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**	

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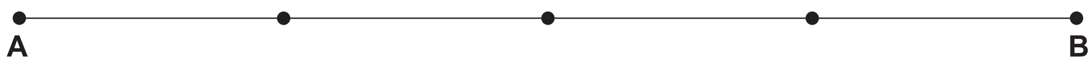
(b) A new stationary wave with a different frequency is set up on the same string. The nodes are as shown.



Calculate the new wave frequency, showing your working. [2]

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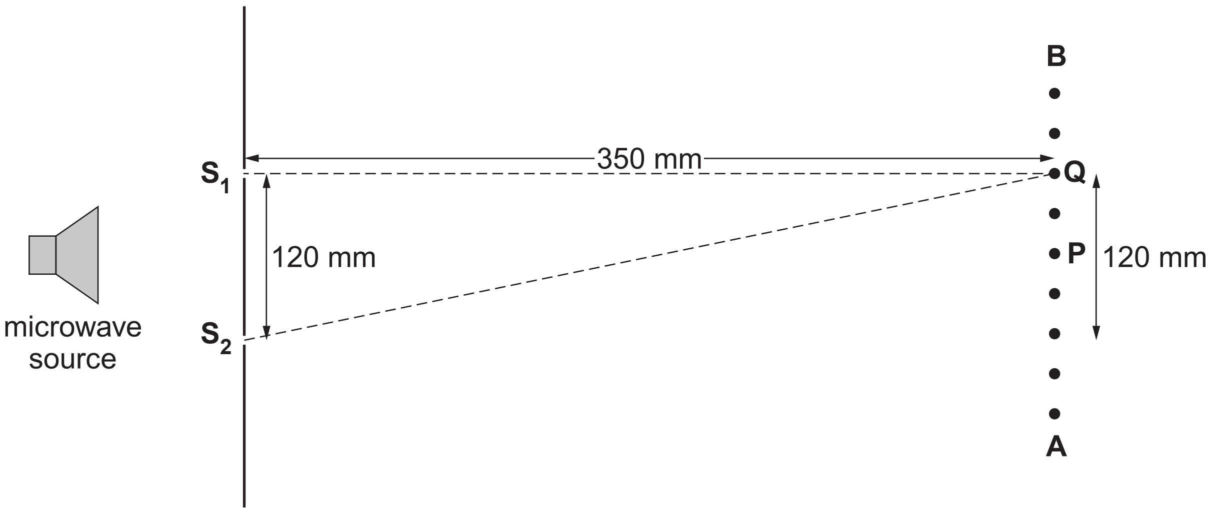
2. *(a)* A microwave source is placed to the left of two narrow slits, $\mathbf{S_1}$ and $\mathbf{S_2}$, so that these slits act as in-phase sources.



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 $\mathbf{S_1}$.

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

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(ii) **Hence** determine the wavelength of the microwaves, giving your reasoning. Note that point **P** is equidistant from $\mathbf{S_1}$ and $\mathbf{S_2}$. [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 μm. [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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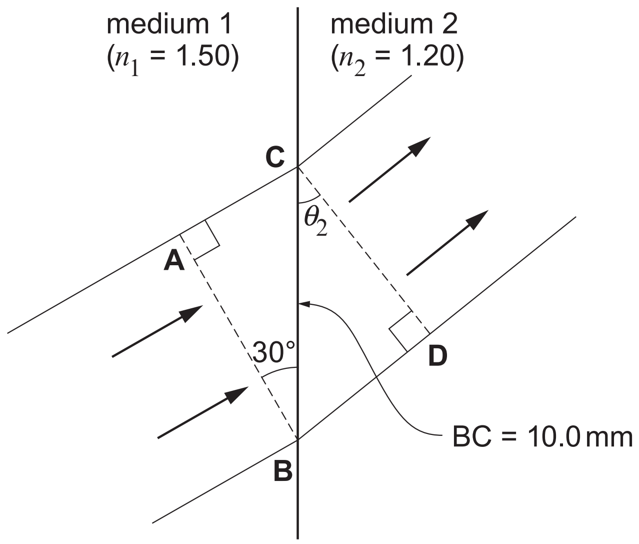
4. *(a)* A beam of light passes from medium 1, of refractive index n_1 = 1.50, into medium 2, of refractive index n_2 = 1.20.



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

medium 1 ....

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medium 2 ....

