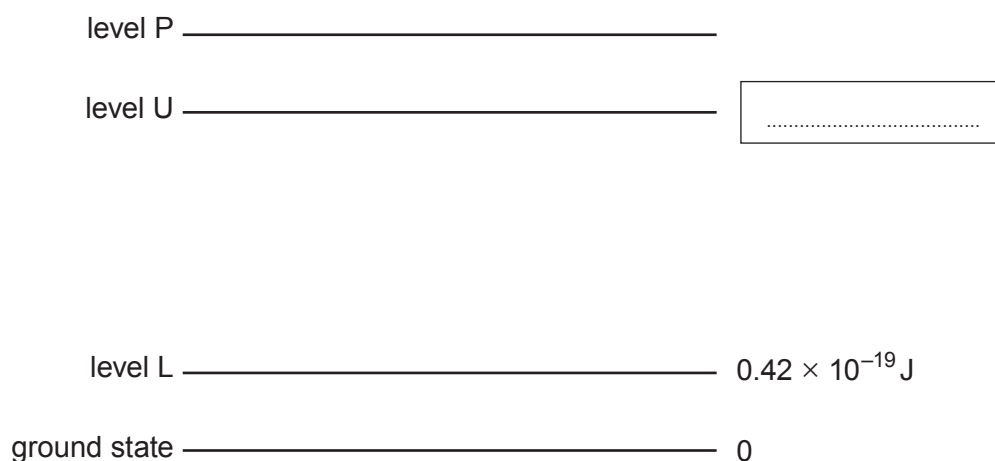
[1]

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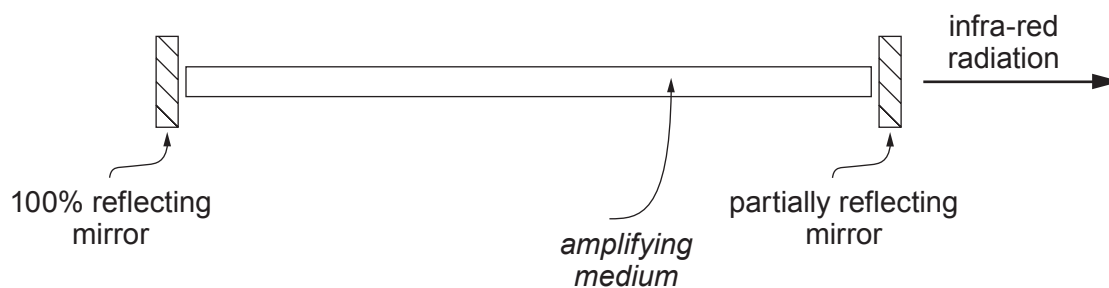
(iv) A simplified energy level diagram for this (four level) laser is given.



(I) **Show, with an arrow,** on the diagram the transition associated with emission of the infra-red radiation. [1]

(II) In the box provided in the diagram above, **write** the energy of level U. [1]

- (b) 'Light' amplification occurs as the radiation passes through the amplifying medium in the laser cavity.



Explain how light amplification occurs. Start by explaining what is meant by *stimulated emission*, referring to the diagram in (a)(iv). [4]

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7. The star Sirius A has a surface temperature of 9900 K and a luminosity (total power output of electromagnetic radiation) of 1.00×10^{28} W.

(a) (i) Calculate the star's wavelength of peak spectral intensity. [2]

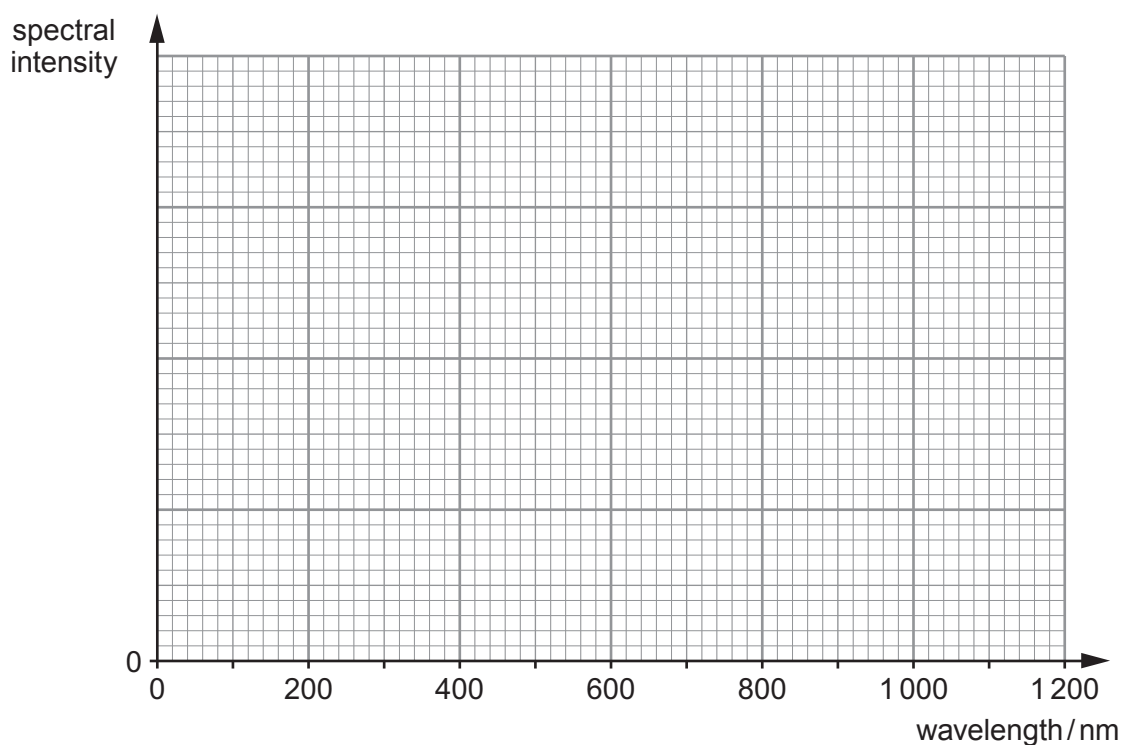
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(ii) Sketch on the axes a graph of spectral intensity against wavelength for the continuous spectrum of Sirius A. (*Note: make the peak spectral intensity three or four large squares above the wavelength axis.*) [2]



(iii) What colour would you expect Sirius A to be? [1]

.....

(b) Use Stefan's Law to calculate the diameter of Sirius A. [3]

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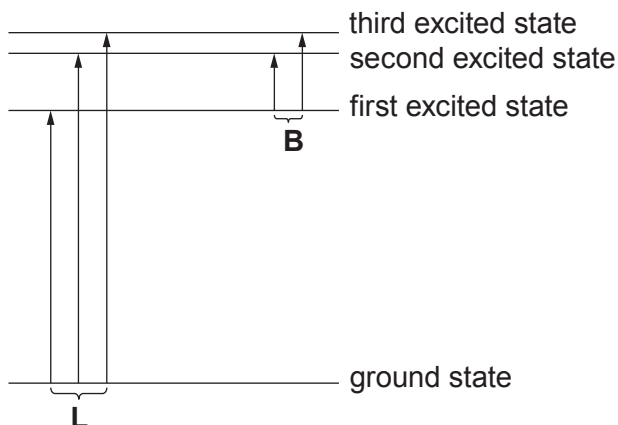
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- (c) The diagram shows the lowest energy levels of a hydrogen atom, and five possible transitions between these levels.



- (i) Name the process (involving photons) which is responsible for the transitions. [1]

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- (ii) Briefly describe the observed feature of the spectrum of a star which this process explains. [1]

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- (iii) All the transitions shown in the diagram take place in the atmosphere of Sirius A. State which group of transitions, **L** or **B**, is almost completely absent in a much cooler star, giving a reason for your answer. [2]

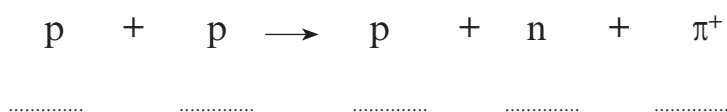
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TURN OVER FOR QUESTION 8

8. (a) When two protons collide at high kinetic energies, the interaction below sometimes occurs.



- (i) **Write** the quark make-up of each particle in the spaces provided above. [2]

- (ii) Explain how this interaction conforms to *baryon number conservation*. [Note that baryon numbers are assigned thus: baryon: 1, antibaryon: -1, non-baryons: 0.] [1]

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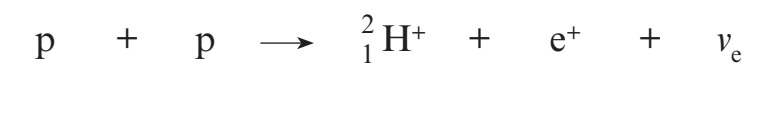
- (iii) State what type of interaction (strong, weak or electromagnetic) this is likely to be, giving a reason for your choice. [1]

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- (iv) State **one** quantity, other than *baryon number* or *lepton number*, which is conserved in this interaction. [1]

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- (b) Another interaction which can occur when two protons collide at high energies is:



${}^2_1\text{H}^+$ represents a deuterium (heavy hydrogen) nucleus.

- (i) **Write** the *lepton number* of each particle in the spaces provided above. [1]

- (ii) State what type of interaction this is, and why the interaction is important to life on Earth. [3]

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END OF PAPER

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GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2014

INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2014 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

	Page
PH1	1
PH2	6
PH3	10
PH4	13
PH5	20
PH6	36

PH2

Question			Marking details	Marks Available
1	(a)	(i)	Attempt at sinusoid, right way up, passing within 1 mm of all dots	1
		(ii)	P and Q are in phase (1) Amplitude of P > amplitude of Q (1)	2
		(iii)	Q and R are in antiphase / exactly out of phase (1) Amplitude of Q = amplitude of R (1)	2
		(iv)	$\frac{\lambda}{2} = 0.20$ [m] or $\lambda = 0.40$ [m] or by implication (1) $v = 96 \text{ m s}^{-1}$ UNIT ecf (1)	2
	(b)		$\frac{\lambda}{2} = 0.15$ [m] (or $\lambda = 0.30$ [m]) or $v = 96 \text{ [m s}^{-1}]$ ecf from (a)(iv) or $f = \left(\frac{4}{3}\right) 240$ [Hz] or by implication (1) $f = 320$ [Hz] but not by cancellation of errors, ecf on v from (a)(iv) (1) Question 1 total	2 [9]
2	(a)	(i)	$S_2Q = \sqrt{(350^2 + 120^2)}$ [mm] or equivalent (1) Therefore $S_2Q - S_1Q = (370 - 350)$ [mm] (1)	2
		(ii)	For any dot, path difference = $n\lambda$, or for P, path difference = 0 or any other remark relevant to the conclusion that ... (1) $\lambda = 10$ [mm] (1)	2
		(iii)	$\lambda = \left(\frac{120 \times 30}{350}\right)$ (1) $\lambda = 10 \text{ mm}$ or 10.3 mm UNIT (1)	2
	(b)		With sensor in front of source either rotate sensor [at least through 90°] or interpose array of metal rods /metal grille and rotate [at least through 90°] (1) Don't accept metal grid Signal strength changes (1) Accept in words or in diagram Question 2 total	2 [8]

Question			Marking details	Marks Available
3	(a)		[Flat, opaque] screen / sheet/ plate / material with slits / gaps (1) Slits are parallel / vertical or equally spaced or closely spaced or many / multiple (1)	2
	(b)	(i)	$\frac{1}{400000} = [2.5 \times 10^{-6} \text{ m}]$	1
		(ii)	$2\lambda = 2.5 \times 10^{-6} \sin 25.2^\circ$ even with the 2 missing or mishandled (1) Correct placing of the 2 (1) $\lambda = 532 \times 10^{-9} \text{ [m]}$ ecf on d only (1)	3
		(iii)	$3 \times 532 = 2\,500 \sin \theta$ or equivalent ecf on λ (1) $\theta = 39.7^\circ$ or 40° ecf on λ (1)	2
		(iv)	Young's slits much further apart than slits in grating Don't accept slits much narrower or gaps are much smaller	1
			Question 3 Total	[9]
4	(a)	(i)	medium 1: $2.0 \times 10^8 \text{ [m s}^{-1}\text{]}$ and medium 2: $2.5 \times 10^8 \text{ [m s}^{-1}\text{]}$	1
		(ii)	Correct use of $\sin 30^\circ$ seen clearly (1) Rest of argument, including use of $t = \frac{d}{v}$ [ecf on v and on value of $\sin 30^\circ$, if failure to reach the stated time is noted]. (1)	2
		(iii)	$BD = 2.5 \times 10^8 \text{ ecf } \times 2.5 \times 10^{-11} \text{ [m]}$ [= 6.25 mm] or by implication (1) $\theta_2 = 38.7^\circ$ (or 39°) ecf on $v = 2.5 \times 10^8 \text{ [m s}^{-1}\text{]}$ (1)	2
		(iv)	$1.50 \sin 30^\circ = 1.20 \sin \theta_2$ (1) Therefore $\theta_2 = 38.7^\circ$ (or 39°) no ecf (1)	2
	(b)	(i)	Use of $v = 2.0 \times 10^8 \text{ [m s}^{-1}\text{]}$ (1) $t = \frac{1600}{2.0 \times 10^8} \text{ [s]}$ ecf on v (1)	2
		(ii)	Critical angle = 76° or by implication (1) $n_{\text{clad}} [\times \sin 90^\circ] = 1.500 \sin 76^\circ$ ecf on 76° or by implication (1) $n_{\text{clad}} = 1.455$ or 1.46 do not accept 1.45 no ecf (1)	3
		(iii)	$\frac{AC}{AB} = \cos 14^\circ$ or equivalent or by implication (1) $\Delta t = 0.24 \mu\text{s}$ ecf on v (1)	2
			Question 4 Total	[14]

Question			Marking details	Marks Available
5	(a)		[Minimum] energy needed to release [or eject] electron from magnesium [or metal or surface or solid not atom]	1
	(b)		$E_{k \max} = 6.63 \times 10^{-34} \times 1.16 \times 10^{15} \text{ [J]} - 5.9 \times 10^{-19} \text{ [J]} \quad (1)$ $E_{k \max} = 1.79 \times 10^{-19} \text{ [J]} \quad (1)$	2
	(c)		<u>Photon</u> energy < work function (1) don't accept photon energy in symbols. Accept not enough energy to liberate an electron. Don't accept $E_{k \max}$ can't be negative. $E_{\text{phot}} = 5.4 \times 10^{-19} \text{ [J]}$ accept $f_{\text{thresh}} = 8.9 \times 10^{14} \text{ [Hz]}$ (1) If negative energy award 1 mark only	2
	(d)	(i)	Planck constant. Accept Planck's constant or h .	1
		(ii)	[–] work function. Accept [–] ϕ .	1
		(iii)	f_0 or minimum frequency to eject electron or threshold frequency	1
	Question 5 Total			[8]
6	(a)	(i)	Any 2 × (1) from: - Monochromatic or same frequency or same wavelength - Wavefronts continuous or light in phase across width of beam <u>Photons</u> in phase	2
		(ii)	Use of $E = hf$ and $f = \frac{c}{\lambda}$ or $E = \frac{hc}{\lambda}$ (1) $1.87 \times 10^{-19} \text{ [J]} \quad (1)$	2
		(iii)	$1.3 \times 10^{20} \text{ [s}^{-1}\text{]} \quad \text{ecf}$	1
		(iv)	Downward arrow from U to L (1) $2.29 \times 10^{-19} \text{ J}$ (or $2.3 \times 10^{-19} \text{ J}$) (1) ecf	2
		(b)	[Passing] photon stimulates electron to drop <u>from U to L</u> (1) Emitting another photon (1)	4
			Any 2 × (1) from: - Process may happen repeatedly (or equivalent) as photons traverse cavity - Population inversion [between U and L] needed for stimulated emission to predominate over absorption - Pumping to P and drop to U brings about inversion - Level L self-emptying so less pumping needed or population inversion easier to accomplish - In phase with or travelling in the same direction as or polarised in the same direction as or identical to passing photon - Stimulated photon must have an energy of $1.87 \times 10^{-19} \text{ J}$ or equivalent	
	Question 6 Total			[11]

Question			Marking details	Marks Available
7	(a)	(i)	$\lambda_{\text{peak}} = \frac{2.90 \times 10^{-3}}{9900} \text{ [m]}$ or equivalent (1) $\lambda_{\text{peak}} = 293 \times 10^{-9} \text{ [m]}$ (1)	2
		(ii)	Peak between 280 and 300 nm (1) Curve goes through origin [with zero gradient at origin] and is consistent with approaching zero at very long wavelengths (1)	2
		(iii)	Blue accept white or violet or purple	1
	(b)		$A = \frac{L}{\sigma T^4}$ with A as subject, with symbols or data or $1.84 \times 10^{19} \text{ m}^2$ (1) Attempt to use $A = 4\pi r^2$ and $d = 2r$ or $A = \pi I^2$ (1) $d = 2.4 \times 10^9 \text{ m}$ ecf on slips of 2^n or 10^n if already penalised (1)	3
		(c)		
	(c)	(i)	Absorption accept excitation Don't accept pumping	1
		(ii)	Dark / black lines crossing or missing wavelengths [continuous] spectrum or coloured background	1
		(iii)	B almost absent and any reference to populations of levels (1) First excited state not populated [so no transitions start here] or all electrons in ground state (1)	2
	Question 7 Total			[12]
8	(a)	(i)	$uud + u\bar{u}d \rightarrow uud + u\bar{d}d$ (1) $+ u\bar{d}$ (1)	2
		(ii)	$1 + 1 > 1 + 1 + 0$ (all numbers must be shown) or equivalent	1
		(iii)	Strong because no [photons (gammas) or] neutrinos or no flavour changes	1
		(iv)	Charge or momentum or energy or strangeness Accept up quark number or down quark number	1
	(b)	(i)	$0 + 0 > 0 + (-1) + 1$ (all numbers must be shown)	1
		(ii)	Weak interaction accept fusion (1) Takes place in the Sun [accept stars] (1) Part of the process whereby we get sunlight or energy or equivalent (1)	3
	Question 8 Total			[9]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

PHYSICS – PH2

Waves and Particles

P.M. WEDNESDAY, 22 January 2014

1 hour 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	7	
2.	8	
3.	12	
4.	11	
5.	9	
6.	12	
7.	11	
8.	10	
Total	80	

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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.

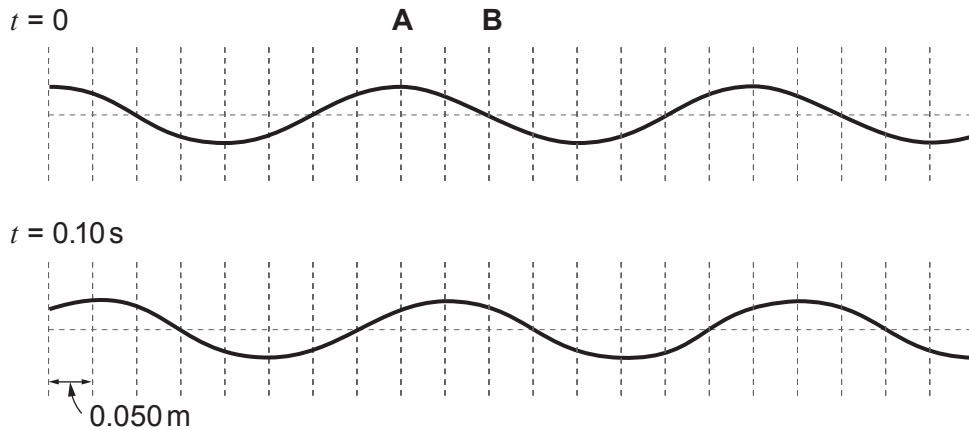
You are reminded of the necessity for good English and orderly presentation in your answers.

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

1322
010001

Answer all questions.

1. A string carrying a progressive transverse wave is photographed against a background of lines spaced 0.050 m apart. The diagrams below are based on two photographs, taken at $t = 0$ and $t = 0.10\text{ s}$. The wave is moving from left to right.



- (a) Write down the wavelength of the waves. [1]
- (b) Calculate the speed of the waves, giving your working and stating any assumption you are making. [2]

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- (c) Calculate the frequency of the waves. [1]

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- (d) Compare the amplitude of the wave at positions A and B along the string. [1]

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- (e) Compare the phases of the wave at A and B. [2]

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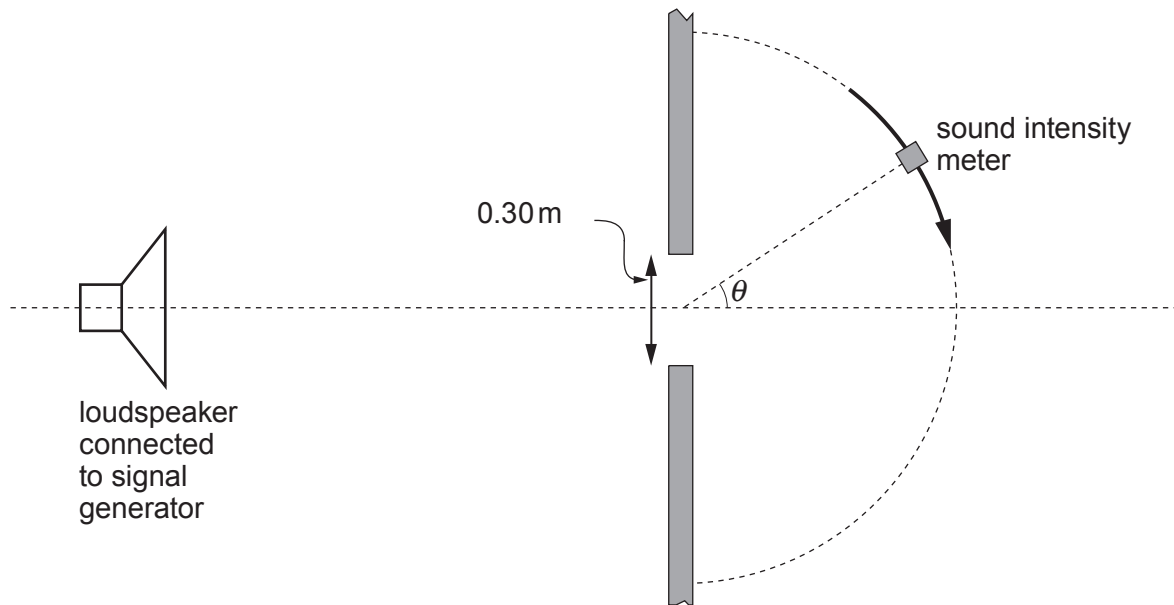
2. (a) Sound waves are longitudinal. Explain what this means.

[1]

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- (b) Two students, Alun and Bryn, investigate the spreading of sound waves passing through a gap of width 0.30 m.

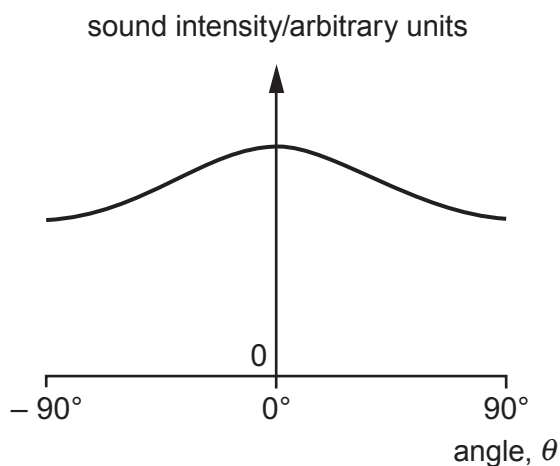


- (i) What name is given to this spreading effect of waves?

[1]

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- (ii) Alun moves a sound-intensity meter around the semicircular path shown opposite, taking readings at various angles, θ . The graph below shows the results.



The frequency of the sound is read from the scale of the signal generator. Alun reads it as 375 Hz, and Bryn, as 3750 Hz. **Explain** which of these frequencies is more likely to be the right one. [Speed of sound in air = 340 m s^{-1}] [3]

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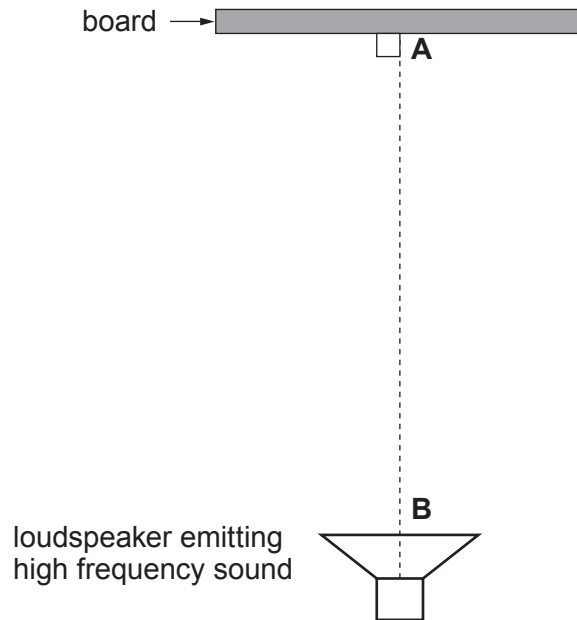
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- (c) In another experiment, the students place a board in front of the loudspeaker.



As they move the sensor for the sound intensity meter along the line **AB**, they find a pattern of alternating maxima and minima. The separation between a **maximum** and the neighbouring **minimum** is 35 mm.