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(ii) Show clearly that the end, **A**, of wavefront **AB** will take 2.5×10^{-11} s to reach the boundary at **C**. [Note that distance BC = 10.0 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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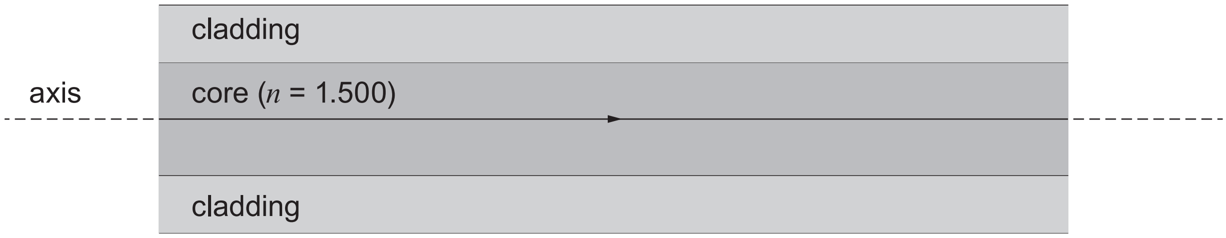
(b) A diagram of an optical fibre is given.



(i) Show clearly that a light pulse travelling along the axis of the fibre takes 8.0 μs to travel through 1.6 km of fibre. [2]

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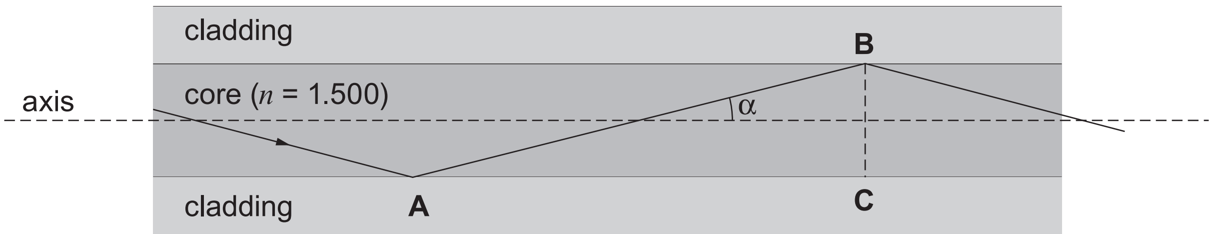
(ii) The greatest angle, α, **to the axis** at which light can travel through the core without escaping is 14°. Calculate the refractive index of the cladding. [3]



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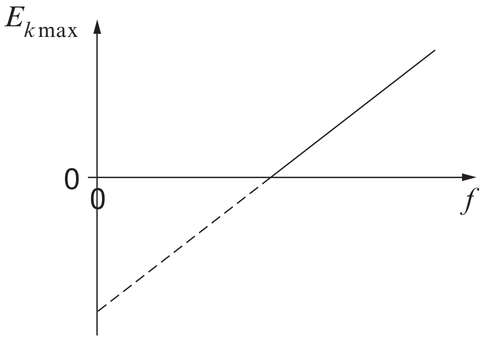
5. *(a)* Magnesium has a *work function* of 5.9×10^{-19} J. What does this statement mean? [1]

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

(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]

(d) The graph shows how the maximum kinetic energy, $E_{k\,\mathrm{max}}$ 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 $E_{k\,\mathrm{max}}$ axis; [1]

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

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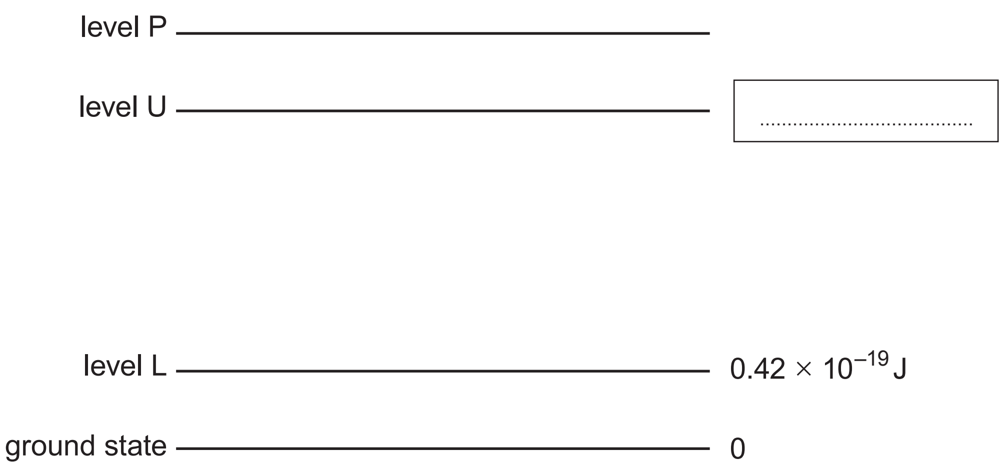
(iv) A simplified energy level diagram for this (four level) laser is given.