Explain how the pattern arises, giving the wavelength of the sound waves.

[3]

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3. (a) S_1 and S_2 are two wave sources, oscillating in phase.

(i) State what is meant by 'oscillating in phase'.

[1]

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(ii) For constructive interference at some point, P , of the waves from S_1 and S_2 the
path difference = 0 or λ or 2λ or 3λ

+ P S_1 ● S_2 ●

State clearly what is meant by *path difference*, adding to the diagram if it will help
your explanation.

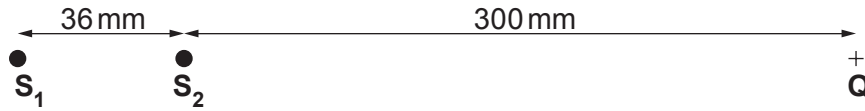
[1]

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- (iii) In the set-up shown below, the in-phase sources, S_1 and S_2 , are emitting, in all directions, microwaves of wavelength 12 mm.



- (I) Determine whether there is constructive or destructive interference at Q , giving your reasoning. [2]

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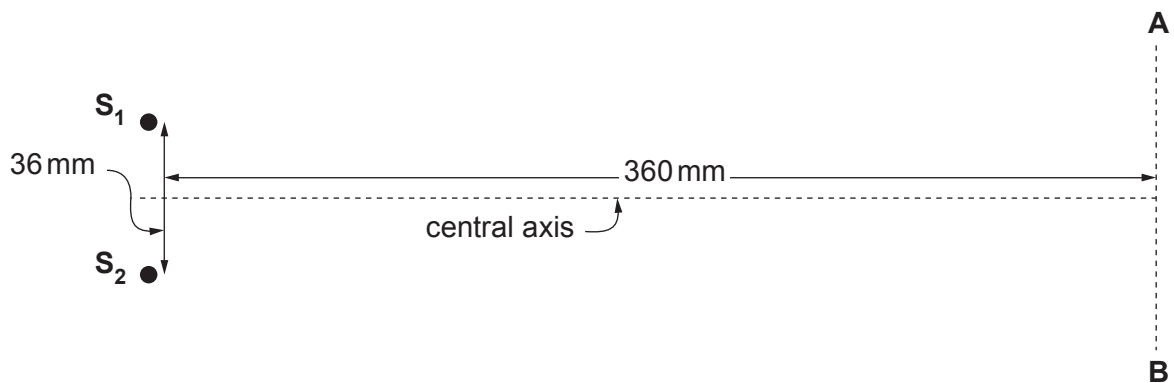
- (II) Discuss whether or not the observed signal strength would vary if a microwave detector were moved to the right, from point Q . [2]

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- (iv) The same microwaves sources are now arranged as shown, and the detector is moved along the line AB .



- Use the equation for double slit interference to determine the approximate spacing between points of maximum microwave intensity. [2]

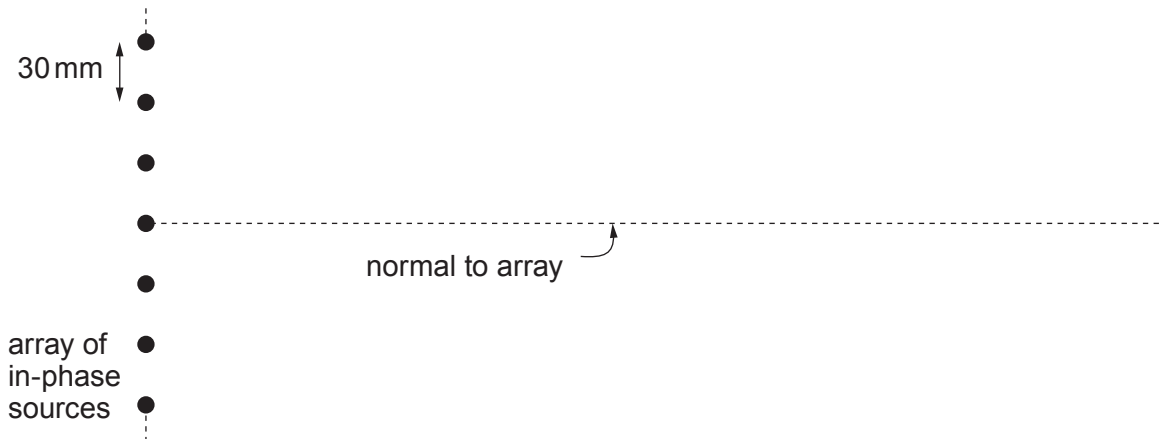
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- (b) An 'array' of regularly-spaced, in-phase wave sources produces an interference pattern similar to that of a diffraction grating, that is sharply-defined beams (maxima) of waves at specific angles to the normal.

In the array shown the sources emit waves of wavelength 12 mm.



Find all the angles to the normal at which beams (maxima) occur.

[4]

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4. (a) Light approaches a medium of refractive index, n_2 from a medium of **greater** refractive index, n_1 .



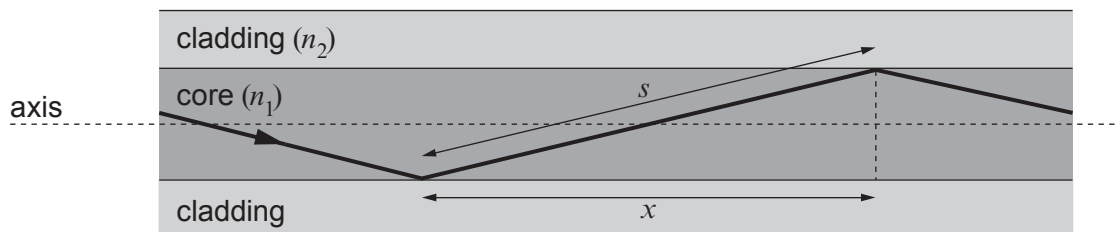
- (i) **Add to the diagram** to show what is meant by the critical angle, c . [1]
- (ii) Show, in clear steps, that: $\sin c = \frac{n_2}{n_1}$ [2]

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- (b) The diagram shows light travelling in the core of a multimode fibre at the greatest angle to the axis so no light can escape into the cladding.



- (i) Making use of the equation from (a)(ii), and marking angle c on the diagram, show clearly that: [2]

$$s = \frac{n_1}{n_2} x$$

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- (ii) Calculate the time taken for a pulse of light to travel 1.2 km through the core in a **straight** path parallel to the axis. [Refractive index, n_1 , of core = 1.500] [2]

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- (iii) Calculate the **extra** time taken for the pulse to travel through the 1.2 km of core via the zig-zag path shown in the diagram. Make use of the equation:

$$s = \frac{n_1}{n_2} x$$

[Refractive index, n_2 , of cladding = 1.485]

[2]

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- (iv) Hence calculate an upper limit to the number of pulses per second that could be sent through 1.2 km of the fibre without overlap occurring. State **one** assumption you are making. [2]

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5. The work function of calcium is 4.60×10^{-19} J.

(a) (i) State what is meant by the work function of a metal. [1]

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(ii) Calculate the lowest frequency of radiation for which Einstein's photoelectric equation applies to a calcium surface. [1]

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(iii) Explain, in physical terms, why the equation does not apply for frequencies lower than this. [2]

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(b) Calculate the frequency of radiation needed to eject electrons of maximum kinetic energy 2.30×10^{-19} J from the calcium surface. [2]

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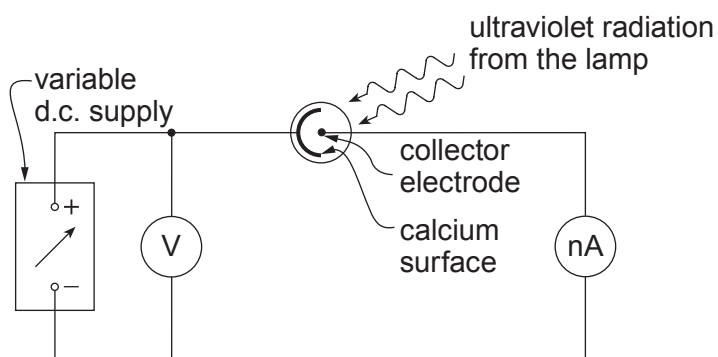
(c) A mercury vapour lamp emits ultraviolet radiation of frequencies 8.2×10^{14} Hz and 11.8×10^{14} Hz.

(i) Calculate the **maximum** kinetic energy of electrons ejected from a calcium surface when the lamp is placed near the surface. Explain your reasoning. [2]

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- (ii) Calculate the potential difference needed to stop electrons reaching the collector electrode in the circuit shown. [1]

Examiner
only

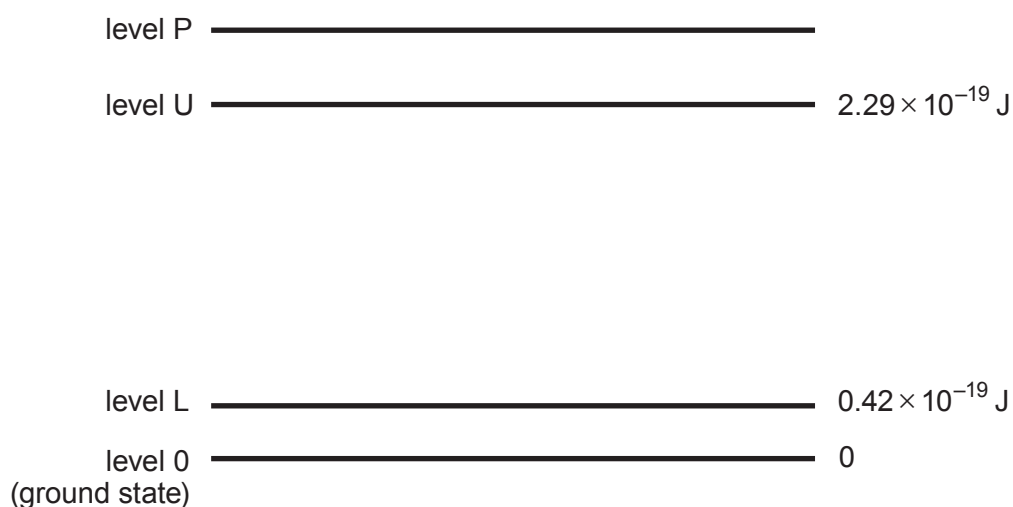


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6. (a) A simplified energy level diagram is given for a four level laser system.



- (i) Calculate the wavelength of photons involved in transitions between levels U and L. [2]

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- (ii) Photons of this wavelength, present in the laser cavity, may be absorbed. Explain what this means, adding an arrow to the diagram to assist your explanation. [2]

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- (iii) In a laser the probability of a photon producing stimulated emission must be greater than the probability of it being absorbed.

- (i) Explain what is meant by stimulated emission, referring to levels U and L. [3]

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- (II) Referring to all four levels, explain how the greater probability of stimulated emission over absorption is achieved in a four level laser system. [3]

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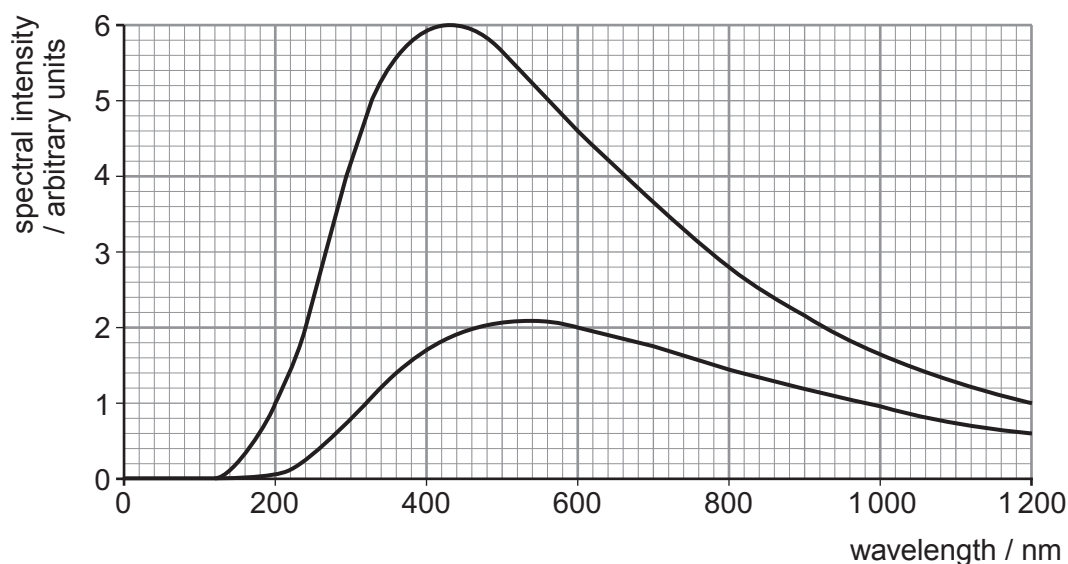
- (b) Light from a laser is coherent. Explain what this means. [2]

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7. Delta Cephei is a variable star, whose surface temperature varies between fixed maximum and minimum values. Its continuous spectrum is given below for the maximum temperature and minimum temperature.



- (a) (i) Show that the star's maximum temperature is approximately 7 000 K. [2]

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- (ii) Calculate the star's minimum temperature. [1]

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- (iii) State the difference you would expect to see in the star's colour at the maximum and minimum temperatures. [1]

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- (b) The star's luminosity (total power emitted as e-m radiation) at its maximum temperature is 1.46×10^{30} W. Calculate its diameter. [4]

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- (c) Calculate the **percentage** decrease in the star's luminosity as its temperature goes from maximum to minimum. [Assume its diameter does not change.] [3]

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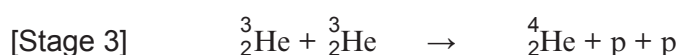
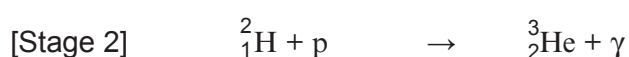
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TURN OVER FOR QUESTION 8

8. (a) The particles in the table below are either first generation leptons or combinations of first generation quarks (and/or antiquarks). Complete the table. [3]

Symbol	Quark make-up (leave blank if no quarks)	Charge / e	Lepton number
p	uud	+1	0
Δ^{++}	uuu		
π^-			
ν_e			

- (b) A sequence of interactions is given.



- (i) Where do these interactions take place naturally? [1]

- (ii) Stage 2 takes place by means of the strong force, but another force is also involved. Identify this force, giving a reason for your answer. [1]

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- (iii) Explain briefly how lepton conservation applies in **each** stage. [2]

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- (iv) u and d are the two flavours of first generation quarks.

- (I) Show clearly that there is a change in quark flavour in stage 1. [2]

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- (II) Explain in terms of the interactions involved why you would not expect a change in quark flavour in stage 2 or stage 3. [1]

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END OF PAPER

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GCE MARKING SCHEME

PHYSICS AS/Advanced

JANUARY 2014

INTRODUCTION

The marking schemes which follow were those used by WJEC for the January 2014 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

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	Page
PH1	1
PH2	6
PH3	10

PH2

Question				Marking details	Marks Available
1	(a)			0.40 [m]	1
	(b)			$v = \frac{0.050}{0.10}, \frac{0.450}{0.10}$ etc or $\left(\frac{1}{0.8}\right) \times 0.4$ or by implication (1)	2
				$v = 0.50, 4.5$ etc [m s ⁻¹] (1)	
	(c)			1.25 Hz UNIT MARK [ecf on v and λ and T]	1
	(d)			same	1
	(e)			B lags A (1)	
				by $\frac{1}{4}$ cycle / 90° / $\frac{\pi}{2}$ accept $\frac{T}{4}$ or $\frac{\lambda}{4}$ (1)	2
Question 1 total					[7]
2	(a)			Direction of wave [or energy] travel and direction of [particle] displacements [or oscillations] are the same [or parallel].	1
	(b)	(i)		diffraction	1
		(ii)		No zeros (or waves spread right round) so $\lambda \geq 0.3$ m (1) $\lambda = 0.9$ m for 375 Hz or $\lambda = 0.09$ m for 3 750 Hz or if $\lambda = 0.3$ m then $f = 1\,100$ Hz (1) 375 Hz more likely with some supporting argument, e.g. the above, or even just “Longer wavelengths [or lower frequencies] spread more.” (1)	3
	(c)			$\lambda = 140$ [mm] (1) Any 2 x (1): Interference occurs between [accept superposition of] waves travelling in opposite directions [accept waves from speaker and reflected waves] Board acts as reflector Stationary wave set up	3
Question 2 total					[8]

Question				Marking details	Marks Available
3	(a)	(i)		Same point in cycle at same time or equivalent	1
		(ii)		$S_2P - S_1P$ or equivalent. [Accept $S_1P - S_2P$]	1
		(iii)	(I)	Path difference = 36 mm (1) which is 3λ , so constructive. (1) Award 1 mark only for : $S_1Q = 28\lambda$, $S_2Q = 25\lambda$ therefore arrive in phase so constructive interference	2
			(II)	[Path difference doesn't change], so always constructive (1) but signal strength will decrease as we move further from sources. (1)	2
		(iv)		$y = \frac{12 \times 360}{36}$ even if units inhomogeneous (1) $y = 120$ mm UNIT (1)	2
	(b)			correct insertion of 12 [mm] and 30 [mm] into grating equation or by implication (1) 24° (1) 53° (1) award 1 mark if both angles wrong because of arithmetic error Either 0° or $\pm 24^\circ$ and $\pm 53^\circ$ or equivalent. (1)	4
Question 3 total					[12]
4	(a)	(i)		incident ray and angle c marked and grazing refracted ray	1
		(ii)		$n_1 \sin c = n_2 \sin 90^\circ$ (1) $\sin 90^\circ = 1$ or $n_1 \sin c = n_2$ (1)	2
	(b)	(i)		$\sin c = \frac{x}{s}$ and c marked on diagram (1) convincing algebra (1)	2
		(ii)		$v = 2.0 \times 10^8 \text{ m s}^{-1}$ [or by implication] (1) $t = 6.00 \mu\text{s}$ [or $t = 4.00 \mu\text{s}$, in which case first mark not gained] (1)	2
		(iii)		time via zigzag = $6.00 \mu\text{s} \times \frac{1.500}{1.485}$ [= $6.06 \mu\text{s}$] or $\frac{1212}{2 \times 10^8}$ (1) [ecf on $t = 6.00 \mu\text{s}$ or by implication] $\Delta t = 0.06 \mu\text{s}$ [ecf on $6.00 \mu\text{s}$] (1)	2
		(iv)		$[\frac{1}{6.00 \times 10^{-6}}] = 17 \times 10^6 \text{ [s}^{-1}]$ [Accept $(18 \pm 2) \times 10^6$] (1) assumes negligible pulse duration [or assumes angles of incidence range from 0 to c or longest path is 1 212 m] (1)	2
	Question 4 Total				[11]

Question				Marking details	Marks Available
5	(a)	(i)		[minimum] energy needed to eject an electron from the metal [or surface or solid not atom]	1
		(ii)		6.9×10^{14} [Hz]	1
		(iii)		Photon energy not high enough [$<$ work function] (1) Electrons can't escape (1)	2
	(b)		$f = \frac{(E_{k_{\max}} + \phi)}{h}$ or correct transposition at any stage or by implic(1) $= 1.0 \times 10^{15}$ [Hz] (1)	2	
	(c)	(i)	3.2×10^{-19} [J] (1) This uses the higher energy [or the higher frequency] photons, or produces the higher energy electrons, or photons don't co-operate or equivalent (1)	2	
		(ii)	2.0 [V] ecf	1	
				Question 5 Total	[9]
6	(a)	(i)		$\lambda = \frac{hc}{\Delta E}$ or [$\lambda = \frac{c}{f}$ and $E = hf$] or $f = 2.8 \times 10^{14}$ [Hz] (1) $\lambda = 1.06 \times 10^{-6}$ [m] (1)	2
		(ii)		<i>up</i> arrow from L to U (1) Photon's energy given to atom or electron (1)	2
		(iii)	(I)	[Incident] photon causes electron to drop from U to L. (1) Incident photon must have energy $E_U - E_L$ or equivalent (1) Photon emitted so now 2 photons present; accept by implic from emitted photon in phase.(1)	3
		(II)	Need more electrons in U than L. <i>Accept</i> : need pop'n inversion (1) Electrons pumped to P and drop to U (1) Electrons drop from L to ground [helping to keep L depopulated].(1)	3	
	(b)		Any 2 x (1): monochromatic [or equivalent e.g. long wave-trains] photons in phase (don't accept waves in phase) light in phase (or wavefronts continuous) across width of beam	2	
					Question 6 Total

Question				Marking details	Mark Available
7	(a)	(i)		$\lambda_{\text{peak}} = 430 \text{ nm}$ [$\pm 10 \text{ nm}$] (1)	2
		(ii)		$T = 6700 \text{ [K]}$ ecf on λ_{peak} , provided it's not 1200 nm (1)	1
		(iii)		$T = 5400 \text{ [K]}$ [$\pm 250 \text{ K}$]	1
	(b)			bluer or whiter at maximum T or redder at minimum T	1
	(b)			$A = \frac{P}{\sigma T^4}$ (transposition at any stage) or by implication (1)	
				$A = \frac{1.46 \times 10^{30}}{5.76 \times 10^{-8} \times 6700^4} [= 1.3 \times 10^{22} \text{ m}^2]$ ecf on T (1)	4
				use of $A = 4\pi r^2$ or $A = \pi d^2$ (1)	
	(c)			$d = 6.4 \times 10^{10} \text{ [m]}$ ecf on T if value from (a)(i) used (1)	
				Slips of factors of 2 or 10 lose 1 mark each.	
	(c)			$\left(\frac{P_{\min}}{P_{\max}}\right) = \left(\frac{T_{\min}}{T_{\max}}\right)^4$ or $P_{\min} = 6.2 \times 10^{29} \text{ W}$ ecf (1)	
				$\frac{P_{\min}}{P_{\max}} = 0.42$ ecf or $P_{\max} - P_{\min} = 8.4 \times 10^{29} \text{ W}$ ecf (1)	3
				$\left(\frac{P_{\max} - P_{\min}}{P_{\max}}\right) = 0.58$ [accept] = 58% (1)	
	Question 7 Total				[11]
8	(a)			+2, 0 (1)	3
				$\bar{u}d$, -1, 0 (1)	
				[blank], 0, 1 [Accept 'none' instead of cell left blank.] (1)	
	(b)	(i)		Sun or stars	1
		(ii)		e-m and γ or photon involvement	1
		(iii)		In stage 1: 0 + 0 goes to 0 - 1 + 1 [or equivalent] (1)	2
				In stages 2 and 3, zeros throughout or equivalent (1)	
	(iv)	(I)		$uud + u\bar{u}d$ goes to $uud + u\bar{d}d$ accept d: 2→3, u: 4→3 (1)	2
				A u is lost and a d is gained [or a u changes to a d]. (1)	
		(II)		Neither involves weak force or equivalent e.g. only strong [and em] force involved.	1
				Question 8 Total	[10]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

PHYSICS – PH2

Waves and Particles

A.M. WEDNESDAY, 5 June 2013

1½ hours

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	8	
2.	9	
3.	13	
4.	10	
5.	12	
6.	10	
7.	10	
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 or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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.

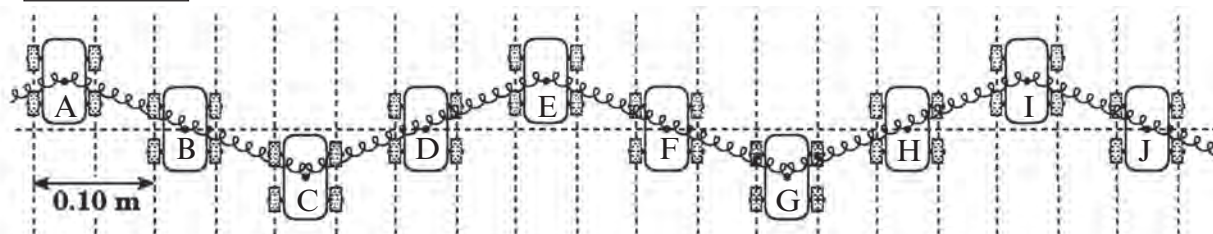
You are reminded of the necessity for good English and orderly presentation in your answers.

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

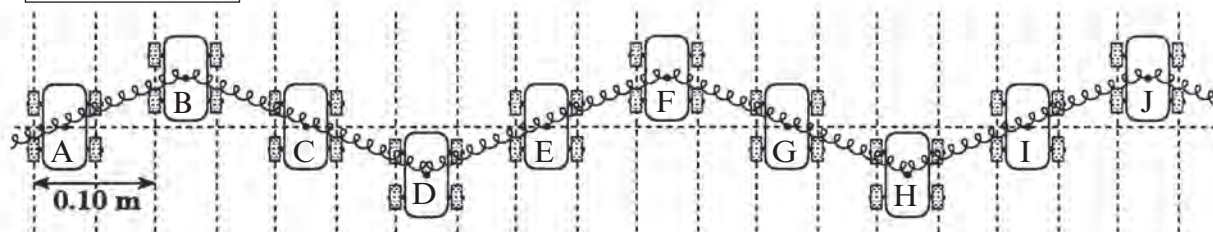
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1. Shown below are three 'snapshots' (three diagrams at different times) of a transverse wave travelling from left to right along a line of toy cars joined by springs.

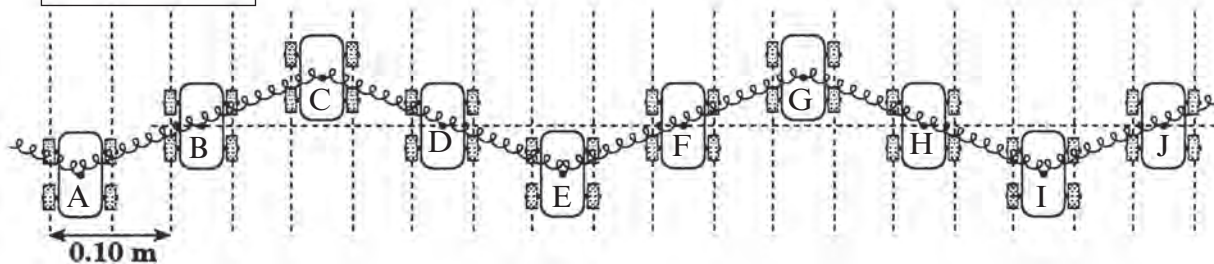
time $t = 0$



time $t = 0.050$ s



time $t = 0.100$ s



(a) Calculate

- (i) the wavelength,

[1]

- (ii) the periodic time (assuming no car changes its direction of motion between one snapshot and the next),

[1]

- (iii) the speed of the wave.

[2]

- (b) Which cars are oscillating in phase with car B?

[1]

- (c) (i) Explain why the wave is described as transverse.

[2]

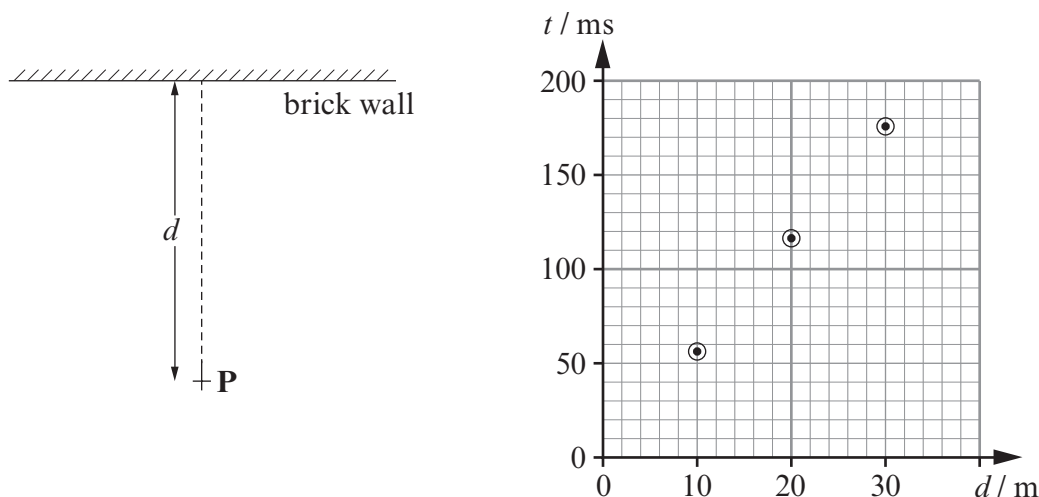
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- (ii) A *longitudinal* wave can be sent along a line of toy cars linked by springs if the cars are arranged differently. Make a sketch of the arrangement, showing **three** cars.

[1]

2. To determine the speed of sound, a student claps her hands at point **P**, which is a measured distance, d , from a brick wall. A microphone at **P** is connected to a timing device, arranged so as to record the time, t , between the original clap and its echo. The experiment is carried out for three distances d , and the results are plotted below.



- (a) Calculate a value for the speed of sound, showing your working. [2]

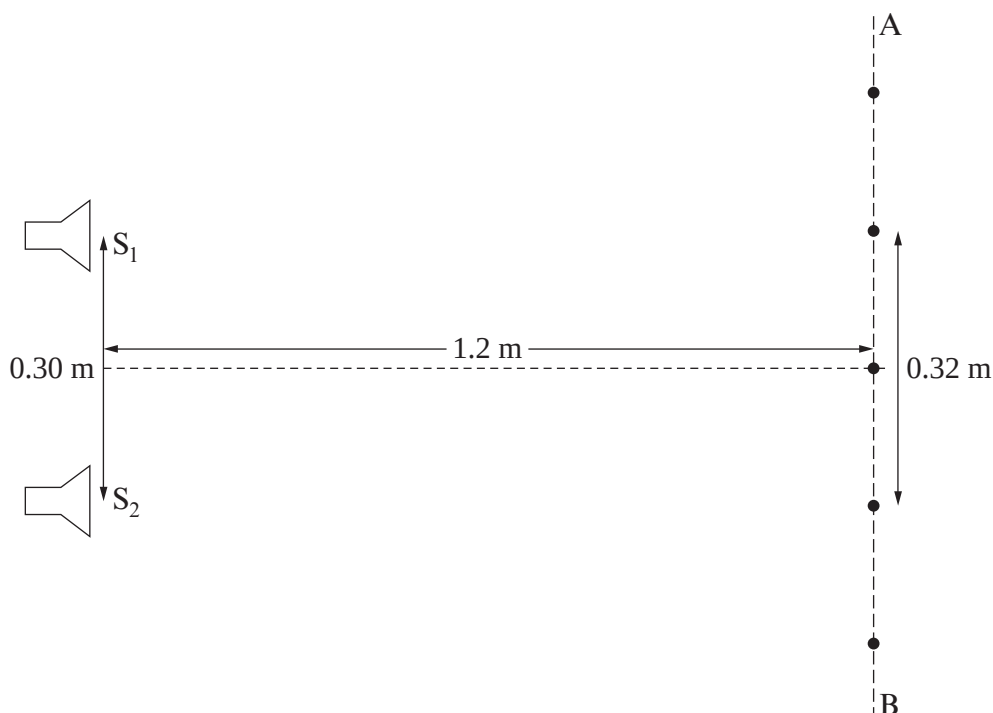
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- (b) In another experiment the student sets up two small loudspeakers, S_1 and S_2 , connected to the same signal generator, set to 8 300 Hz. She moves a microphone along the line AB, and finds maxima of sound at the positions shown by dots, with minima in between.



- (i) (I) Use the equation for Young's double slit experiment to calculate a value for the wavelength, λ . [2]

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- (II) Hence calculate a value for the speed of sound from this experiment. [1]

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- (ii) (I) **Label** with a letter 'M' the particular maximum (one of the dots on the diagram opposite) for which the path difference, $S_2M - S_1M = 2\lambda$. [1]

- (II) Explain why the condition, $S_2M - S_1M = 2\lambda$, gives a maximum at M. [1]

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- (iii) When the signal generator is set to 300 Hz the student does not find a succession of maxima and minima as the microphone is moved along the line AB. Explain why this is to be expected. [2]

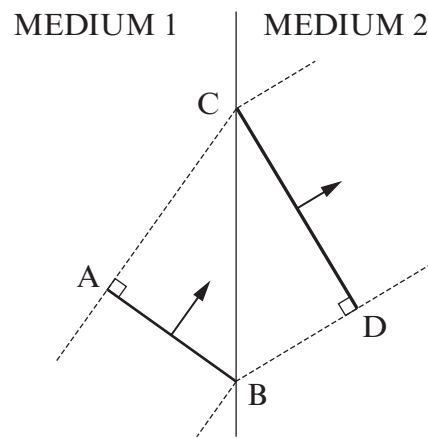
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3. (a) Explain, in terms of waves, why *refraction* occurs. Refer to the diagram below in your answer. [Mathematics is not needed.] [3]



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- (b) A laser beam is directed on to the end-face of a rod of clear plastic of refractive index 1.33, surrounded by air (refractive index 1.00).



- (i) Calculate the angle α .

[2]

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- (ii) At P, 90% of the light power is refracted out into the air, and 10% is reflected.

- (I) **Draw** carefully on the diagram above the paths of the light refracted and reflected at P. The reflected ray need extend no further than the bottom of the rod. [2]

- (II) Estimate how far the reflected light travels along the rod **from P** before the power drops to a millionth of the power of the beam incident on P. [Consider successive reflections.] [3]

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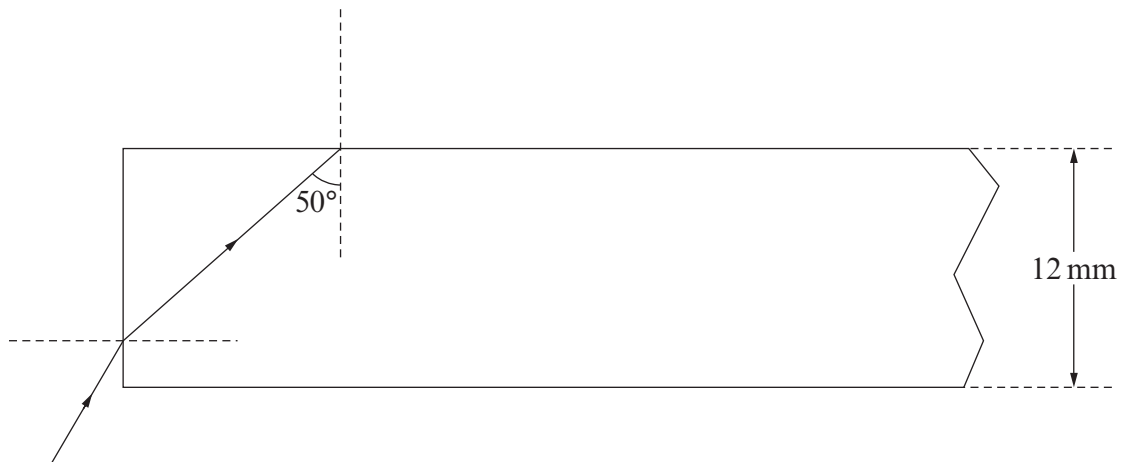
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- (c) The angle of the laser beam is changed as shown.



- (i) By first calculating the critical angle, explain why the laser beam now travels along the rod with no loss of power at reflections. [2]

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- (ii) Give the full name of the type of reflection occurring. [1]

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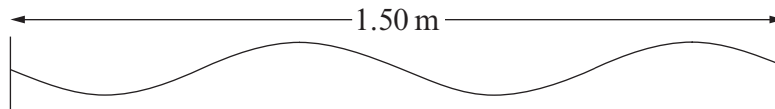
4. (a) Explain how a stationary wave can be regarded as being formed from progressive waves. [2]

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- (b) A string, fixed at both ends, vibrates in a stationary wave pattern. The diagram shows the string at a time of maximum displacement.



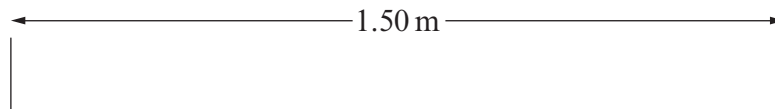
- (i) On the same diagram, **draw** the string
- (I) a quarter of a cycle later [label the drawing 'I'], [1]
- (II) half of a cycle later [label the drawing 'II']. [1]
- (ii) The speed, v , of the progressive waves on the string is 96 ms^{-1} . Calculate the frequency of the stationary wave. [2]

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- (c) (i) Sketch the string at its maximum displacement when it is vibrating in a stationary wave with a single antinode. [1]



- (ii) Calculate the frequency of vibration. [2]

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- (d) Write down an equation which gives the frequency of a stationary wave on this string when it is vibrating with a total of n antinodes. [1]

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5. (a) (i) The threshold frequency for electrons to be emitted in the photoelectric effect is $f_0 = \frac{\phi}{h}$. Explain, in terms of energy, why this is so. [3]

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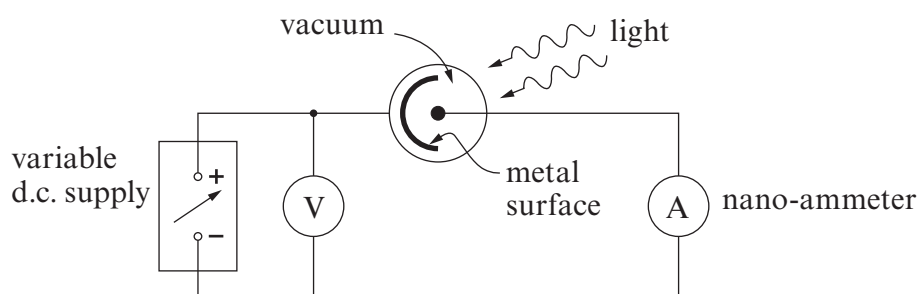
- (ii) Explain why increasing the *intensity* of light will not increase the maximum kinetic energy, $E_{k \text{ max}}$, of the emitted electrons. [2]

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- (b) Monochromatic light is shone on to a metal surface in a photocell connected as shown. Describe how you would find the maximum kinetic energy of the emitted electrons. [3]



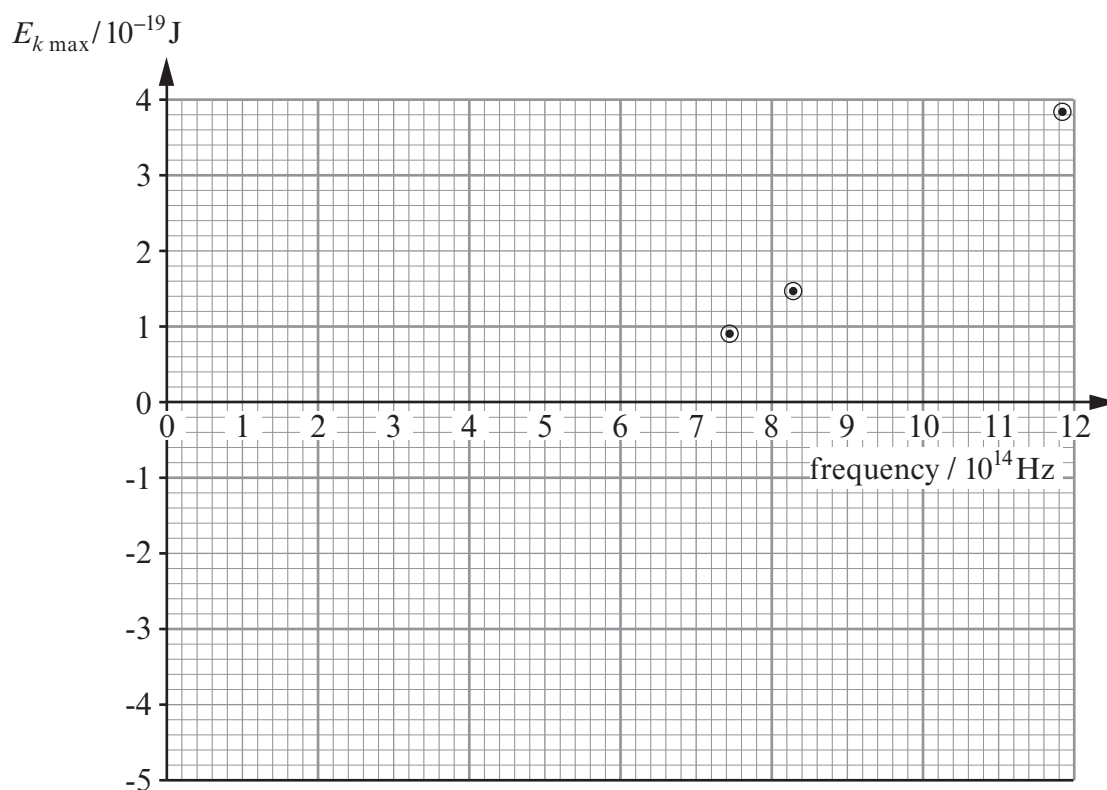
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- (c) The experiment is carried out, using three known frequencies of light in succession, giving the points plotted on the grid.



- (i) Calculate the gradient of the graph and check whether or not it has the expected value, giving your working and conclusion clearly. [2]

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- (ii) The metal with the exposed surface in the photocell is known to be one of the five metals whose work functions are listed.

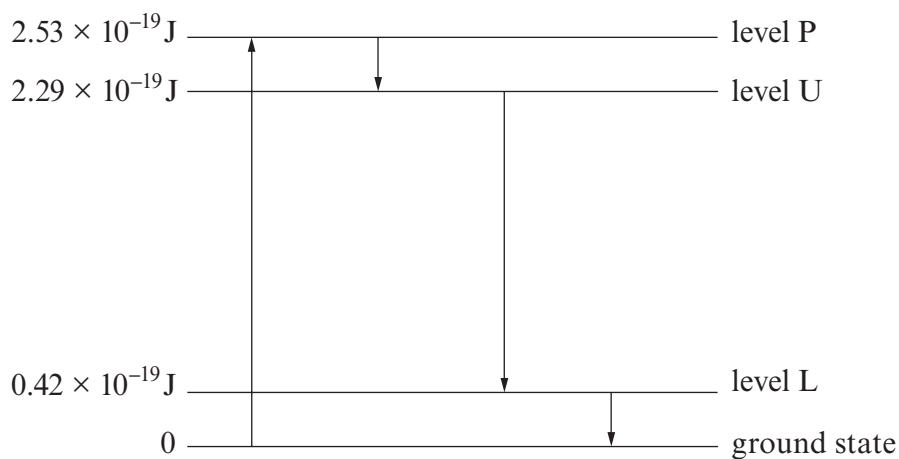
metal	caesium	potassium	sodium	barium	calcium
$\phi / 10^{-19}$ J	3.12	3.68	3.78	4.03	4.59

Use the graph to determine which of these metals is in the photocell, giving your reasoning. [2]

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6. A simplified energy level diagram is given for the amplifying medium of a 4-level laser. The useful output of the laser is due to the 'lasing' transition between level U and level L. The laser is *pumped* using photons from an external source.



(a) Calculate the wavelength of

- (i) the radiation emitted in the lasing transition,

[3]

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- (ii) the radiation needed for pumping.

[1]

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(b) Pumping is needed to produce a population inversion.

- (i) State what is meant by a *population inversion* for this system.

[1]

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- (ii) Explain carefully why a population inversion is needed for light amplification to take place. [3]

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- (iii) In a *three* level laser system, level L would be the ground state. Explain why it is an advantage for level L to be *above* the ground state. [2]

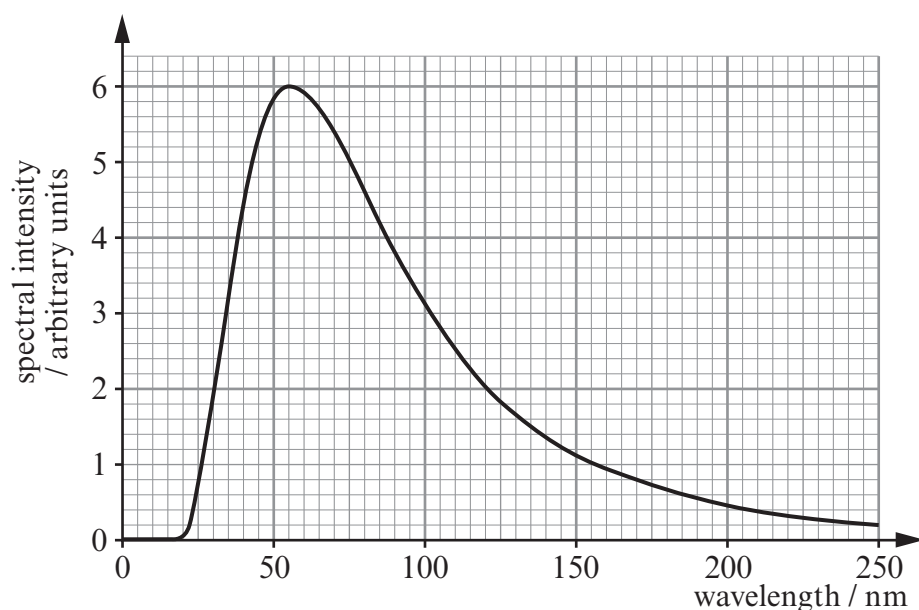
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7. One of the hottest stars known is HD93129A in the Carina nebula. Its continuous spectrum is shown.



- (a) (i) Name the region of the electromagnetic spectrum in which the wavelength of peak emission lies. [1]

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- (ii) Show that the star's temperature is approximately 50 000 K. [2]

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- (iii) The star is blue. Explain how this could be deduced from the spectrum. [1]

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- (b) (i) The star is $7.10 \times 10^{19} \text{ m}$ away, and the intensity of its electromagnetic radiation reaching the Earth is $3.33 \times 10^{-8} \text{ W m}^{-2}$. Show that its luminosity is approximately $5 \times 10^6 P_{\text{sun}}$, in which P_{sun} is the Sun's luminosity ($3.84 \times 10^{26} \text{ W}$). [3]

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- (ii) Use Stefan's law to calculate the star's **diameter**. [3]

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TURN OVER FOR QUESTION 8

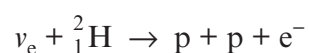
8. (a) Discuss why neutrinos and antineutrinos are difficult to detect. [2]

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- (b) In a special laboratory in Canada neutrinos from the Sun are detected by looking for electrons released in the interaction



The ${}^2_1\text{H}$ is a deuterium nucleus.

- (i) A proton (p) is a baryon. State what is meant by a baryon. [1]

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- (ii) Explain how *lepton number* and *charge* are conserved in this interaction. [2]

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- (iii) The quarks in ${}^2_1\text{H}$ and p occur in two ‘flavours’, u and d. Determine whether any quark *changes* its flavour in the interaction above. [2]

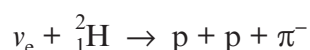
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- (iv) Explain why the interaction below is considered to be impossible. [1]



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END OF PAPER



GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2013

INTRODUCTION

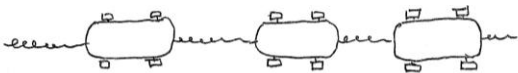
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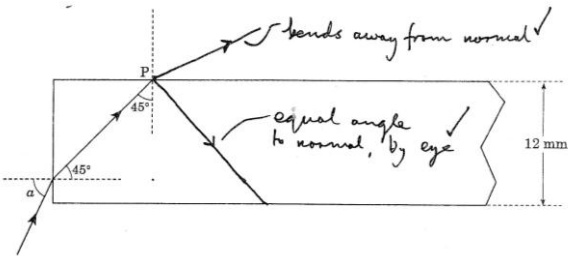
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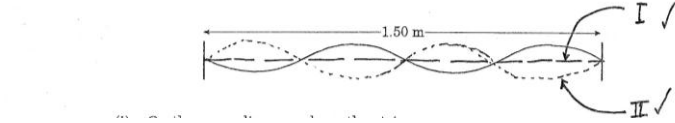
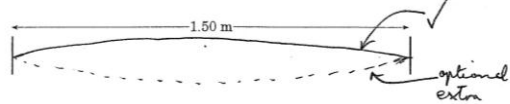
	Page
PH1	1
PH2	5
PH4	10
PH5	17

GCE Physics - PH2

Question 1			Marking details	Marks Available
1.	(a)	(i)	0.40 [m]	[1]
		(ii)	0.20 [s]	[1]
		(iii)	$f = 5.0$ [Hz] (1) or $v = \frac{\lambda}{T}$ or by implication $v = 2.0$ [m s ⁻¹] (1) ecf on T and λ F and J	[2] [1]
	(b)	(i)	Direction of oscillations or trolley motion (accept particle vibration or wave oscillations) and direction of [wave] travel (1) are at right angles. (1)	[2]
	(c)	(ii)		[1]
	Question 1 total			[8]

Question 2			Marking details	Marks Available
2.	(a)		Use of $v = \frac{d}{t}$ even if factor of 2 is omitted, or powers of 10 adrift (but not both these faults). (1)	
			$v = 340 \pm 10$ m s ⁻¹ UNIT (1) Answer must be seen to be derived. No marks for gradient attempt.	[2]
	(b)	(i) I	$\lambda = \frac{0.30 \times 0.16}{1.2}$ [m] (1) or by implication $\lambda = 0.040$ [m] (1) [0.080 m, arising from $y = 0.32$ m, loses 1 mark]	[2]
		II	$v = 332$ [m s ⁻¹] ecf	[1]
		(ii) I	Dot nearest A should be marked 'M'.	[1]
		II	Waves [from S_1 and S_2] arrive in phase at M Accept constructive interference <u>and</u> whole number of wavelengths path difference.	[1]
	(iii)		$\lambda = 1.1$ [m] or $\lambda > a$ or $\lambda > 0.3$ [m] or $\lambda > S_1 S_2$ (1) Maximum path difference possible [for waves from S_1 and S_2] is [the slit separation, which is only] 0.30 m or path difference can never be large enough (1) Or [Young's fringes equation gives] 'first' maximum at 4.4 m from central dot. Accept fringes too far apart.	[2]
			Question 2 total	[9]

Question 3			Marking details	Marks Available
3.	(a)		Award 3 x (1) of: • Refraction is change in direction of travel as waves change medium / air to glass (or equivalent). • AB, CD are wavefronts (or peaks or crests). • AB goes to CD. • Waves travel more <u>slowly</u> in 2 than in 1. • Hence $BD < AC$ Accept wavelength less in medium 2. • Direction of travel of waves is normal to wavefronts.	[3]
	(b)	(i)	$[1.00] \sin \alpha = 1.33 \sin 45^\circ$ (1) or equivalent or by implication	[2]
		(ii)	I	
			 No need for arrow heads. No penalty if reflected ray doesn't reach the bottom of the fibre.	[2]
	(c)	(ii)	II	
			6 reflections needed [including that at P] (1) Light travels 12 mm parallel to rod axis between successive reflections. (1) or by implication Light has to travel 60 [mm] beyond P (1) Accept 72 [mm] Award 2 marks for $17 \text{ mm} \times 5 = 85 \text{ [mm]}$ Award 1 mark for $17 \text{ mm} \times 6 = 102 \text{ [mm]}$	[3]
		(i)	$c = 49^\circ$ (1) $50^\circ > 49^\circ$ or $50^\circ > c$ AND so refraction not possible / TIR / no power loss (1)	[2]
		(ii)	Total internal reflection	[1]
Question 3 Total				[13]

Question 4			Marking details	Marks Available
4.	(a)		Interference between or superposition of or sum of two [progressive] waves [of equal amplitude and frequency] (1) Travelling in opposite directions or reflect (1)	[2]
	(b)	(i) I II		[2]
		(ii)	$\lambda = 0.75 \text{ [m]}$ (1) or by implication $f = 128 \text{ Hz}$ UNIT (1)	[2]
	(c)	(i)		[1]
		(ii)	$\lambda = 3.00 \text{ [m]}$ or by implication ecf provided λ consistent with diagram (1) $f = 32 \text{ [Hz]}$ (1) ecf	[2]
	(d)		32 n [Hz] or equivalent	[1]
			Question 4 Total	[10]

Question 5			Marking details	Marks Available
5.	(a)	(i)	ϕ is [minimum] energy needed to release an electron <u>from surface</u> [or <u>from metal</u> or <u>from material</u>]. (1) No marks for giving meaning of f_0 . So [minimum] <i>photon</i> energy needed is ϕ . (1) So $hf_0 = \phi$ or $E_{\text{photon}} = hf$ (1)	[3]
		(ii)	Award 2 x (1) of: • More photons per second • Individual photon energies unchanged • $E_{k\text{max}}$ depends on energy of individual photon or $E_{k\text{max}} = hf - \phi$ does not include intensity. Accept: Photons don't co-operate [in releasing electrons].	[2]
	(b)		Increase / adjust pd until nano-ammeter shows zero current [or equiv.] (1) Read voltmeter (1) or by implication $E_{k\text{max}} = eV$ (1)	[3]
	(c)	(i)	Gradient = $6.7 [\pm 0.2] \times 10^{-34} \text{ [J s]}$ (1) Mention of Planck's constant and sensible comparison (1)	[2]
		(ii)	$\phi = 4.1 [\pm 0.2] \times 10^{-19} \text{ [J]}$ (1) barium but only award mark if some reasoning given e.g. correct reference to intercept (1)	[2]
			Question 5 Total	[12]

Question 6			Marking details	Marks Available
6.	(a)	(i)	$\Delta E = 1.87 \times 10^{-19} \text{ [J]}$ (1) $\lambda = \frac{hc}{\Delta E}$ (1) or equivalent, including $\lambda = \frac{c}{f}$ and $f = \frac{c}{\lambda}$. $\lambda = 1.06 \times 10^{-6} \text{ m}$ (1) ecf on arithmetical slip in ΔE .	[3]
		(ii)	$\lambda = 7.9 \times 10^{-7} \text{ [m]}$	[1]
	(b)	(i)	More electrons [accept atoms, ions] in <u>U than in L</u>	[1]
		(ii)	PI ensures stimulated emission (1) more likely [frequent] than absorption [for photons of energy $1.87 \times 10^{-19} \text{ J}$] (1) Stimulated emission needed for light amplification because in each stimulated emission event 2 photons out for 1 in or implied by “in phase”. (1)	[3]
		(iii)	Electrons drop from L [to ground state] leaving L depopulated. (1) Making it easier to have more electrons in U than L or making a PI easier to establish or needing less pumping. (1)	[2]
		Question 6 Total		

Question 7			Marking details	Marks Available
7.	(a)	(i)	Ultraviolet [or u-v]	[1]
		(ii)	$\lambda_{\text{peak int}} = \underline{55 \text{ nm}}$ and $T = \frac{W}{\lambda_{\text{peak int}}}$ or by implication (1) $T = 53\,000 \text{ K}$ (1) ecf on 50 or 60 nm	[2]
		(iii)	In tail of curve [or equivalent] greater intensity at smaller λ . Accept blue end of visible nearer peak than red end.	[1]
	(b)	(i)	$I = \frac{P}{4\pi r^2}$ (1) or equivalent so $P = 2.11 \times 10^{33} \text{ [W]}$ (1) or by implication So $P/P_{\text{sun}} = 5.49 \times 10^6$ or $5 \times 10^6 P_{\text{sun}} = 1.9 \times 10^{33} \text{ [W]}$ (1)	[3]
		(ii)	$A = \frac{P}{\sigma T^4}$ with A as subject ecf on P and T (1) or by implication $r = \sqrt{\frac{A}{4\pi}}$ (1) or $d = \sqrt{\frac{A}{\pi}}$ or by implication $d = 4.0 \times 10^{10} \text{ [m]}$ (1) [one mark lost for factor of 2 or 10^n adrift.]	[3]
		Question 7 Total		

Question 8			Marking details	Marks Available
8.	(a)	(i)	They interact by the <u>weak interaction</u> . (1) Interactions [very] infrequent compared with strong or e-m. (1) [or other correct and relevant comment e.g. no charge]	[2]
		(b)	(i) Combination of 3 quarks	[1]
		(ii)	Lepton no: $1 + 0 = 0 + 0 + 1$ (1) or equivalent Charge: $0 + e = e + e + (-e)$ (1) or equiv. e.g. $0+1 = 1+1-1$	[2]
		(iii)	For the 1 st mark either of these (u or d): - u: $[0+] 1 + 2 \rightarrow 2 + 2 [+0]$ or $3 \rightarrow 4$ - d: $[0+] 2 + 1 \rightarrow 1 + 1 [+0]$ or $3 \rightarrow 2$ For the 2 nd mark: the other (i.e. u or d) and remark that a d has changed to a u OR equivalent N.B. $uud + udd \rightarrow uud + uud$ is an alternative for the 1 st mark.	[2]
		(iv)	<u>Lepton</u> number not conserved.	[1]
			Question 8 Total	[8]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

PHYSICS – PH2

Waves and Particles

A.M. FRIDAY, 18 January 2013

1½ hours

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	12	
2.	13	
3.	13	
4.	11	
5.	11	
6.	11	
7.	9	
Total	80	

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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.

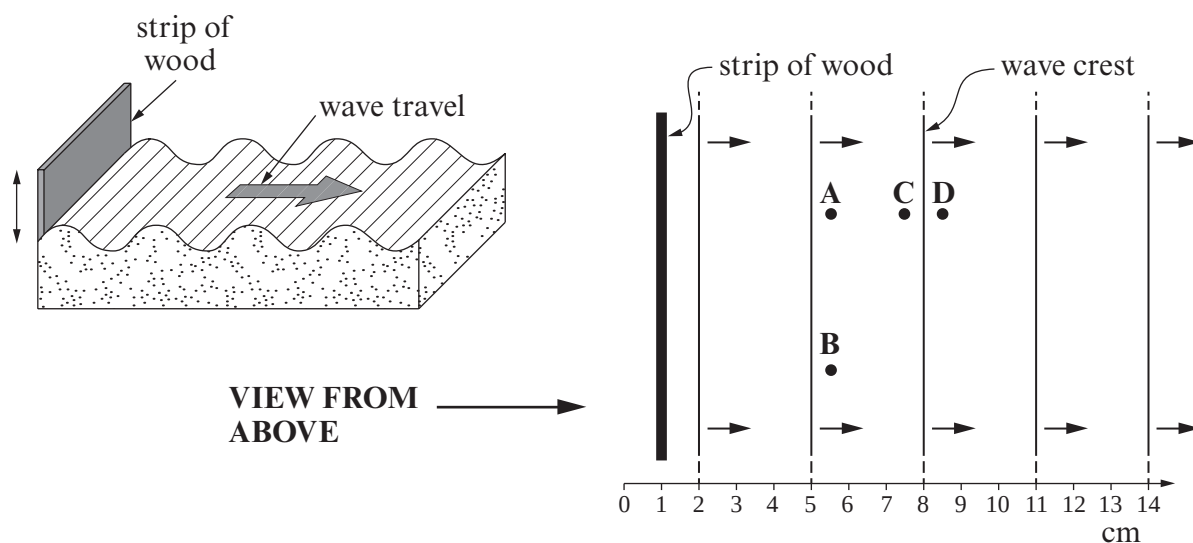
The number of marks is given in brackets at the end of each question or part-question.

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.

1322
010001

1. (a) A strip of wood, in contact with the surface of water in a tank, oscillates up and down at a frequency of 5.0 Hz. The view from above shows the positions of wave crests (where the water height is a maximum) at one instant.



- (i) Determine the wavelength of the wave. [1]
-
- (ii) Calculate the time it takes for a wave crest to travel a distance of 10.5 cm. [3]
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- (iii) State whether or not the oscillations at points **B**, **C** and **D** are *in phase* with the oscillations at **A**. Justify your answers. [3]

Point **B**

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Point **C**

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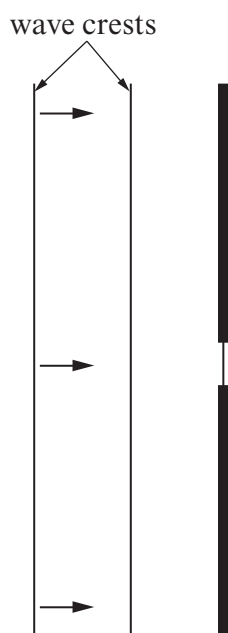
Point **D**

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(b) The waves of frequency 5.0 Hz approach a barrier with a gap in it (see diagram below). The waves that pass through the gap spread out.

(i) What name is given to the spreading of the waves? [1]

(ii) Carefully sketch the **two** wave crests to the right of, and nearest to, the gap. [2]



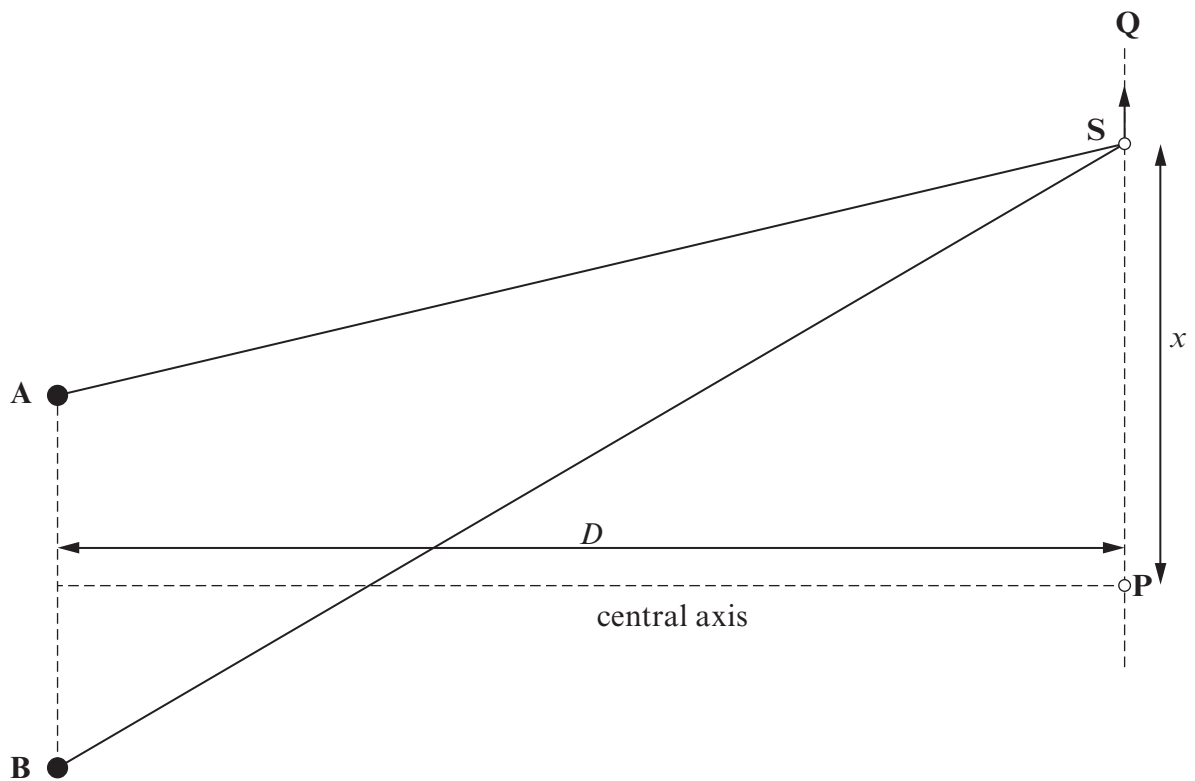
(iii) What changes would occur to the diagram above if the **frequency** of the wave were increased by a factor of 4? No calculations are needed. [2]

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2. (a) Two in-phase sources, **A** and **B**, emit microwaves.



As a microwave sensor, **S**, is moved from **P** towards **Q**, the intensity is found to vary, with the first three maxima when $x = 0$, when $x = 10.0$ cm and when $x = 22.0$ cm.

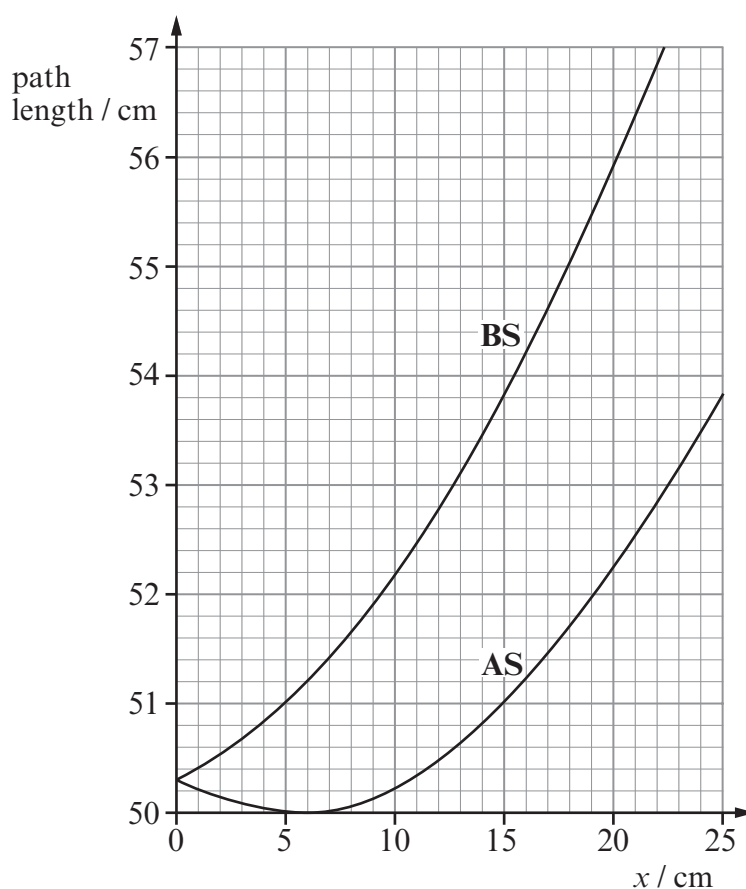
- (i) Explain why there is a maximum at point **P**.

[2]

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- (ii) The graphs show how the *path lengths*, **BS** and **AS** depend on the distance x of the sensor from **P**.



Use these graphs to determine the wavelength of the microwaves, showing your working. [2]

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- (iii) (I) The distance marked D on the diagram on the page opposite is 50.0 cm. The distance **AB** between the sources is 10.0 cm. Use the Young's fringes formula to obtain a value for the wavelength. [Make use of the distance from the central maximum at **P** to the next maximum.] [2]

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- (II) Give one reason, based on the set-up, or on the positions of the maxima, why it is not strictly appropriate to use the Young's fringes formula here. [1]

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- (b) A diffraction grating has 5.0×10^5 slits per metre. When a laser beam is shone normally at the grating, the third order beams emerge at angles of 72.3° to the normal.

- (i) Determine the wavelength of the light. [3]

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- (ii) Show that 7 (but no more than 7) beams of light emerge from the grating. [3]

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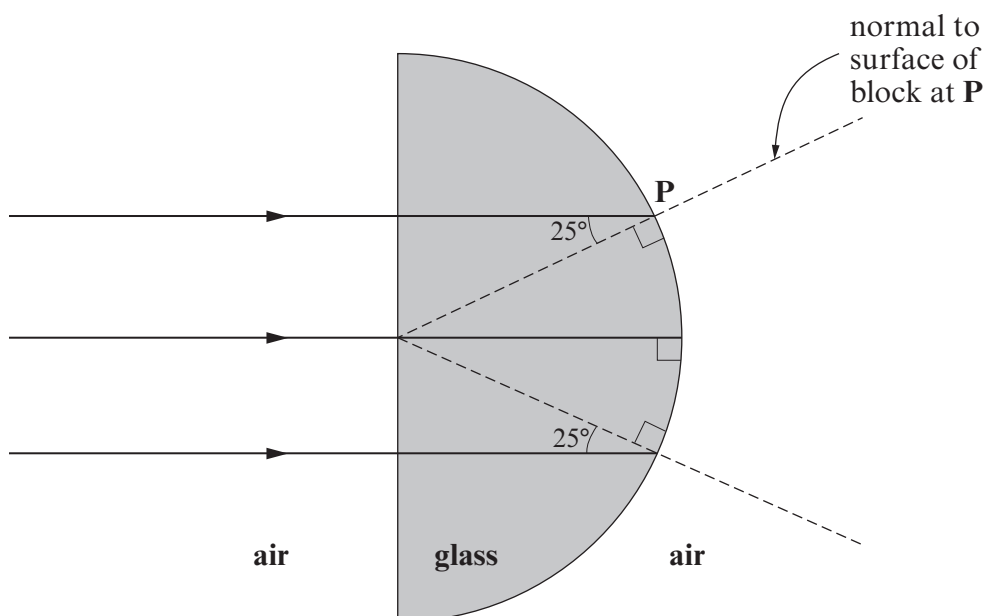
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3. (a) (i) The diagram shows three beams of light travelling through a glass block of semicircular cross-section and refractive index, n , of 1.58. The block is surrounded by air (refractive index 1.00).



- (I) **Sketch, on the diagram above, the paths** of all three beams when they emerge into the air from the curved surface of the block. [2]
- (II) Calculate the angle to the normal at which the top beam emerges into the air at P. [2]

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- (ii) (I) Show by calculation that a beam of light striking the curved surface at **Q** (see diagram alongside) will not re-enter the air at **Q**. [2]

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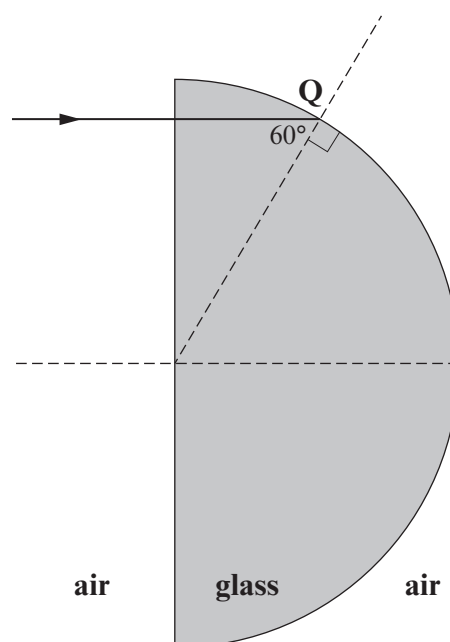
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- (II) **Continue** carefully on the diagram the path of the beam until it re-emerges into the air. [2]

- (b) (i) State how the core of a *monomode* optical fibre differs from that in a multimode fibre. [1]

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- (ii) How do the paths of light in monomode and multimode fibres differ? [1]

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- (iii) Explain the advantage of monomode fibres over multimode fibres for communicating a rapid sequence of data encoded as light pulses. [3]

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4. (a) Here is a summary of a theory (now considered incorrect) to account for the photoelectric effect:

“The electrons in a surface gradually gain energy from light waves falling on the surface. After a time they will have gained enough energy to escape. The greater the intensity of the light waves the greater the maximum kinetic energy of the emitted electrons.”

State some ways in which Einstein’s explanation (in terms of photons) of the photoelectric effect differs from the theory above. [4]

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- (b) The work function of sodium is $3.8 \times 10^{-19} \text{ J}$.

- (i) Calculate the maximum kinetic energy of electrons emitted from a sodium surface irradiated with ultraviolet radiation of frequency $8.7 \times 10^{14} \text{ Hz}$. [2]

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- (ii) Discuss whether or not this maximum kinetic energy would change if the surface were also irradiated **at the same time** with radiation of frequency $8.5 \times 10^{14} \text{ Hz}$. [2]

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- (iii) Determine whether or not visible light can cause the emission of electrons from a sodium surface, giving your reasoning and conclusion. Take the range of visible wavelengths to be 400 nm to 700 nm. [3]

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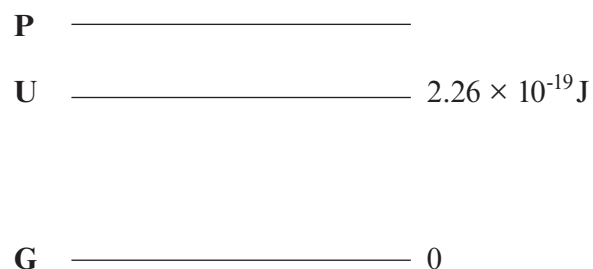
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5. A simplified diagram of the energy levels in a 3-level laser system is given alongside.



- (a) Calculate the wavelength of a photon associated with a transition between levels **U** and **G** (the ground state). [2]

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- (b) Explain in terms of electrons and photons what happens in the three possible processes listed below, in which photons are involved in transitions between levels **U** and **G** (or **G** and **U**). [Assume in each case that the levels are suitably populated.]

- (i) absorption [1]

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- (ii) stimulated emission [4]

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- (iii) spontaneous emission [1]

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- (c) (i) Explain what is meant by *pumping* in a laser.

[1]

Examiner
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- (ii) Explain why pumping is essential to the operation of the laser.

[2]

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6. (a) A table of astronomical data includes the following about the star *Alpha Centauri A*: Radius = 8.54×10^8 m, Temperature = 5790 K, Luminosity = 5.83×10^{26} W.

- (i) Investigate whether the data above is consistent with the star radiating as a black body. Show your working clearly, and give your conclusion. [3]

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- (ii) The star is 4.1×10^{16} m from the Earth. Calculate the intensity (energy per second per m^2) of electromagnetic radiation reaching the Earth from the star. [2]

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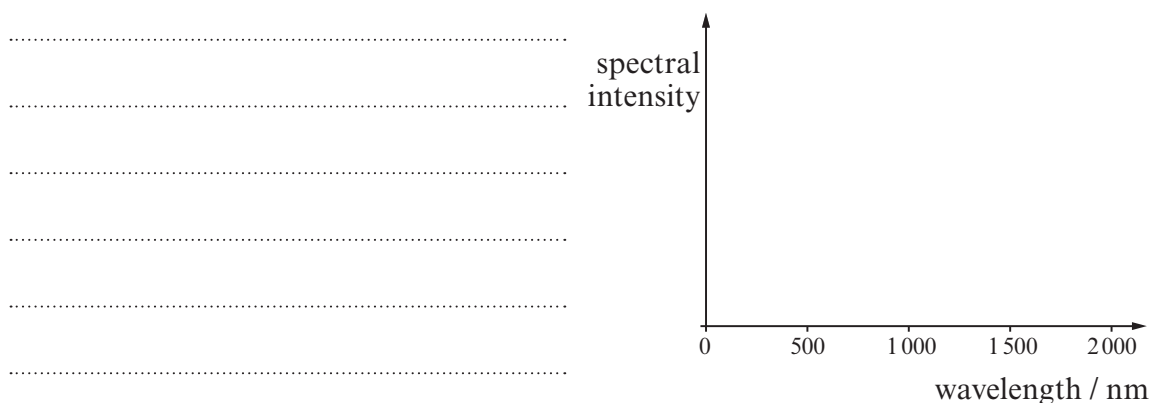
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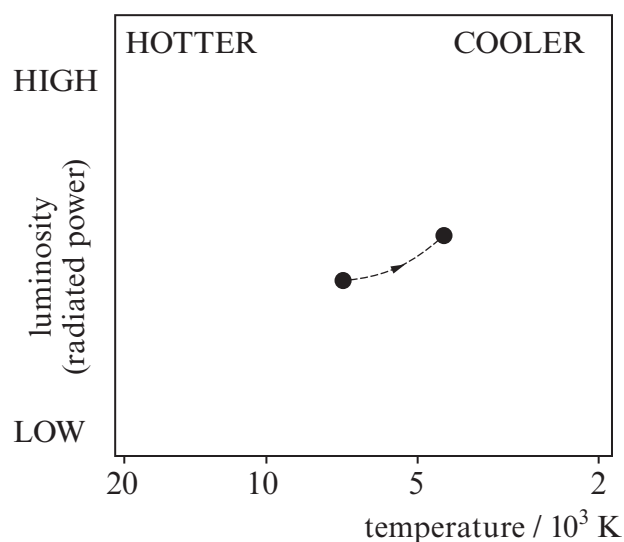
- (iii) Calculate the wavelength of the star's peak spectral intensity, and sketch the spectrum on the axes provided. [4]



- (b) Astronomers assign to each star a position on a chart, according to the star's luminosity and temperature.

During one stage in the life of *Alpha Centauri A*, its position on the chart will move as shown by the dotted line.

Use Stefan's law to show clearly what happens to the *size* of the star during this stage. [**Numerical calculations are not needed.**] [2]



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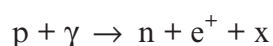
7. (a) A law of Physics is that the baryon number is always conserved.

[Baryon number = number of baryons – number of antibaryons.]

Name one antibaryon, giving its quark make-up.

[2]

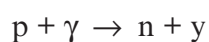
- (b) (i) A gamma ray photon of high enough energy can interact with a proton to produce a neutron and a particle x in the following interaction:



Identify x, giving your reasoning.

[2]

- (ii) Another possible interaction is:



Identify y, giving your reasoning.

[3]

- (iii) For each of the above interactions ((b)(i) and (b)(ii)) discuss whether the *weak force* is involved.

[2]

END OF PAPER

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GCE MARKING SCHEME

**PHYSICS
AS/Advanced**

JANUARY 2013

INTRODUCTION

The marking schemes which follow were those used by WJEC for the January 2013 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

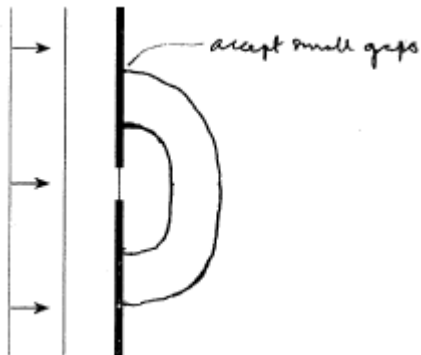
It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

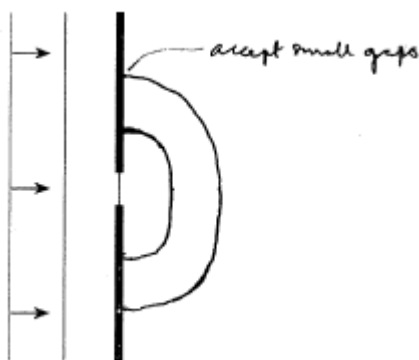
WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

Unit	Page
PH1	1
PH2	5
PH4	12

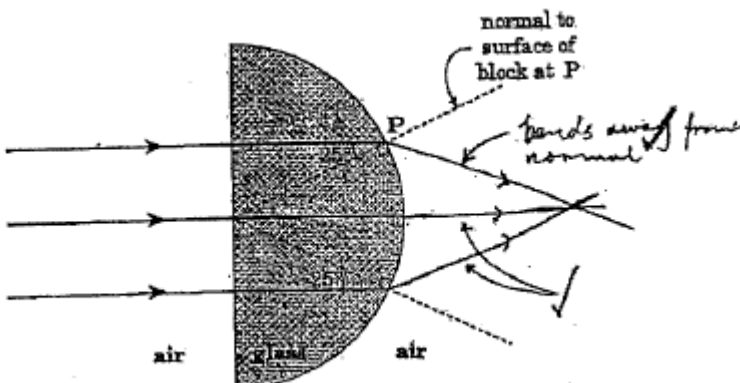
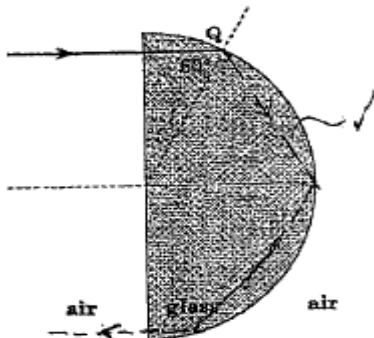
GCE Physics - PH2

Mark Scheme - January 2013

Question			Marking details	Marks Available
1	(a)	(i)	3.0 [cm] [accept 3 cm]	[1]
		(ii)	$v = 3.0 \times 5.0$ (1) [cm s ⁻¹] or by implication. Full ecf on λ $t = \frac{d}{v}$ applied (1) $t = 0.70$ s (ecf on λ) (1) OR $d = \frac{10.5}{3.0}$ (1) $T = 0.20$ [s] (1) $[t = 0.20 \times \frac{10.5}{3.0}] t = 0.70$ [s] (1)	[3]
		(iii)	B in phase, C not in phase (in antiphase not acceptable), D in phase - irrespective of explanations. (1) Correct answer and understandable explanation or 'in phase' explained, for one of B, C or D. (1) Correct answer and understandable explanation for another of B, C, or D. (1)	[3]
	(b)	(i)	Diffraction	[1]
		(ii)	Rounded and (almost) semicircular (Accept gaps of ≤ 3 mm) (1) λ constant (1) (within about 30%)	[2]
				
		(iii)	Any 2 x (1) from: λ decreased [No penalty for (say) 'halved'] - less spreading - side beams	[2]
	Question 1 total			[12]

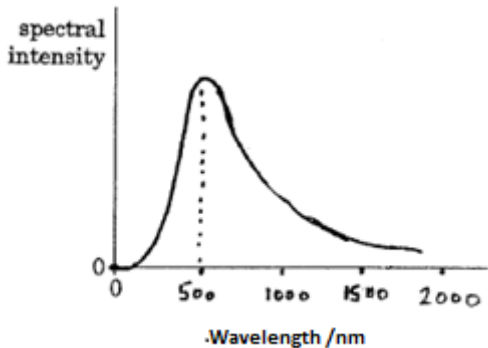


Question			Marking details	Marks Available
2	(a)	(i)	Constructive interference at P / waves arrive in phase at P (1) Same path length from sources / AP = BP / no path difference (1)	[2]
		(ii)	52.2 and 50.2 (1) $\lambda = 2.0$ [cm] (1) ecf on slips OR 56.8 and 52.8 (1) $\lambda = 2.0$ [cm] (1) ecf on slips	[2]
		(iii) (I)	$\lambda = \frac{10.0 \times 10.0}{50}$ (1) = 2.0 cm (1) UNIT OR $\lambda = \frac{10.0 \times 12.0}{50}$ (1) = 2.4 cm (1) UNIT	[2]
		(II)	AB or SP not very small compared with D OR maxima not evenly spaced	[1]
	(b)	(i)	$d = 2.0 \times 10^{-6}$ [m] (1) or by implication $3\lambda = d \sin 72.3^\circ$ (1) [d^* needs to be related to d , even 5.0×10^5 would do] $\lambda = 6.35 \times 10^{-7}$ [m] (1)	[3]
		(ii)	Up to 3 rd order visible, 1 + 3x2 beams seen OR diagram (1) $\frac{d}{\lambda} = 3.15$ (1) so only 3 orders (1) not a freestanding mark OR $\frac{4\lambda}{d} > 1$ (1) so only 3 orders (1) not a freestanding mark	[3]
			Question 2 total	[13]

Question			Marking details	Marks Available
3.	(a)	(i)	(I)  (II) $1.58 \sin 25^\circ = [1.00] \sin a$ (1) or equivalent or by implication $a = 42^\circ$ (1)	[2]
		(ii)	(I) Either $c = 39^\circ$ (1) $60^\circ > 39^\circ$ or equivalent (1) OR $1.58 \sin 60^\circ$ gives error (1) So refraction not possible or TIR [needs <i>attempt</i> to justify] (1) (II) TIR at Q and at least one more instance of TIR with subsequent ecf (1) As drawn with reflected ray at Q going off East of South, eventually emerging through diameter face, with at least one more TIR event. (1) 	[2]
	(b)	(i)	Thinner	[1]
		(ii)	Monomode: parallel to axis (accept straight) Multimode: zig-zag paths as well (1) or some paths involve reflections	[1]
		(iii)	Only one route for data (1) [no zig-zag routes] Each pulse [data element etc] arrives [at other end of fibre] at same time (1) No overlapping of pulses (1) [even over long distances]	[3]
Question 3 Total				[13]

Question			Marking details	Marks Available
4	(a)		Any 4 x (1) from: - light [energy] in discrete packets - one electron ejected by one photon OR photons don't co-operate - energy not accumulated [by electron] over time or emission from instant light shines - intensity has no effect on $E_{k\max}$ or accept intensity affects number emitted per second - wave theory doesn't predict Einstein's equation or doesn't predict threshold frequency	[4]
	(b)	(i)	$E_{k\max} = (6.63 \times 10^{-34} \times 8.7 \times 10^{14} - 3.8 \times 10^{-19})$ (1) $E_{k\max} = 1.97 \times 10^{-19}$ [J] (1)	[2]
		(ii)	These photons eject electrons with smaller $E_{k\max}$ (1) $E_{k\max}$ same as previously with some explanation given (1)	[2]
		(iii)	Correct use of $c = f\lambda$ (1) e.g. to give $\lambda_{\text{thresh}} = 523$ [nm] OR $f_{400 \text{ nm}} = 7.5 \times 10^{14}$ [Hz] OR $f_{700 \text{ nm}} = 4.3 \times 10^{14}$ [Hz] Comparison of 400 [nm] with λ_{thresh} (1) or 7.5×10^{14} [Hz] with f_{thresh} (5.73×10^{14} [Hz]) or substitution of 7.5×10^{14} [Hz] into Einstein's equation. Conclusion : It can (1) [if reasoned]	[3]
			Question 4 Total	[11]

Question			Marking details	Marks Available
5	(a)		$E = \frac{hc}{\lambda}$ (1) or equivalent e.g. $E = hf$ and $f = \frac{c}{\lambda}$ $\lambda = 880$ [nm] (1)	[2]
	(b)	(i)	Photon disappears and the electron gains its energy or electron promoted from G to U	[1]
		(ii)	1. [Passing] photon 2. Of energy 2.26×10^{-19} [J] or $\lambda = 880$ [nm] or equivalent 3. Causes electron to drop [from U to G] 4. Releasing additional photon 5. Identical to or in phase or polarised in the same direction or travelling in the same direction with the incident photon Award (1) mark for each of statements 1, 3 and 4 Award the 4 th mark for either statement 2 or 5.	[4]
		(iii)	Electron drops [from U to G] by itself (or randomly or without stimulation...), with emission of photon	[1]
	(c)	(i)	Raising electrons to higher level or causing population inversion	[1]
		(ii)	So more electrons in higher level than lower (1). So stimulated emission more probable than absorption (1).	[2]
			Question 5 Total	[11]

Question			Marking details	Marks Available
6	(a)	(i)	$A = 4\pi(8.54 \times 10^8 \text{ [m]})^2$ (1) $[9.16 \times 10^{18} \text{ [m}^2\text{]}]$ $P = 5.67 \times 10^{-8} \times \text{area attempt} \times 5790^4$ (1) [W] $P = 5.84 \times 10^{26} \text{ [W]}$ and consistency ecf on slips (1) [One mark to be lost for slips e.g. powers of 10, factors of 2, 4, π] Or alternative solution using Stefan's law is acceptable.	[3]
		(ii)	$I = \frac{\text{power}}{4\pi(4.1 \times 10^{16})^2}$ (1) $I = 2.76 \times 10^{-8} \text{ Wm}^{-2}$ UNIT (1) [penalty of 1 mark for slips of 10^n , 4, π etc no penalty if same slip as in (i)]	[2]
		(iii)	$\lambda_{\text{pmax}} = \frac{2.9 \times 10^{-3}}{5790}$ (1) $= 5.01 \times 10^{-7} \text{ [m]}$ (1) GRAPH - Goes through origin and doesn't hit the axis (1) Peak at $\sim 500 \text{ nm}$ (Apply ecf) (1) 	[4]
	(b)		P goes up and T goes down and then A goes up (1) Because $A = \frac{P}{\sigma T^4}$ or any convincing explanation (1)	[2]
Question 6 Total				[11]

Question			Marking details	Marks Available
7	(a)		Name (1) [e.g. antiproton, antineutron] Quarks (1) [e.g. $\bar{u}\bar{u}\bar{d}$, $\bar{u}\bar{d}\bar{d}$]	[2]
	(b)	(i)	Must be neutral or lepton number conserved (1) ν_e by considering charge and lepton number (1)	[2]
		(ii)	1 st mark : π^+ (1) Either 2 x (1) from: - y can't be a lepton [violates lepton conservation] - y must be positive - y can't be a baryon OR y must have u quark number [2-1] = 1 (1) and d quark number [1-2] = -1 (1)	[3]
		(iii)	In (i) Yes – quark flavour changes or neutrino (1) In (ii) No – quark flavours conserved (1) [accept no neutrino]	[2]
			Question 7 Total	[9]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

**PHYSICS
ASSESSMENT UNIT PH2:
WAVES AND PARTICLES**

P.M. FRIDAY, 25 May 2012

1½ hours

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	8	
2.	6	
3.	8	
4.	8	
5.	8	
6.	11	
7.	13	
8.	10	
9.	8	
Total	80	

1322
010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

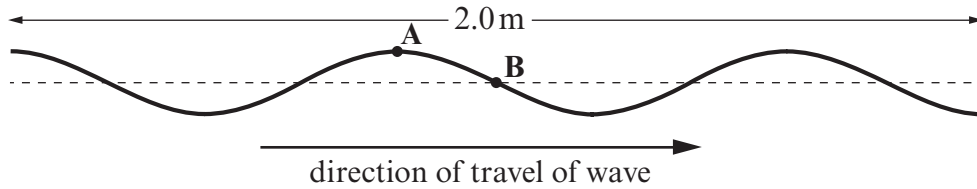
The total number of marks available for this paper is 80.

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.

1. (a) A water wave is travelling from left to right along a canal. The diagram shows the wave at one instant.



- (i) (I) Show that the wavelength of the wave is 0.80 m. [1]

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- (II) How do the *amplitudes* compare for water particles **A** and **B**? [1]

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- (ii) A graph of displacement, y (vertical component) against time is given alongside for water particle **A**.

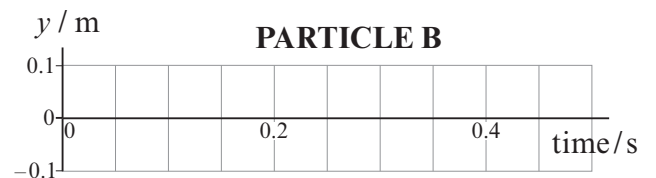
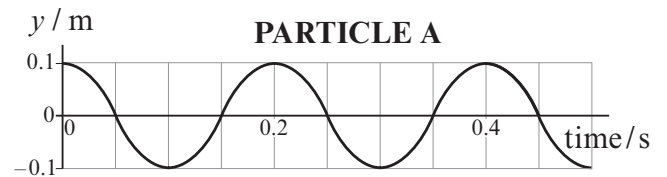
- (I) Calculate the *frequency*. [1]

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- (II) Sketch the corresponding graph for particle **B** on the axes given. [2]



- (iii) Calculate the *speed* of the wave. [1]

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- (b) When the wave in the first diagram has travelled further, it reaches a length of the canal where the water is shallower. The wavelength in the shallow water is 0.60 m.

Calculate the speed of the wave in the shallow water, **giving your reasoning**. [2]

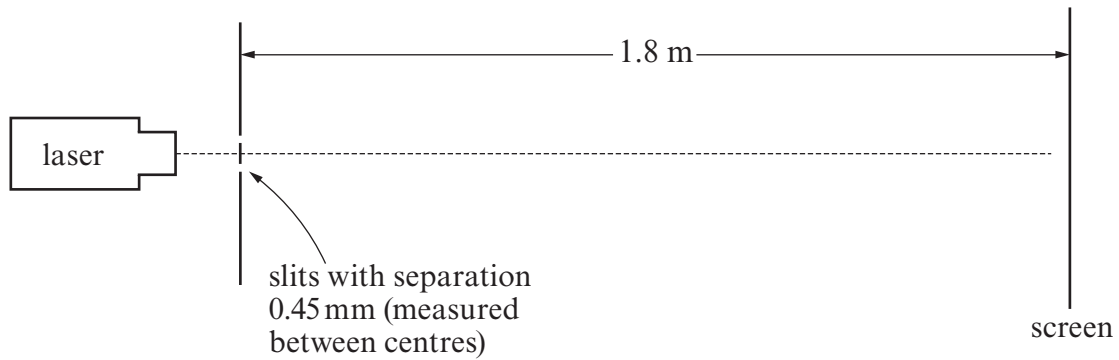
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2. The apparatus shown is set up to produce a clear display on the screen of Young's fringes.



- (a) The bright fringes result from constructive interference. Explain, in terms of *phase* and *path difference*, why there are bright fringes. You may add to the diagram above, or draw your own diagram(s) to assist your explanation. [2]

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- (b) (i) The centres of the bright fringes are measured to be 2.4 mm apart. Calculate the wavelength of the light from the laser. [2]

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- (ii) To obtain an accurate value of wavelength, it is better to use a diffraction grating than a double slit. Give **two** reasons for this. [2]

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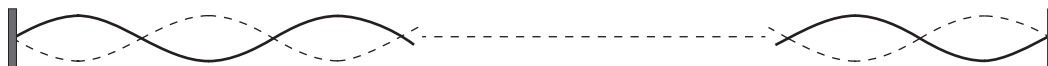
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3. The cavity of a laser has reflecting ends a distance L apart. Assuming there is a node at each end, the possible wavelengths of stationary waves are given by the equation

$$\lambda = \frac{2L}{n} \quad \text{in which } n \text{ is a whole number.}$$

- (a) Label relevant lengths on the diagram, and hence show how this equation arises. [The stationary wave is shown as if it were a stationary wave on a stretched string.] [2]



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- (b) For a particular semiconductor laser, $L = 0.2050$ mm.

- (i) Using the equation above, show that a stationary wave of wavelength 820.0 nm can exist in the cavity, but that a stationary wave of wavelength 821.0 nm cannot. [2]

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- (ii) Find the next wavelength above 820.0 nm of stationary wave that could exist in the cavity. [2]

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- (c) A stationary wave is equivalent to a superposition of progressive waves of equal amplitude travelling in opposite directions. Why is this condition not exactly met in a laser emitting a beam of light? [2]

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4. (a) A rod made of clear plastic of refractive index 1.55 is shaped as shown. The surrounding air has refractive index 1.00.

- (i) Calculate the critical angle for light approaching a boundary between the plastic and the air. [2]

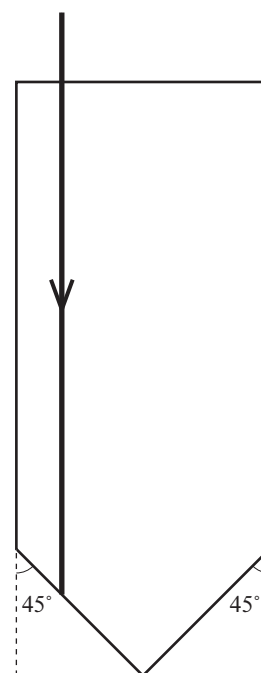
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- (ii) Hence complete the path of the beam in the diagram, showing its emergence into the air. [2]



- (b) The bottom of the rod now dips into water, of refractive index 1.33.

- (i) Calculate the angle of refraction of the beam into the water at **P**. [2]

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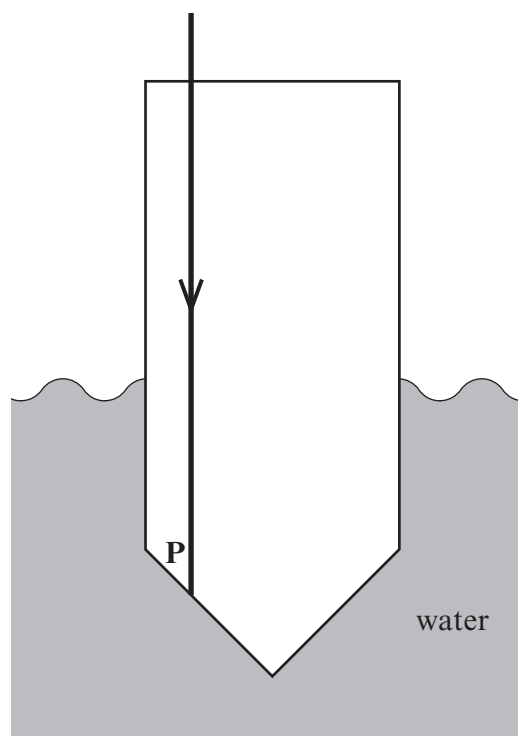
- (ii) Sketch the refracted beam on the diagram. [1]

- (iii) Suggest how this plastic rod might be used as part of a device to give a warning when the water level in a tank falls below a certain height. [1]

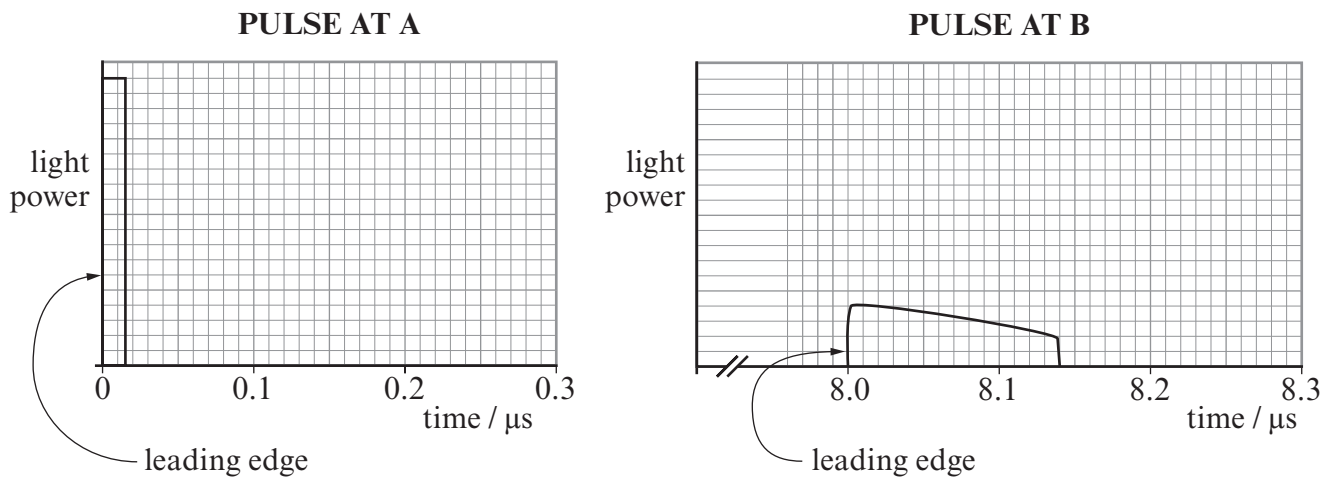
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5. (a) Pulses of monochromatic light are sent from **A** to **B** through a multimode optical fibre. The graphs show the pulse at **A** and when it arrives at **B**.



- (i) By considering the leading edge (the start) of the pulse, calculate the distance from **A** to **B** along the axis of the fibre. The refractive index of the fibre's core is 1.50. [3]

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- (ii) Explain why the pulse is spread out over time when it arrives at **B**. A sketched diagram may help your explanation. [2]

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(b) Suppose a second pulse is sent from **A** to **B**.

- (i) State the minimum time interval $t_{\min}$, between the leading edges of the first and second pulses at **A**, for them to arrive at **B** without overlapping. [1]
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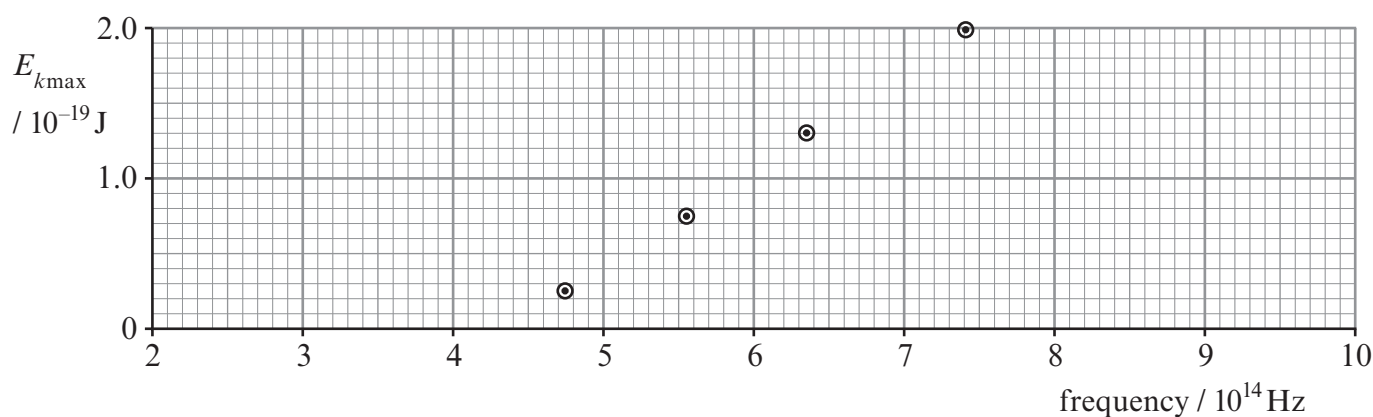
- (ii) Show the second pulse on both graphs opposite, if the time interval between pulses at **A** is $t_{\min}$. [2]

6. (a) State, **in terms of energy**, the meaning of each term in Einstein's photoelectric equation

$$E_{k\max} = hf - \phi.$$

- (i) $E_{k\max}$ [1]
- (ii) hf [1]
- (iii) ϕ [1]

- (b) Monochromatic light of frequency 7.40×10^{14} Hz is shone on to a caesium surface, and $E_{k\max}$ is measured. The procedure is repeated for three other frequencies, enabling four points to be plotted on the grid below.



- (i) Showing your working, determine from the grid above

- (I) a value for the Planck constant, [2]

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- (II) the work function of caesium. [2]

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- (ii) When a lithium surface is used instead of a caesium surface, $E_{k\max}$ is found to be $0.40 \times 10^{-19} \text{ J}$ for light of frequency $7.40 \times 10^{14} \text{ Hz}$.

(I) Draw the expected line of $E_{k\max}$ against frequency on the same grid. [2]

(II) This line cannot be checked satisfactorily by experiment using visible light. Name the region of the electromagnetic spectrum which is required. [1]

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(III) What is different about lithium, as compared to caesium, which makes it necessary to use this region of the electromagnetic spectrum? [1]

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7. A simplified energy level diagram for the amplifying medium of a 3-level laser is given.

level P _____

level U _____ $2.10 \times 10^{-19} \text{ J}$

- (a) Suppose that the laser is at room temperature and that it is **not being pumped**.

level O _____ 0
(ground state)

- (i) Compare the (electron) populations of the three levels.

[1]

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- (ii) A photon of energy $2.10 \times 10^{-19} \text{ J}$ in the laser cavity could interact with the amplifying medium. Name the process involved, and explain briefly what happens.

[2]

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- (b) The laser is now pumped, to create a *population inversion* between levels U and O.

- (i) Explain what is meant by a population inversion.

[1]

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- (ii) Draw **two** arrows on the diagram to show how the population inversion is achieved.

[1]

- (iii) Explain in detail how light amplification takes place.

[4]

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- (iv) Calculate the wavelength of the radiation emitted.

[2]

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- (c) In a 4-level laser the light output results from a transition to a lower level which is above the ground state. Explain the advantage over a 3-level system. [2]

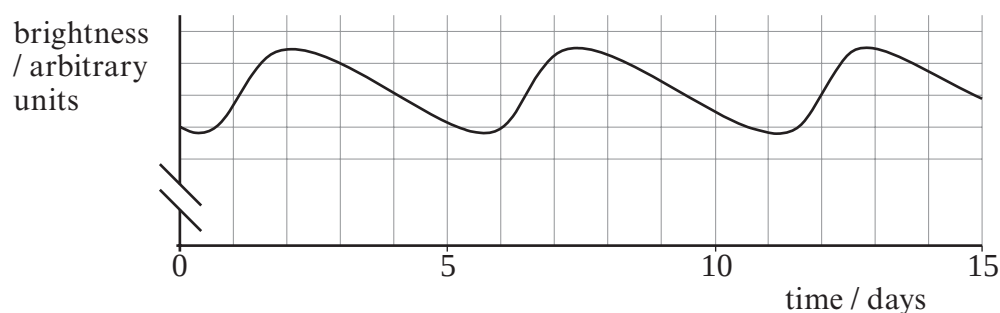
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8. *Cepheid variables* are stars whose brightness varies in a characteristic, regular way. The variation is shown below for one such star.



The mean power, P , emitted as electromagnetic radiation from a Cepheid variable is related to the period of its brightness variation, as shown alongside.

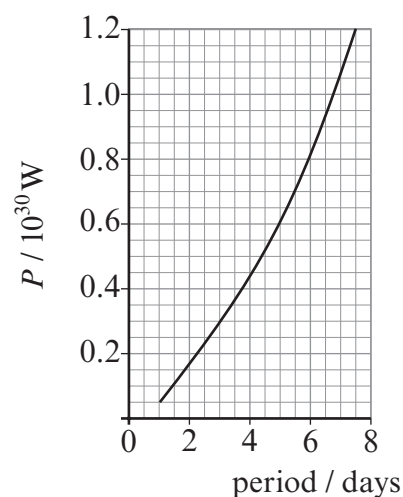
- (a) (i) Use the graphs to determine P for the star, showing briefly how you obtained your answer.

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[2]

- (ii) The mean *intensity* of the radiation from the star, as measured at the Earth is $8.0 \times 10^{-13} \text{ W m}^{-2}$. Using your answer to (a)(i), calculate the distance, r , between the star and the Earth.

[2]

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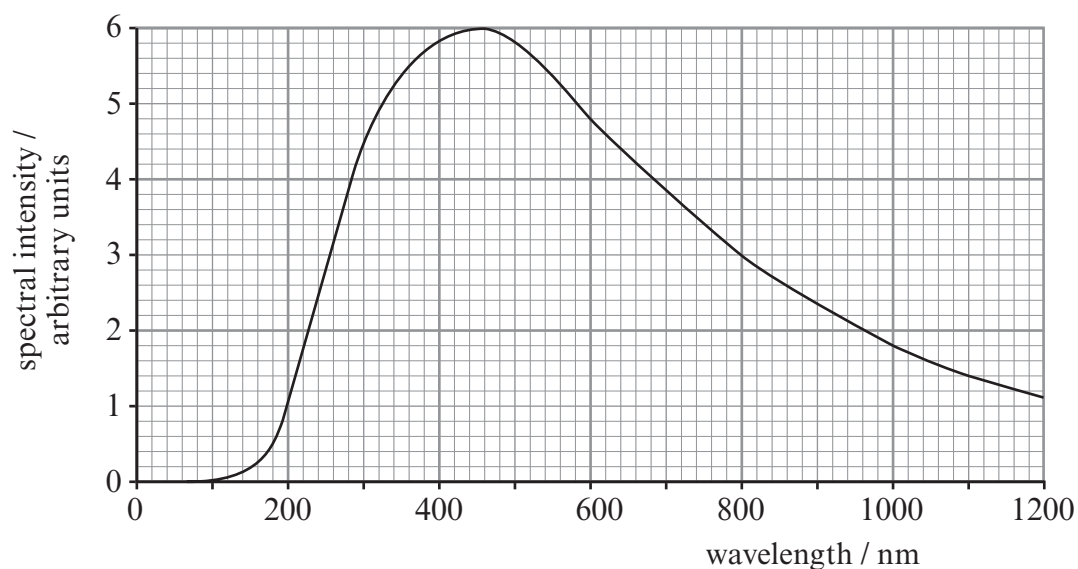
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- (b) The maximum power emitted by the star during its cycle of variation is estimated to be $9.5 \times 10^{29} \text{ W}$, and the spectrum of its radiation corresponding to this point in its cycle is given below.



- (i) Use Wien's law to calculate the temperature of the star. [2]

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- (ii) Calculate the **diameter** of the star. [4]

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9. (a) An electron and a positron can annihilate (destroy) each other, in this interaction:



- (i) Explain how *lepton number* is conserved in this interaction. [2]

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- (ii) State which force (strong, weak or electromagnetic) is involved in this interaction, giving a reason for your answer. [1]

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- (b) A proton and an antiproton can annihilate each other, in this **strong** interaction:



- By applying conservation rules, suggest the identity of particle x. [2]

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- (c) The π^{+} is unstable. It can decay, thus:



- (i) Identify y. [1]

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- (ii) Which force is involved? [1]

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- (d) Show below, as an equation, how the π^{-} might decay. [1]

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**THERE ARE NO MORE QUESTIONS
IN THE EXAMINATION.**



GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2012

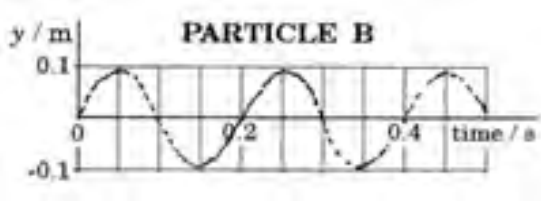
INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2012 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

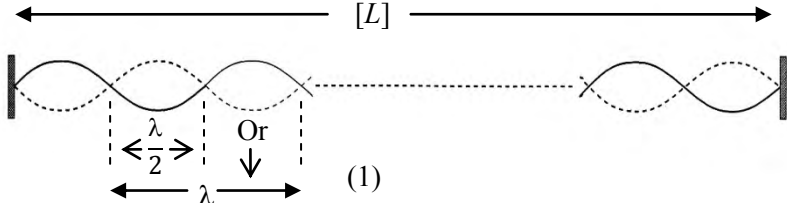
It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

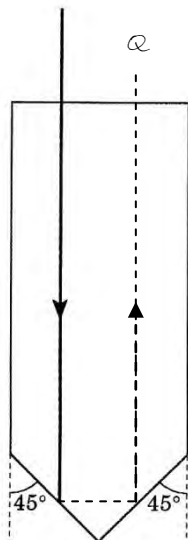
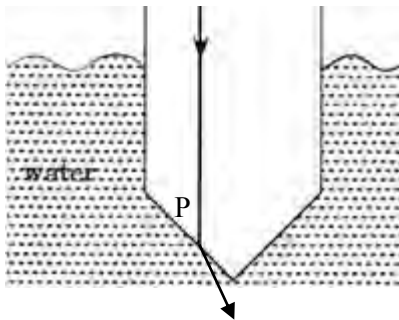
WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

PH2

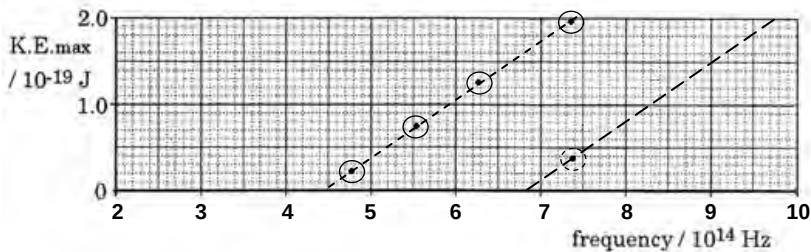
Question			Marking details	Marks Available
1	(a)	(i)	I. 2.0 [m] / 2.5 or <u>clear</u> equivalent	1
			II. The same	1
	(b)	(ii)	I. 5.0 Hz / s ⁻¹ UNIT	1
			II. 	
			Same f and A (1) Delayed by $\frac{1}{4}$ cycle (1)	2
		(iii)	4.0 [m s ⁻¹] ecf	1
			Statement that f doesn't change (1), or working based on this principle (e.g. $v = 5.0$ [Hz] x 0.60 [m]) $v = 3.0$ [m s ⁻¹] (1) ecf	2
			Question 1 total	[8]

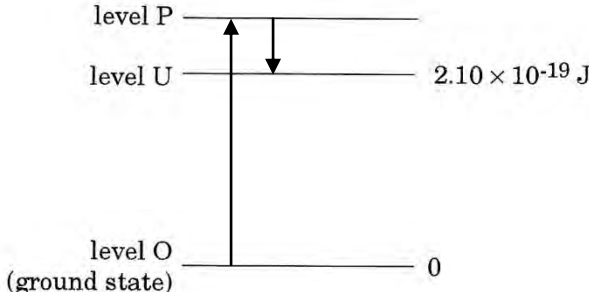
Question			Marking details	Marks Available
2	(a)		Waves arrive in phase at P. (1) Accept twin graphs: displacement along paths or displacement versus time at P.	
			This occurs if path difference = $[0], \lambda, 2\lambda \dots\dots\dots$ (1) Accept $n\lambda$	2
	(b)	(i)	Insertion of a, D and y into $\lambda = \frac{ay}{D}$, <u>even if powers of 10 incorrect</u> . (1)	
			$\lambda = 600$ n[m] (1)	2
		(ii)	Beams (fringes, orders) : brighter / sharper or more defined or narrower / further apart / slit separation more accurately known (Any 2 x (1))	2
			Question 2 total	[6]

Question			Marking details	Marks Available
3	(a)		 (1) Convincing algebra, e.g. $n \frac{\lambda}{2} = L$ (1)	2
	(b)	(i)	When $\lambda = 820.0 \text{ nm}$, $\frac{2L}{\lambda} = 500$ (1) When $\lambda = 821.0 \text{ nm}$, $\frac{2L}{\lambda} = 499.4$ (1) (Give 1 mark if same arithmetical error in both)	2
		(ii)	$n = 499.00$ (1) ecf [or by implication] $\lambda = 821.60 \text{ [nm]}$ (1) No mark if previous mark not given.	2
	(c)		Less amplitude [or fewer photons...] reflected back from [partially reflecting] mirror than arrive at it. (1) + (1) of the following: • Mirror not a proper node • Amplitudes of progressive waves travelling in opposite directions not equal. (Except near fully reflecting mirror).	2
			Question 3 total	[8]

Question			Marking details	Marks Available	
4	(a)	(i)	$1.55 \sin c = 1.00 \sin 90^\circ$ (1) [or equivalent, or by implication] $c = 40^\circ$ (1)	2	
		(ii)	First reflection (1) No ecf Rest of path (1)	2	
					
	(b)	(i)	$1.55 \sin 45^\circ = 1.33 \sin w$ (1) [or equivalent, or by implication] $w = 56^\circ$ (1)	2	
		(ii)	Bends as shown	1	
					
		(iii)	[Sensor at] Q receives more light when water level drops and exposes lower end of rod to the air. No ecf if paths badly wrong.	1	
Question 4 Total			[8]		

Question			Marking details	Marks Available
5	(a)	(i)	$d = v \times t$ (1) [Attempt to use, or by implication] $v = \frac{3.00 \times 10^8}{1.50} \text{ [m s}^{-1}\text{]} (1)$ $d = 1600 \text{ [m]} (1)$ [Omission of n (giving 2400 [m]) loses 1] Arithmetical error loses 1 mark.	3
		(ii)	Zig-zag routes [take] longer than straight. (1) (1) For one of the following: • <u>Good</u> diagram (angles equal by eye) • A continuous <u>range</u> of zig-zag routes, all of different lengths	2
	(b)	(i)	0.14 [μs] [$\pm 0.02 \mu\text{s}$]	1
		(ii)	PULSE AT A PULSE AT B 1 mark for the correct pulse on each graph. ecf from (b)(i)	2
	Question 5 Total			[8]

Question			Marking details	Marks Available
6	(a)	(i)	Maximum k.e. of <u>emitted</u> / <u>photo electrons</u>	1
		(ii)	Energy of a photon[s]	1
		(iii)	[Minimum] energy needed to remove electron [from surface]. Don't accept from an atom	1
	(b)	(i)	I. Gradient calculation attempted (1) – no penalty for wrong powers of 10. $6.6 [\pm 0.3] \times 10^{-34}$ [J s] (1) <u>agreeing with working</u>	2
			II. $f_{\text{thresh}} = 4.4 \times 10^{14}$ Hz (1) $[\pm 0.1 \times 10^{14} \text{ Hz}]$ <u>or</u> valid algebraic method $\phi = 2.9 \times 10^{-19}$ J UNIT (1) ecf	2
		(ii)	I.	
				2
			Correct point (1), parallel line (1)	1
			II. Ultraviolet [or UV]	1
			III. Lithium has higher work function / needs more energy to remove an electron	1
			Question 6 Total	[11]

Question			Marking details	Marks Available
7	(a)	(i)	P and U : zero <u>or</u> very low and / or O : 100%	1
		(ii)	Absorption (accept excitation) (1) : electron promoted from O to U (1)	2
	(b)	(i)	More electrons in U than O or more electrons in higher level	1
		(ii)		1
	(c)	(iii)	Incident (or by implication) <u>photons</u> (1) causes an electron to drop (1). Emitting photon: so two photons where one previously (or by implication) (1). (1) For one of the following: - Atom / electron drops [from U] to O. - Incident photon energy must be $2.10 \times 10^{-19} \text{ J}$ or equivalent - Process happens repeatedly as photons traverse cavity to and fro - Stimulated photon in phase with incident photon	4
		(iv)	$\lambda = \frac{hc}{\Delta E}$ <u>or</u> $\lambda = \frac{c}{f}$ and $f = \frac{\Delta E}{h}$ <u>or</u> equivalent or by implication (1) $\lambda = 950 \text{ n[m]}$ (1)	2
			Electrons in lower level drop [spontaneously] to ground state (1) (accept de-excite)	
			Making population inversion easier to maintain or lowering number of electrons in lower level or making photon absorption less likely. (1) [or equivalent]	2
			Question 7 Total	[13]

Question			Marking details	Marks Available	
8	(a)	(i)	$= 5.4 \text{ } [\pm 0.2] \text{ [day]} \text{ (1)}$ $P = 0.70 \text{ } [\pm 0.1] \times 10^{30} \text{ [W]} \text{ (1) ecf}$	2	
		(ii)	$I = \frac{P}{4\pi r^2} \text{ (1)}$ [or equivalent, or by implication] $r = 2.6 \times 10^{20} \text{ [m]} \text{ (1) ecf}$ [1 mark only lost if factor of 4 omitted]	2	
		(b)	(i)	$\lambda_{\text{peak}} = 450 \text{ n[m]} \text{ (1)}$ [$\pm 10 \text{ nm}$] $T = 6400 \text{ [K]} \text{ (1)}$ [ecf on λ_{peak}]	2
			(ii)	$A = \frac{P}{\alpha T^4} \text{ (1)}$ [transposition at any stage] $= 10 \times 10^{21} \text{ [m}^2\text{]} \text{ (1)}$ [or by implication] ecf on T $r = \sqrt{\frac{A}{4\pi}} \text{ (1)}$ [= $2.8 \times 10^{10} \text{ [m]}$] [or by implication] $d = 5.6 \times 10^{10} \text{ [m]} \text{ (1) ecf}$ (missing factor of 4 loses 1 mark)	4
	Question 8 Total			[10]	

Question			Marking details	Marks Available
9	(a)	(i)	$e^- : +1 \quad e^+ : -1 \quad (1) \quad \gamma : 0 \quad (1)$	2
		(ii)	electromagnetic : γ involvement (1) both	1
	(b)		π^- (1)	
			<u>because</u> either charge of x = -e [accept -1] and x must be a hadron / can't be a lepton	
			<u>Or</u> u number = 0 - 1 = -1, d number = 0 - (-1) = 1 or equivalent (1)	2
	(c)	(i)	e^+ or positron	1
		(ii)	Weak	1
	(d)		π^- [accept μ or $\bar{u}d$] $\rightarrow e^- + \bar{\nu}_e$ (accept $+\bar{\nu}$) [In fact, $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ much more likely]	1
Question 8 Total				[8]

Surname	Centre Number	Candidate Number
Other Names		2



GCE AS/A level

1322/01

PHYSICS

PH2: WAVES AND PARTICLES

A.M. FRIDAY, 20 January 2012

1½ hours

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

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.

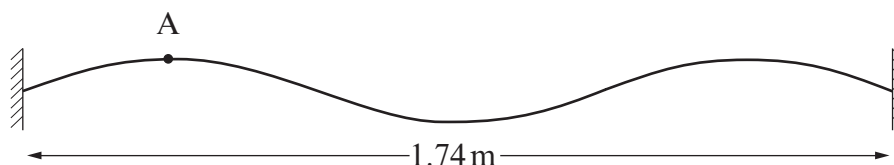
You are reminded to show all working. Credit is given for correct working even when the final answer is incorrect.

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	13	
2.	13	
3.	13	
4.	10	
5.	11	
6.	10	
7.	10	
Total	80	

1322
010001

1. (a) A string is stretched between two fixed supports, 1.74 m apart, and is set vibrating in a stationary wave with a periodic time of 0.020 s.

The diagram shows the string at time $t = 0$, when its displacement is at a maximum.



- (i) **On the same diagram** draw the string at times

(I) $t = 0.010$ s, [Label it 'I'.] [1]

(II) $t = 0.015$ s. [Label it 'II'.] [1]

- (ii) Show that the speed of waves in the string is approximately 60 ms^{-1} . [3]

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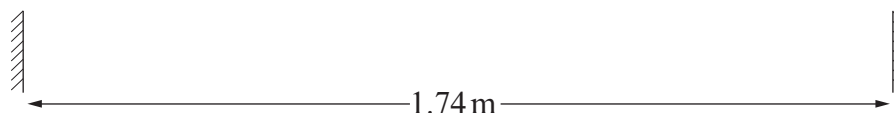
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- (iii) Use 'N' to show on the diagram the positions of **all** nodes. [1]

- (iv) Use crosses to mark on the diagram two points on the string which are vibrating *in phase* with point A on the string. **One of your crosses must be on the left hand half of the string, the other on the right hand half.** [1]

- (b) (i) Show the lowest frequency mode of vibration of the same string, by drawing the string (at a time of maximum displacement) in the diagram below. [1]



- (ii) Calculate this lowest frequency, giving your reasoning. [2]

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(c) (i) State the *Principle of Superposition*.

[1]

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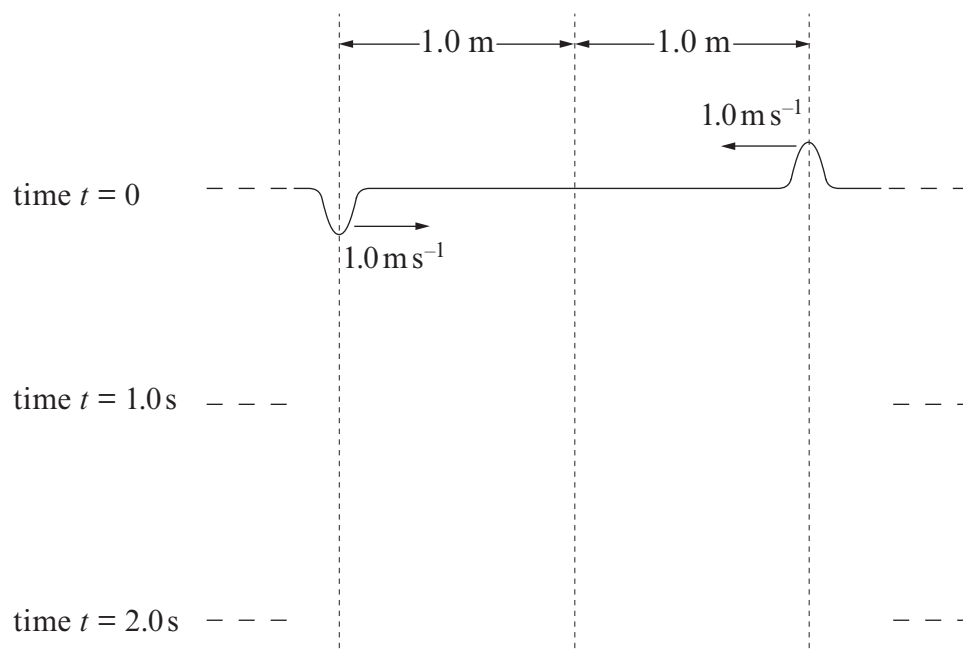
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(ii) Waves in the form of single pulses are sent along a string from both ends, and travel in opposite directions at a speed of 1.0 ms^{-1} .

At time $t = 0$, the pulses are 2.0 m apart, as shown below in the top diagram.

In the labelled gaps directly below this diagram, sketch the string at times of 1.0 s and 2.0 s .

[2]



2. (a) (i) (I) Light is a transverse wave. Explain what is meant by a *transverse* wave. [1]

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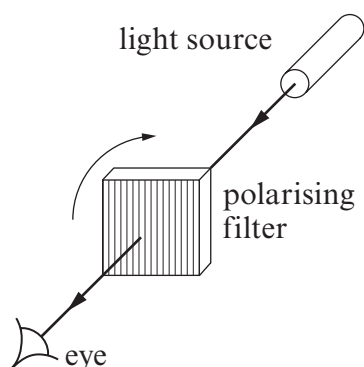
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- (II) What is meant by *polarised* light? [1]

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(ii)



Describe what is seen when a source of **polarised** light is viewed through a polarising filter (polaroid) which is rotated slowly as shown through 360° . [2]

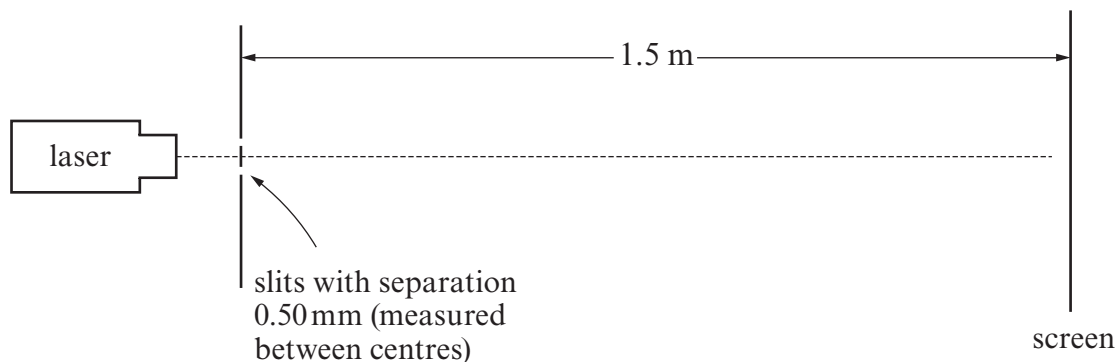
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- (b) A modern version of Young's *double slit* experiment is set up as shown.



- (i) Light *diffracts* at each slit.

- (I) What does this statement mean? [1]

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- (II) Explain why diffraction at the slits is essential to produce interference fringes. [1]

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- (ii) The fringe separation (the separation of the centres of adjacent bright fringes) is 2.0 mm.

(I) Calculate a value for the wavelength of light from the laser. [2]

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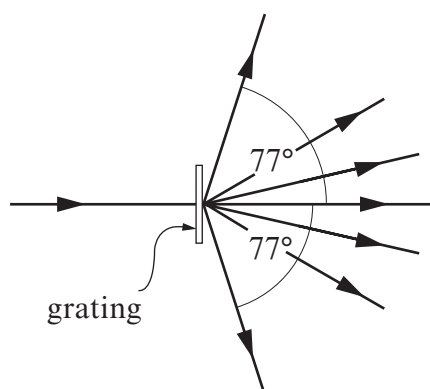
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(II) The distance from the double slits to the screen is increased to 7.5 m. State **two** ways in which the appearance of the fringes on the screen is changed. [2]

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(c)



A diffraction grating with 5.00×10^5 slits per metre is used to measure the wavelength of the laser light, which is shone normally on to the grating. The emerging beams (see diagram) are found to leave the grating as shown.

Calculate the wavelength of the light. [3]

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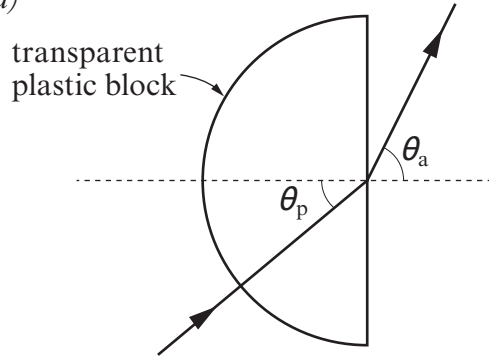
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3. (a)

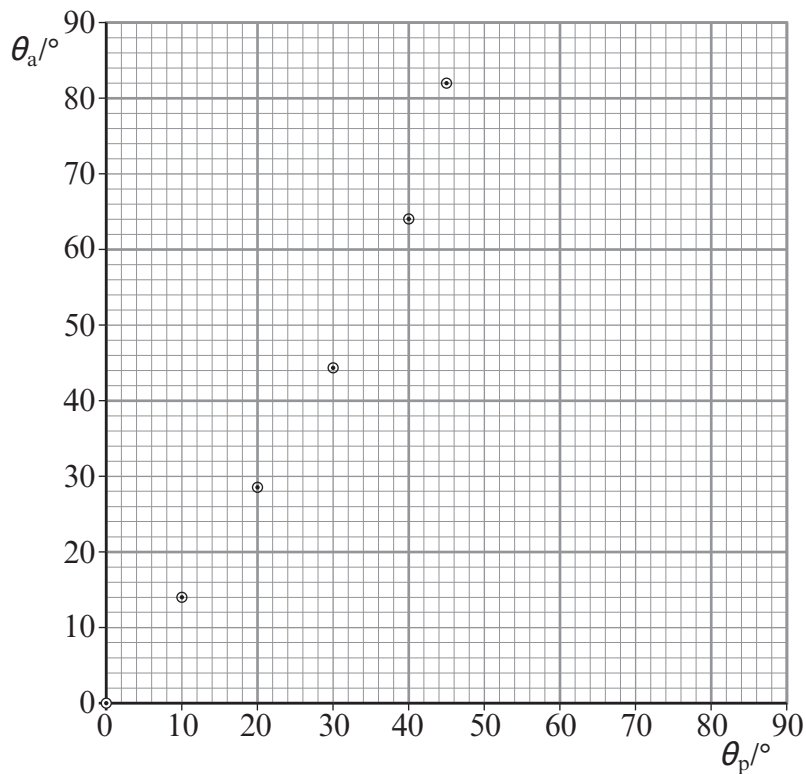


A student traces the path of a narrow beam of light through a transparent plastic block, and measures the angles θ_a and θ_p (see diagram). She repeats the measurements for various chosen values of θ_p , and her results are plotted below.

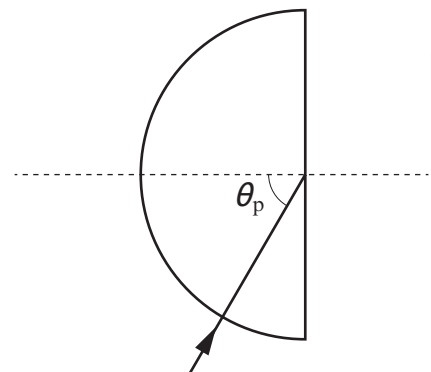
(i) Draw a curve of best fit. [1]

(ii) Without calculation, use the graph to obtain a value for the *critical angle* of the plastic.

Critical angle = ... [1]



(iii) Carefully continue the light path on the diagram, to show what would happen if the student had selected an angle θ_p which was greater than the critical angle.



[1]

- (iv) Use data from any one of the plotted points to calculate a value for the refractive index, n , of the plastic. [2]

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- (v) (I) Describe the line of best fit you would expect if $\sin \theta_a$ were plotted on the vertical, 'y', axis against $\sin \theta_p$. [2]

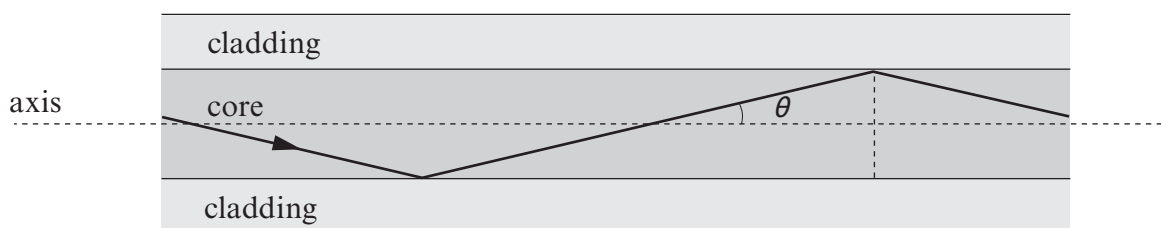
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- (II) Briefly, how would you find n from this graph? [1]

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- (b) A multimode optical fibre has a core of refractive index 1.530 and a cladding of refractive index 1.520.



- (i) Calculate the *critical angle* for the boundary between the core and the cladding. [2]

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- (ii) Hence determine the maximum angle, θ , between a light path and the axis of the fibre (see diagram) if the light is to travel for a long distance through the fibre. [1]

- (iii) Explain why it is an advantage for this angle to be small if data are being transmitted. [2]

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4. (a) The *work function* of caesium is $3.4 \times 10^{-19} \text{ J}$.

Calculate the lowest *frequency* of light that will cause photo-electric emission from a caesium surface. [2]

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- (b) Light of frequency $7.4 \times 10^{14} \text{ Hz}$ is shone on to a caesium surface.

- (i) Calculate the maximum kinetic energy, KE_{max} , of the emitted electrons for this frequency of light. [2]

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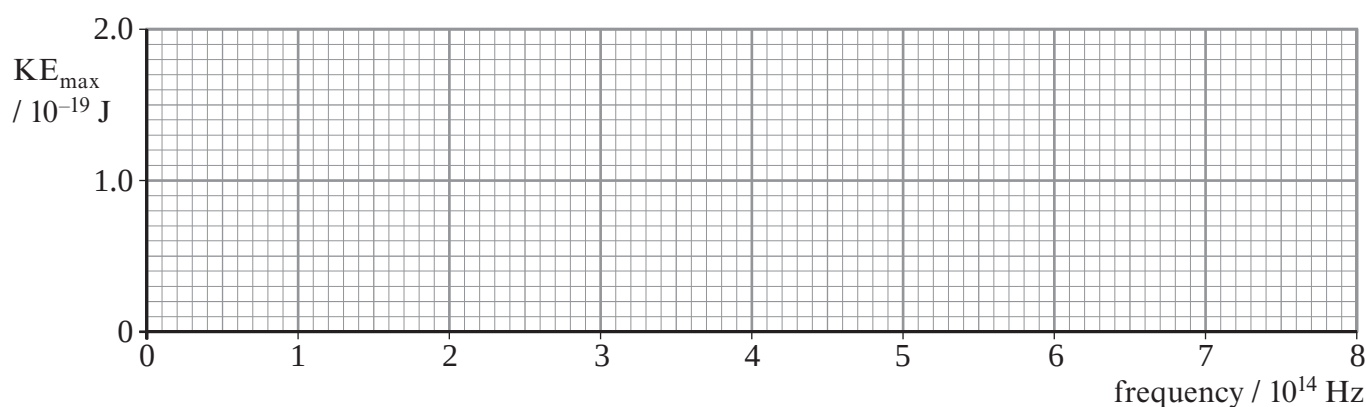
- (ii) Explain **in physical terms** why KE_{max} is less than the energy of an incident photon. [2]

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- (c) (i) Making use of your answers to (a) and (b)(i), draw a graph, on the axes provided, to show how KE_{max} would depend on the frequency of incident light. [2]

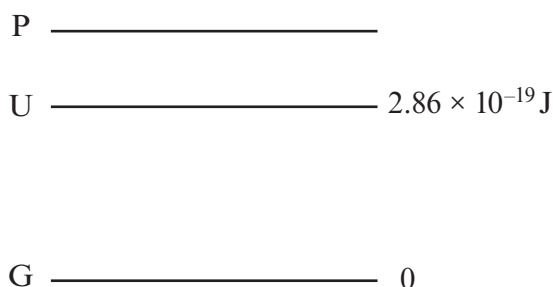


- (ii) What does the gradient of this graph represent? [1]

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- (iii) On the same axes sketch a graph that could be obtained for a metal with a greater work function than caesium. **Label this graph '(iii)'.** [1]

5. The first laser used *ruby*, a crystal containing chromium ions, as its amplifying medium. A simplified energy level diagram is given for the chromium ions.



- (a) Calculate the wavelength, λ_{UG} , of radiation associated with transitions between levels U and G. [2]

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- (b) For the laser to work there needs to be a *population inversion* involving levels U and G.

- (i) What does this statement mean? [1]

- (ii) What would happen to photons of wavelength λ_{UG} present in the ruby if there were **no** population inversion, and what would become of their energy? [2]

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- (iii) *Pumping*, involving level P, is used to cause a population inversion. **Add arrows** to the diagram to show the transitions by which the inversion is achieved. [1]

- (iv) The population inversion makes possible light amplification by stimulated emission (from the chromium ions). Explain what is meant by *stimulated emission* and explain how this leads to *light amplification*. [3]

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- (c) State three properties of the **light** from a laser which distinguish it from light from an 'ordinary' source, such as a filament lamp. [2]

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6. *Neutron stars* are very small, dense ‘dead’ stars. Sometimes they can acquire an outer layer of ‘active’ material which becomes very hot and radiates as a *black body*. One such star has a **radius** of 11 km, and radiates at a temperature of 2.5×10^7 K.

- (a) (i) Show that the wavelength of greatest spectral intensity is approximately 1×10^{-10} m. [2]

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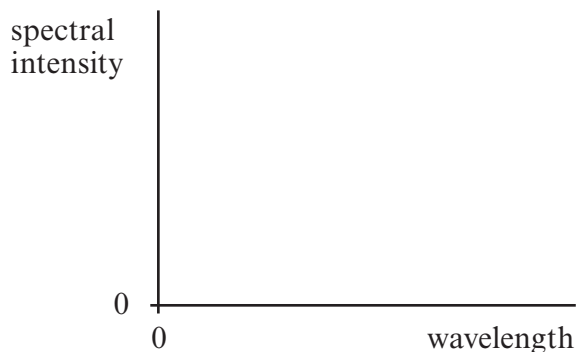
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- (ii) Name the region of the electromagnetic spectrum in which this wavelength lies. [1]

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- (iii) Sketch a black body spectrum on the axes provided. [1]



- (iv) Discuss briefly whether the star in question emits any **visible** radiation. [1]

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- (b) Calculate the total *power* emitted as electromagnetic radiation by the star. [3]

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- (c) The outer layer of the star expands rapidly and cools. The total power emitted remains roughly constant. Estimate the temperature of the outer layer when its **surface area** has doubled. [2]

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7. (a) (i) State **three** ways in which the properties of down-quarks and electrons differ. [3]

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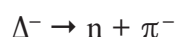
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- (ii) The Δ^- ('delta-minus') particle has the quark make-up ddd. Deduce its charge. [1]

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- (b) The Δ^- particle decays in a typical time of 6×10^{-24} s into a neutron and a pion (π meson).



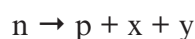
State **two** features of the decay which point to it being a *strong* interaction. [2]

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- (c) The neutron and the pion formed in the decay are themselves unstable. The neutron decays thus:



in which p is a proton and x is a charged (first generation) lepton.

- (i) Use the laws of conservation of charge and of lepton number to identify x and y, setting out your reasoning clearly. [3]

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- (ii) Which force is responsible for this decay? [1]

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THERE ARE NO MORE QUESTIONS IN THE EXAMINATION.



GCE MARKING SCHEME

PHYSICS
AS/Advanced

JANUARY 2012

INTRODUCTION

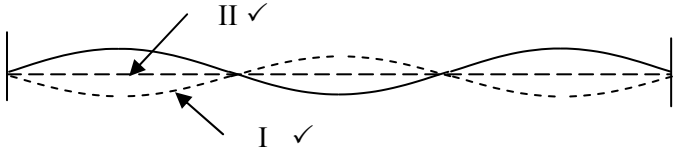
The marking schemes which follow were those used by WJEC for the January 2012 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

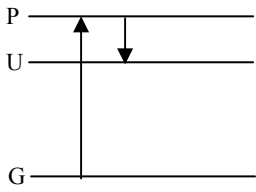
Unit	Page
PH1	1
PH2	5
PH4	10

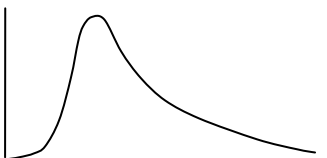
PH2

Question			Marking details	Marks Available
1	(a)	(i)		2
		(ii)	Either $\lambda = 1.16 \text{ [m]} (1)$ $f = 50 \text{ [Hz]} (1)$ $v = 58 \text{ [m s}^{-1}\text{]}(1)$ Or $\lambda = 1.16 \text{ [m]} (1)$ $v = \frac{\lambda}{T} \text{ or } v = \frac{1.16}{0.02} (1)$ $v = 58 \text{ [m s}^{-1}\text{]}(1)$ [1 mark only if either 1.2m used or 1.74/0.03 used]	
		(iii)	All 4 nodes labelled	
		(iv)	Any crosses placed in first and last loops	
	(b)	(i)		1
		(ii)	Either line drawn ✓ $f = 17 \text{ Hz} (1)$ UNIT mark New wavelength = 3.48 m or $3 \times$ previous λ or appeal to $f = [n] \frac{v}{2L} (1)$ (Allow 1 mark only if $f = 34 \text{ Hz}$) Allow e.c.f. from (b)(i)	
	(c)	(i)	The displacement at any point is the [vector] sum of the displacements of the individual waves.	1
		(ii)	$t = 1.0 \text{ s}$: horizontal line shown (1) $t = 2.0 \text{ s}$: inversion of $t = 0$ shown (1)	2
		Question 1 total		[13]

Question			Marking details	Marks Available
2	(a)	(i)	I. Vibrations / oscillations / displacements [accept particle displacements] are perpendicular / at right angles / 90° to the propagation directions [or equiv.]	1
			II. Vibrations / oscillations / displacements [accept particle displacements] are in one direction [accept in one plane]	1
		(ii)	Alternates [gradually] between light and dark (1)	
			2 extinctions / dark places in 360°/ or equivalent (1)	
			[Accept an answer which assumes initially bright or initially dark]	2
	(b)	(i)	I. Light spreads out [round edge of each slit] [or equiv.]	1
			II. So light from the two slits overlaps [or equiv.]	1
		(ii)	I. $\lambda = \frac{2.0 \text{ mm} \times 0.50 \text{ mm}}{1.5 \text{ m}}$ (1)	
			= 670 n[m] (1) [667 nm, accept 700 nm]	2
	(c)		II. Fringe separation increased (1); [bright] fringes dimmer (1)	2
			$3\lambda = d \sin 77^\circ$ [or by impl.] (1)	
			$d = \frac{1}{5.00 \times 10^5} \text{ m} [= 2.00 \times 10^{-6} \text{ m}]$ [or by impl.] (1)	
			$\lambda = 650 \text{ n[m]}$ (1)	3
	Question 2 total			[13]

Question			Marking details	Marks Available					
3	(a)	(i)	Smooth curve drawn through all the points	1					
		(ii)	46° [or as appropriate from drawn line]	1					
		(iii)	Reflected ray drawn with angle of reflection equal to θ_r by eye .	1					
		(iv)	Any of: <table><tr><td>$\frac{\sin 14^\circ}{\sin 10^\circ}$ ✓ 1.39 [±0.05] ✓ or by implication</td><td>$\frac{\sin 28.5^\circ}{\sin 20^\circ}$ 1.40 [±0.05]</td><td>$\frac{\sin 44^\circ}{\sin 30^\circ}$ 1.40 [±0.05]</td><td>$\frac{\sin 64^\circ}{\sin 40^\circ}$ 1.40 [±0.05]</td><td>$\frac{\sin 82^\circ}{\sin 45^\circ}$ 1.40 [±0.05]</td></tr></table>	$\frac{\sin 14^\circ}{\sin 10^\circ}$ ✓ 1.39 [±0.05] ✓ or by implication	$\frac{\sin 28.5^\circ}{\sin 20^\circ}$ 1.40 [±0.05]	$\frac{\sin 44^\circ}{\sin 30^\circ}$ 1.40 [±0.05]	$\frac{\sin 64^\circ}{\sin 40^\circ}$ 1.40 [±0.05]	$\frac{\sin 82^\circ}{\sin 45^\circ}$ 1.40 [±0.05]	2
		$\frac{\sin 14^\circ}{\sin 10^\circ}$ ✓ 1.39 [±0.05] ✓ or by implication	$\frac{\sin 28.5^\circ}{\sin 20^\circ}$ 1.40 [±0.05]	$\frac{\sin 44^\circ}{\sin 30^\circ}$ 1.40 [±0.05]	$\frac{\sin 64^\circ}{\sin 40^\circ}$ 1.40 [±0.05]	$\frac{\sin 82^\circ}{\sin 45^\circ}$ 1.40 [±0.05]			
	(v)	I. Any 2 × (1) from • Straight ✓ • Through the origin ✓ • Gradient > 1 ✓ II. [<i>n</i> is the] gradient	2 1						
	(b)	(i)	1.530 sin <i>c</i> = 1.520 [sin 90°] (1) [or by impl.] <i>c</i> = 83° (1)	2 1					
		(ii)	$\theta = 7^\circ$ [accept 6.5°] e.c.f. from (b)(i)						
		(iii)	Smaller <u>differences</u> in distances travelled or times taken [by light travelling different paths] (1), so less blurring / smearing / overlap of data / pulses (1) [or data can be transmitted at a greater rate] Less multimode dispersion only award 2 nd mark	2					
		Question 3 Total			[13]				
4		(a)	$f_{\text{Thresh}} = \frac{\phi}{h}$ (1) [or by impl.] = 5.1[3] × 10 ¹⁴ [Hz] (1)	2					
	(b)	(i)	Photon $E = 6.63 \times 10^{-34} \times 7.4 \times 10^{14}$ [= 4.91 × 10 ⁻¹⁹ J] [or by impl.] (1) $E_{k \text{ max}} [= 4.91 \times 10^{-19} - 3.4 \times 10^{-19}] = 1.5 \times 10^{-19}$ [J] (1)	2					
		(ii)	[A single] photon gives its energy to an electron (1) Some of the energy used to escape from the metal (1).	2					
	(c)	(i)	Points plotted at (5.1 × 10 ¹⁴ Hz, 0) and (7.4 × 10 ¹⁴ Hz, 1.5 × 10 ⁻¹⁹ J) (1) Allow e.c.f. from (a) and (b)(i) Straight line drawn through points (1) (One correct point only and a positive slope line = 1 mark)	2					
		(ii)	<i>h</i> / the Planck constant	1					
		(iii)	Straight line drawn with same gradient as (i) and to the right	1					
	Question 4 Total			[10]					

Question			Marking details	Marks Available
5	(a)		$E = \frac{hc}{\lambda}$ [or equiv. eg. $E = hf$ and $\lambda = \frac{c}{f}$ or by impl] (1) $\lambda_{UG} = 6.95 \times 10^{-7}$ [m] (1)	2
	(b)	(i)	More electrons in level U than in level G	1
		(ii)	They / the photons would be absorbed [accept 'disappear'] (1). The energy would be used to excite ions [accept atoms] / raise electrons from G to U [or equiv.] (1)	2
		(iii)	 Both transitions shown	1
		(iv)	Any 2 x (1) from • Passing / incident photon ✓ • Excited ion ✓ • Electron drops to lower level ✓ • The incident photon must have wavelength = λ_{UG} [or 695 nm] or must have energy 2.86×10^{-19} J ✓ 3 rd mark • 2 photons where there was one previously. Accept by implication e.g. in phase with the incident photon.	3
	(c)		Any 2 → (1); any third → (2) from • [plane] polarised ✓ • Coherent ✓ • Monochromatic ✓ • Parallel beam ✓	2
Question 5 Total				[11]

Question			Marking details	Marks Available
6	(a)	(i)	$\lambda_{\text{Peak}} = \frac{2.90 \times 10^{-3} \text{ K m}}{2.5 \times 10^7 \text{ K}} (1) = 1.16 \times 10^{-10} \text{ [m]} (1)$	2
		(ii)	X-ray / γ -ray	1
		(iii)		1
		(iv)	Spectral intensity low <u>in high λ</u> 'tail' but not zero.	1
		(b)	$P = \sigma A \times (2.5 \times 10^7 \text{ K})^4$ [or by impl.] (1) $A = 4\pi \times 11000^2$ [or by impl.] (1) [= $1.52 \times 10^9 \text{ m}^2$] $P = 3.4 \times 10^{31} \text{ W}$ (1) UNIT mark	3
	(c)		$A_2 T_2^4 = A_1 T_1^4$ (1) or $T_2^4 = \frac{3.4 \times 10^{31}}{5.67 \times 10^{-8} \times 3.04 \times 10^9} \text{ K}^4$ e.c.f from (b) $T_2 = 2.1 \times 10^7 \text{ K}$ (1)	2
			Question 6 Total	[10]
7	(a)	(i)	Any 3 $\times$ (1) from • d have $\frac{1}{3}$ electronic charge / $-\frac{1}{3}e$ charge ✓ • ds have greater mass than e ✓ • ds feel strong force [or interact with gluons]; e don't ✓ • ds cannot be isolated; e can [~~or~~ d can only be found in specific groupings; e can be by itself] ✓ • ds have lepton number 0, es have lepton number 1 ✓	3
		(ii)	$[3 \times (-\frac{1}{3}e)] = -e$ [accept e or -1 or $1.6 \times 10^{-19} \text{ C}$ with some justification]	1
		(b)	Any 2 $\times$ (1) from • Very short decay time ✓ • Individual quark flavours conserved ✓ • Accept: no neutrino [and no γ] emission	2
		(c)	(i) x is an electron (1) y is an antineutrino (1) clear logical reasoning based on the laws of conservation of charge and of lepton number (1)	3
		(ii)	Weak	1
			Question 7 Total	[10]

Candidate Name	Centre Number	Candidate Number



GCE AS/A level

1322/01

PHYSICS

**ASSESSMENT UNIT PH2:
WAVES AND PARTICLES**

P.M. MONDAY, 6 June 2011

1½ hours

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

For Examiner's use only.		
1.	10	
2.	13	
3.	13	
4.	12	
5.	14	
6.	9	
7.	9	
Total	80	

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.

1. (a) (i) Sound waves in air are *longitudinal*. Explain what this means. [2]

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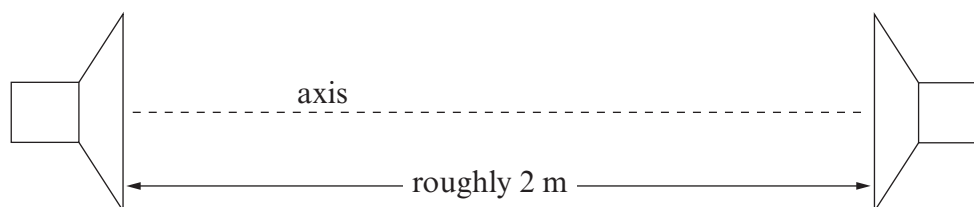
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- (ii) What is meant by the *wavelength* of a progressive sound wave? [1]

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- (b) In the set-up shown, both loudspeakers are connected to the same signal generator.

- (i) Explain briefly why a stationary wave is produced. [2]

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- (ii) With the signal generator set to 750 Hz, the quietest points on the axis are found to be 0.22 m apart. Calculate a value for the speed of sound, giving your reasoning. [3]

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- (iii) Show that it would not be possible to use this method, with the set-up just as shown, if the signal generator were set to 50 Hz. [2]

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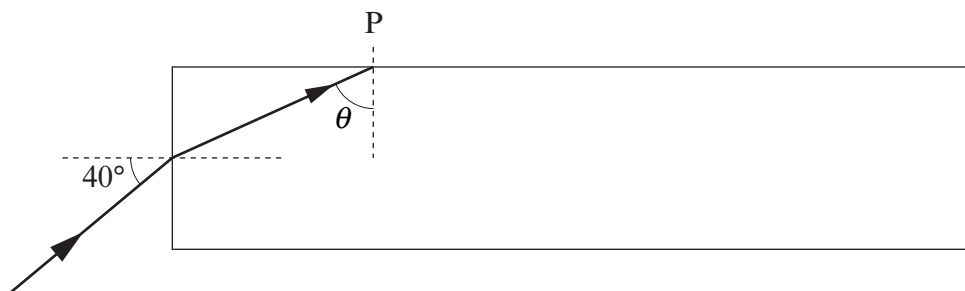
2. (a) (i) Insert the correct symbol (< or = or >) to compare the *speeds* (v), *frequencies* (f) and *wavelengths* (λ) of a monochromatic light beam as it passes from air to glass.

v_{air} v_{glass} , f_{air} f_{glass} , λ_{air} λ_{glass} . [2]

- (ii) Justify your choice of symbol for the case of the frequencies. [Your justification should not require use of the equation $v = f\lambda$.] [1]

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- (b) The diagram shows a narrow beam of light entering a solid cuboid (block) of glass of refractive index 1.52, surrounded by air (of refractive index 1.00).



- (i) Show clearly that $\theta = 65^\circ$. [3]

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- (ii) Show that the beam will not emerge into the air at point P. [2]

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- (iii) (I) Carefully complete the path of the beam, showing it eventually emerging into the air and travelling through the air. [1]
- (II) Indicate clearly on the diagram sections of the **whole** path which are parallel to each other. [2]
- (c) In a multimode fibre, light travels at a range of angles **to the fibre axis**. Explain why, for clear communication of rapid streams of data, the range of angles should be restricted so that even the greatest value of the angle is very small. [2]

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3. (a) When ultraviolet radiation of high enough frequency falls on a tin plate (held by an insulating support) the plate acquires a charge. Explain, in terms of electrons and photons, why this happens, and whether the charge is positive or negative. [3]

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- (b) The *work function* of tin is 7.1×10^{-19} J.

- (i) What is meant by the work function of a metal? [1]

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- (ii) Calculate the minimum frequency of ultraviolet radiation needed for photoelectric emission from tin. [2]

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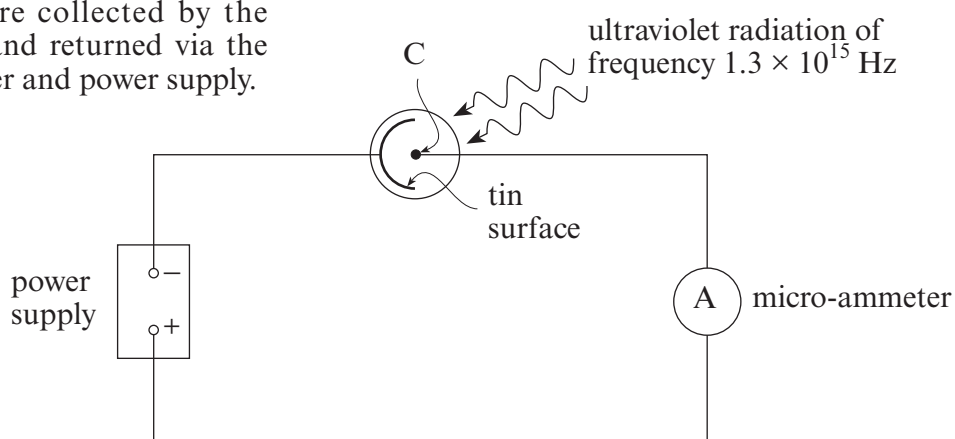
- (iii) Calculate the **frequency** of ultraviolet radiation needed for the emitted electrons to have a maximum kinetic energy of 1.5×10^{-19} J. [2]

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- (c) In the set-up shown, assume that all the electrons emitted from the tin surface are collected by the electrode C, and returned via the micro-ammeter and power supply.



- (i) The micro-ammeter reads $0.64 \mu\text{A}$ (0.64×10^{-6} coulombs per second). Show that 4.0×10^{12} electrons are emitted per second. [1]

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- (ii) Only 1 in 1200 of the incident photons causes emission of an electron. By considering the energy of an individual photon, calculate the ultraviolet energy per second falling on the tin surface. [4]

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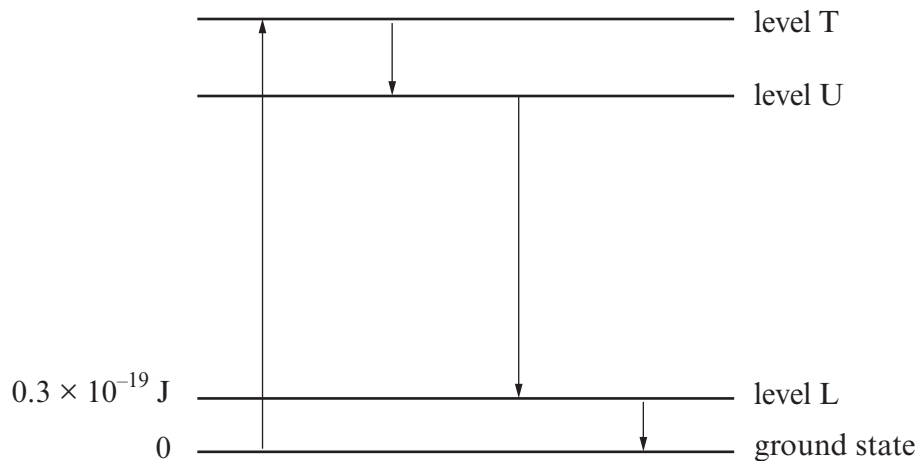
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4. (a) A simplified energy level diagram for a 4-level laser system is given. The arrows show the sequence of transitions which electrons make between leaving the ground state and returning to it.



- (i) Label the transitions associated with (I) *pumping* (II) *stimulated emission*. [2]
- (ii) The wavelength of the output radiation from the laser is $1.05 \times 10^{-6} \text{ m}$. Calculate the energy **above the ground state** of level U. [3]

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- (iii) (I) What triggers a stimulated emission event? [2]

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- (II) How does stimulated emission produce light amplification? [1]

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- (III) What feature of stimulated emission makes the laser's output *coherent*? [1]

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- (iv) T_U is the typical time spent by an electron in level U before spontaneously 'falling' to a lower level. T_L is the typical time spent by an electron in level L before spontaneously falling to the ground state. Explain why it is an advantage for laser operation for T_U to be much greater than T_L . [2]

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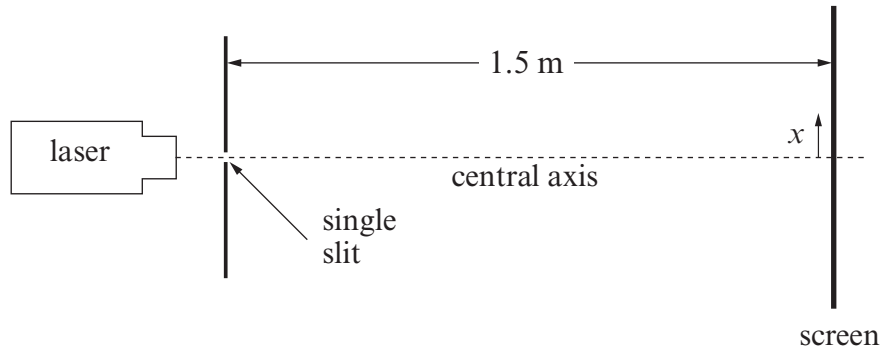
- (b) Semiconductor (diode) lasers are much cheaper to make and much more compact than other types of laser. What advantage do they have in terms of *energy* over other types of laser? [1]

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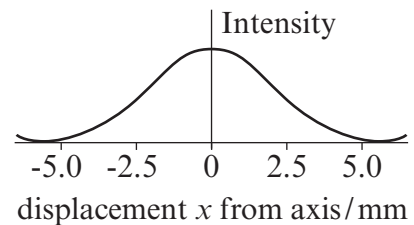
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5. (a) Apparatus is set up as shown.



The graph shows how the intensity of light on the screen varies with displacement x from the central axis.

[Note the expanded displacement scale.]



- (i) Name the wave property being demonstrated. [1]
- (ii) What can be deduced about the width of the slit compared with the wavelength of the light from the laser? Give your reasoning. Calculations are not needed. [2]

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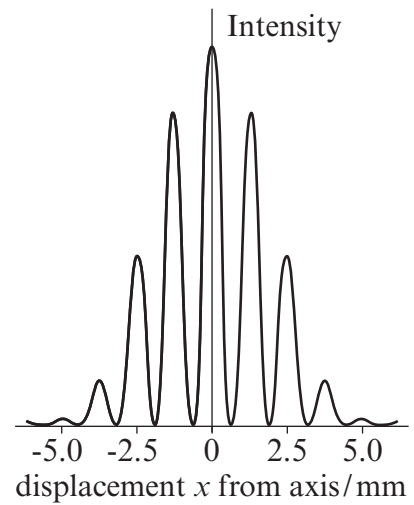
- (iii) What would happen to the graph if the width of the slit were to be increased? [2]

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- (b) The single slit is now replaced by two parallel slits, each of the same width as the single slit in (a). The centres of the slits are 0.75 mm apart. The intensity of light on the screen near the central axis now varies as shown.



- (i) Determine from the graph the separation of the bright interference fringes. [1]

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- (ii) Hence find the wavelength of the light. [2]

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- (iii) Explain in terms of *interference*, *phase*, and *path difference* how the **bright** fringes arise. Assume that the slits act as in-phase sources. [3]

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- (iv) Suggest why the brightness of the bright fringes decreases with displacement x from the central axis, in the region shown on the graph. [1]

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- (c) It is easier to obtain clear fringes in the experiment of part (b) using a laser rather than an ordinary light source. Give two reasons for this. [2]

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6. (a) (i) What is a *meson*?

[1]

(ii) A π^+ particle is a (first generation) meson with a positive charge. Explain why its quark make-up must be $u\bar{d}$.

[1]

(b) An interaction sometimes observed at high energies is



[${}^2_1\text{H}$ symbolises here the **nucleus** of a ${}^2_1\text{H}$ atom.]

(i) Determine whether or not

(I) u quark number is conserved.

[1]

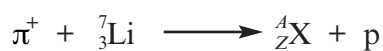
(II) d quark number is conserved.

[1]

(ii) Discuss which force is likely to be responsible for this interaction.

[2]

(c) A similar interaction can be observed between a π^+ particle and a ${}^7_3\text{Li}$ nucleus.



(i) Determine A and Z .

[2]

(ii) What is in common between the nuclei ${}^A_Z\text{X}$ and ${}^7_3\text{Li}$?

[1]

7. (a) (i) The spectrum of the star *Rigel* in the constellation *Orion* peaks at a wavelength of 260 nm. Calculate the temperature of the surface of Rigel. [2]

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- (ii) What assumption were you making about the way the star's surface radiates? [1]

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- (b) To a good approximation the Kelvin temperature of Rigel's surface is twice that of the Sun, and the **radius** of Rigel is 70 times the radius of the Sun. Use *Stefan's Law* to estimate the ratio

$$\frac{\text{total power of electromagnetic radiation emitted by Rigel}}{\text{total power of electromagnetic radiation emitted by the Sun}} . \quad [3]$$

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- (c) We can discover the presence of particular atoms in the atmosphere of a star by measuring the wavelengths of dark lines in the star's spectrum.

Explain how the lines arise, and why they occur at specific wavelengths. [3]

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Candidate Name	Centre Number	Candidate Number



GCE AS/A level

1322/01

PHYSICS

ASSESSMENT UNIT PH2:

WAVES AND PARTICLES

P.M. MONDAY, 17 January 2011

1½ hours

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

For Examiner's use only.		
1.	10	
2.	7	
3.	8	
4.	10	
5.	12	
6.	13	
7.	9	
8.	11	
Total	80	

INFORMATION FOR CANDIDATES

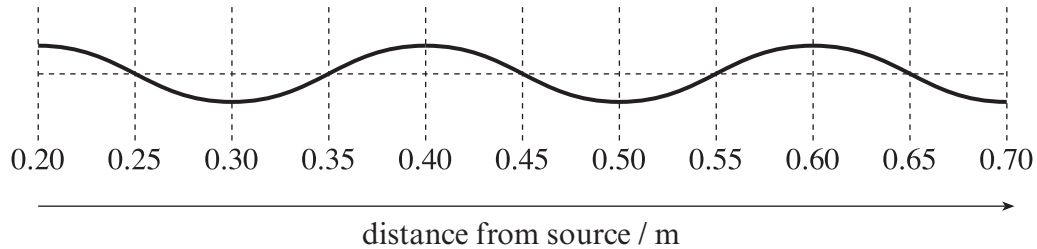
The total number of marks available for this paper is 80.

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.

1. (a) A transverse progressive wave is travelling from left to right along a stretched string. The diagram shows part of the string at one instant.



(i) Write down the *wavelength*. [1]

(ii) The *frequency* is 50 Hz.

(I) Calculate the *speed* of the waves. [1]

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(II) Calculate the time taken for 1 cycle of oscillation. [1]

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(III) **On the diagram above**, draw the string at a time of 0.005 s later. [2]

(iii) Explain why the waves are called *transverse*. [2]

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(b) It is also possible to set up a *stationary wave* on a stretched string. Describe how progressive waves and stationary waves differ in regard to

(i) transfer of energy along the string, [1]

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(ii) **variation** of *amplitude* with distance along the string. [2]

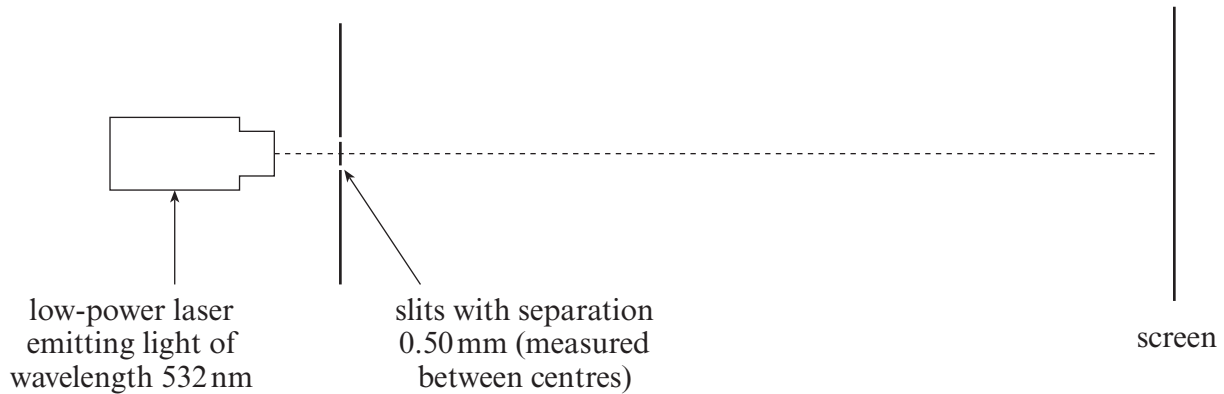
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2. A student sets up the apparatus shown, in order to demonstrate two-source interference (Young's fringes).



- (a) State what is meant by the following statements.

(i) Light *diffracts* at each slit.

[1]

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(ii) The slits act as *coherent* sources.

[1]

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- (b) The separation of the centres of neighbouring bright fringes on the screen is 2.0 mm. Calculate the distance between the slits and the screen. [3]

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- (c) If one of the slits is covered, the dark fringes become brighter. Explain this observation. [2]

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3. (a) The label indicating slit separation on a *diffraction grating* has been removed. A student decides to determine the slit separation (the separation between the centres of its slits) by shining a laser normally at the grating. The wavelength of the laser light is $5.32 \times 10^{-7} \text{ m}$.

He measures the angle between a **second order** emerging beam and the central (*zero order*) beam to be 28.9° .

- (i) Show clearly that the slit separation is approximately $2 \times 10^{-6} \text{ m}$. [3]

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- (ii) Suggest an advantage of choosing a second order, rather than a first order, beam. [1]

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- (b) The student now uses the grating to determine the wavelength of the light from another laser. He measures the second order beam to be at an angle of 35.1° .

- (i) Calculate the wavelength of the light. [2]

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- (ii) Determine the highest order that the grating will produce with this wavelength. Show your working. [2]

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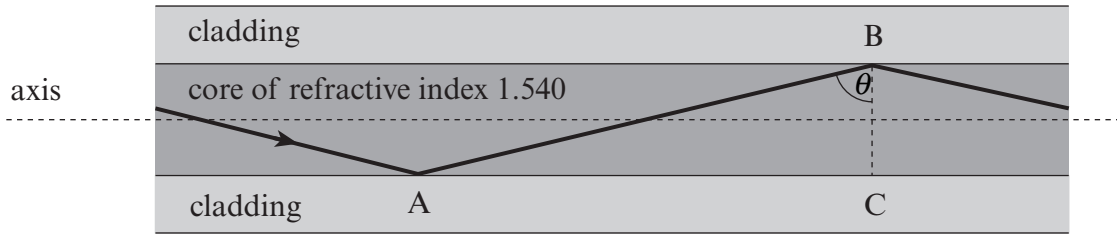
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4. The diagram shows a path which light can take along a 'thick' (multimode) optical fibre.



- (a) The smallest angle θ at which *total internal reflection* can take place is 77° . Calculate the refractive index of the cladding. [2]

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- (b) (i) Calculate the time it takes light to travel along 2.0 km of the fibre if it travels through the core **in a straight line parallel to the axis of the fibre**. [3]

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- (ii) (I) Show that for $\theta = 77^\circ$, the length of AB is 1.026 times greater than the length of AC (see diagram). [1]

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- (II) Hence calculate the **extra** time it takes for light to travel 2.0 km along the fibre via the zigzag path (i.e. for $\theta = 77^\circ$). [2]

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- (iii) Without further calculation explain how this difference in times limits the rate at which data (encoded in the light) can be sent through 2.0 km of the fibre. [2]

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5. (a) Define the *work function* of a metal surface.

[1]

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(b) The work function of sodium is 3.8×10^{-19} J. Use Einstein's photoelectric equation to find

(i) the lowest frequency of light which will eject electrons from a sodium surface, [2]

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(ii) the maximum kinetic energy of electrons emitted from a sodium surface when light of frequency 7.0×10^{14} Hz is shone on to the surface. [2]

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(c) (i) The answer to (b)(ii) is unaffected if the *intensity* of light is increased. Explain, in terms of *photons*, why this should be the case. [2]

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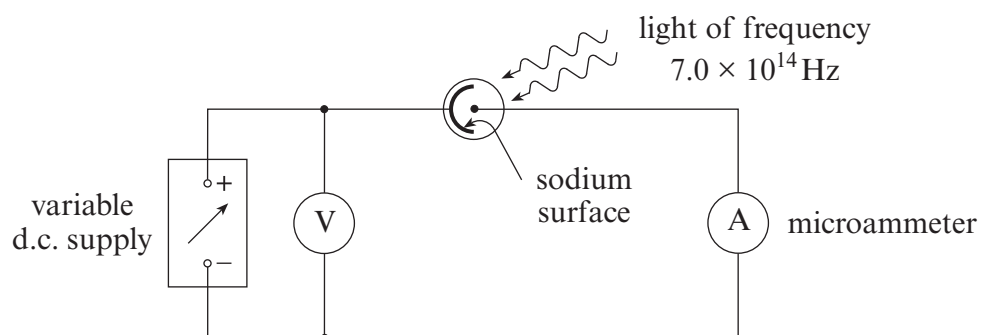
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(ii) What aspect of photo-electric emission *is* affected by the light intensity? [1]

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- (d) The diagram shows apparatus set up to check experimentally the answer to (b)(ii). Describe how you would make this check. [4]



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6. (a) A laser emits light with a photon energy of $3.14 \times 10^{-19} \text{ J}$.

(i) Calculate the wavelength of the light.

[2]

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(ii) What is the colour of the light? [1]

(iii) A simplified energy level diagram for the amplifying medium of the laser is given. $32.97 \times 10^{-19} \text{ J}$

Add an arrow to show the transition giving rise to these photons. $29.83 \times 10^{-19} \text{ J}$

[1]

_____ 0

(b) Almost all these photons are emitted by the process of *stimulated emission*.

(i) State what triggers an atom to emit a photon by stimulated emission.

[2]

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(ii) The light from the laser may be more intense than that from a light-emitting diode (LED), which emits by *spontaneous emission*. State **two** other ways in which the light emitted by the laser differs from that emitted by the LED. [2]

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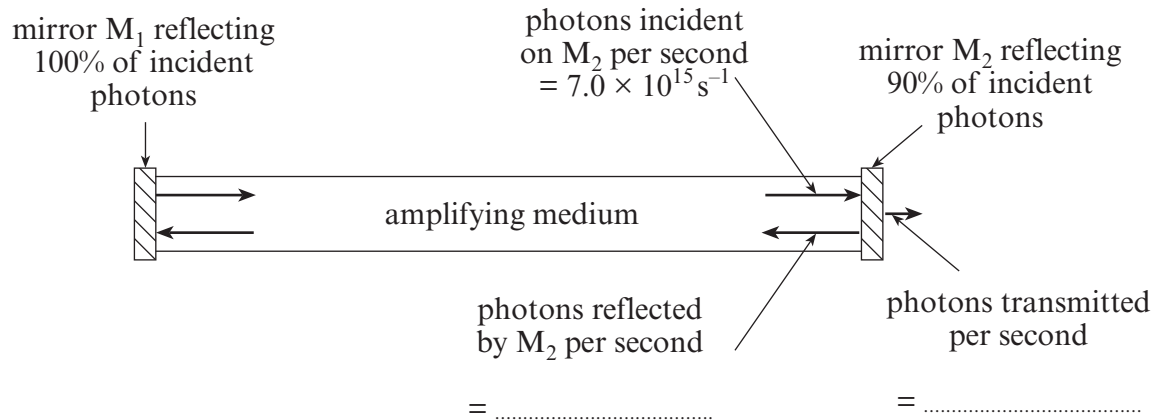
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(c) The (simplified) diagram shows the cavity of the laser.

- (i) Mirror M_2 is only partially reflecting. The light that it does not reflect is transmitted through it.



Fill in the numbers of photons per second reflected and transmitted. [1]

- (ii) Calculate the **power output** of the laser. [2]

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- (iii) Photons reflected from M_2 travel to M_1 and are reflected from it. Explain, using the concept of stimulated emission, why more photons arrive back at M_2 than are reflected from it. [2]

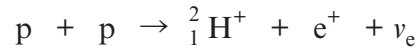
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7. When protons with high enough kinetic energies collide, they occasionally interact thus:



[${}^2_1\text{H}^+$ stands for a *deuteron*, that is the nucleus of a ${}^2_1\text{H}$ atom.]

- (a) (i) Show how *lepton number conservation* applies in this interaction. [2]

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- (ii) Compare the initial and final numbers of

- (I) u-quarks, [1]

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- (II) d-quarks. [1]

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- (b) State which force (*strong*, *weak* or *electromagnetic*) is involved in this interaction, giving a reason for your choice. [2]

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- (c) Explain why this interaction is vital for life on Earth. [2]

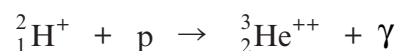
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- (d) Deuterons from this interaction may interact with protons according to



- Which force is involved in the γ emission? [1]

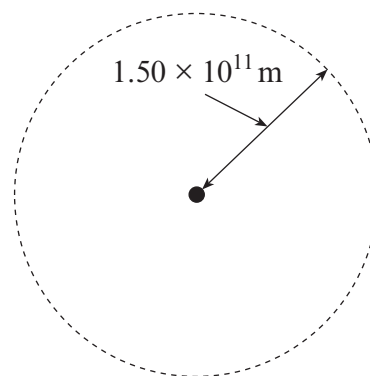
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8. (a) (i) The *intensity* of the Sun's electromagnetic radiation at a distance of $1.50 \times 10^{11} \text{ m}$ from its centre is 1.36 kW m^{-2} .

Show that the power the Sun emits is approximately $4 \times 10^{26} \text{ W}$. Give your answer to 3 significant figures.



[2]

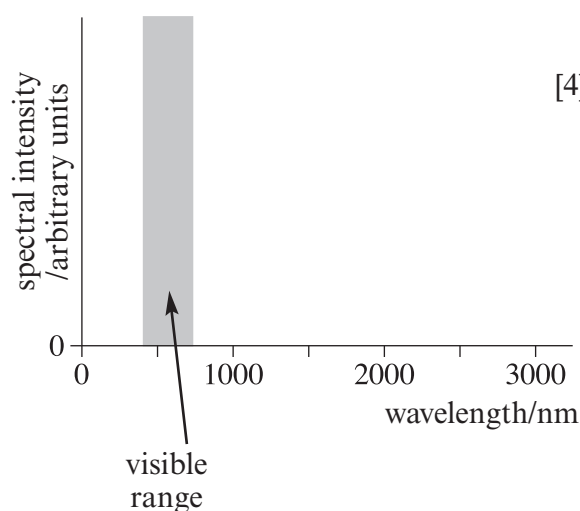
- (ii) $1.50 \times 10^{11} \text{ m}$ is the radius of the Earth's orbit. Suggest why the intensity of radiation, as measured on the Earth's surface, is less than 1.36 kW m^{-2} . [1]

- (b) The temperature of the Sun's surface is 5780 K .

- (i) Use Stefan's Law to calculate the *surface area* of the Sun. [2]

- (ii) The Sun's *diameter* is measured, by optical methods, to be $1.4 \times 10^9 \text{ m}$. Show clearly whether or not your answer to (b)(i) is consistent with this. [2]

- (c) A biologist claims that our eyes are sensitive to the region of the Sun's spectrum of greatest intensity. Use Wien's law to support this claim, and sketch the Sun's spectrum on the axes provided.



[4]

This image shows a full page of a document template. It consists of approximately 28 horizontal dotted lines spaced evenly down the page, providing a guide for handwriting or typing. The background is plain white, and there are no margins, headers, or footers visible.