(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]

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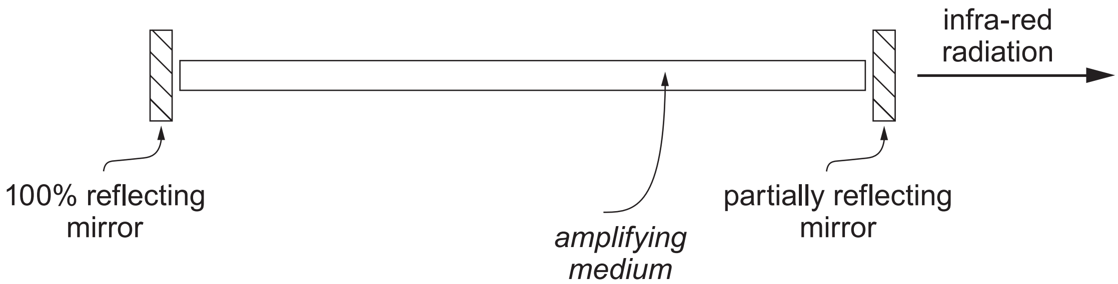
(b) 'Light' amplification occurs as the radiation passes through the amplifying medium in the laser cavity.



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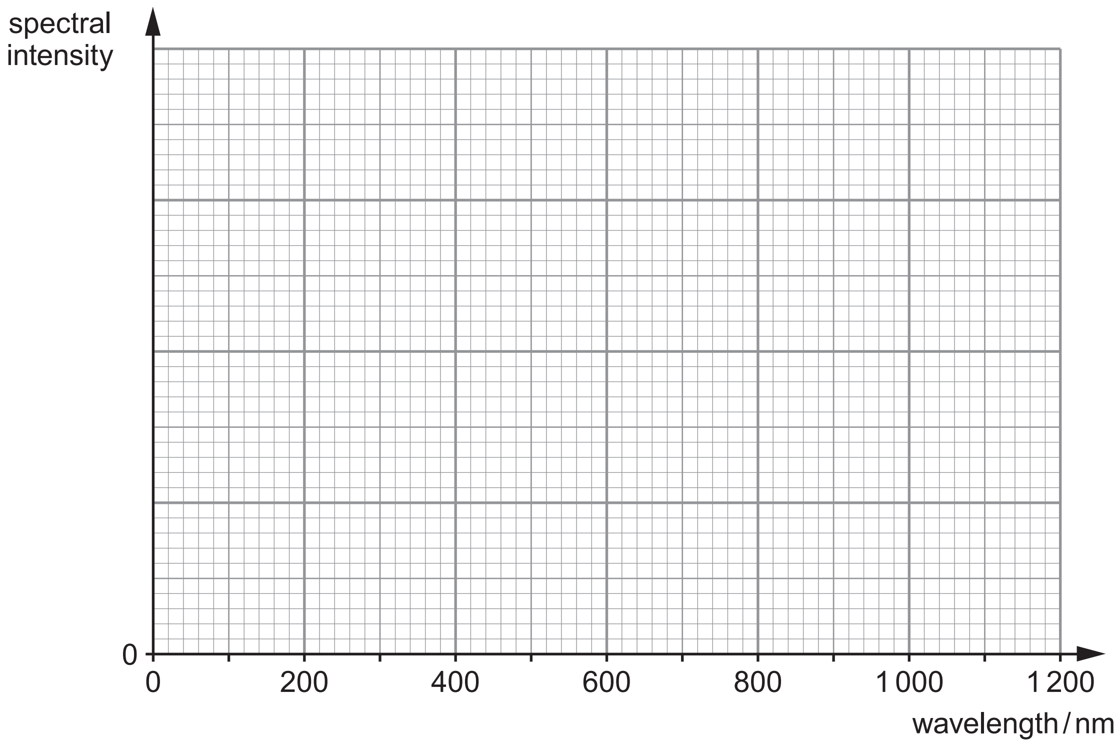
(ii) Sketch on the axes a graph of spectral intensity against wavelength for the continuous spectrum of Sirius A. *(Note: make the peak spectral intensity three or four large squares above the wavelength axis.)* [2]



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

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

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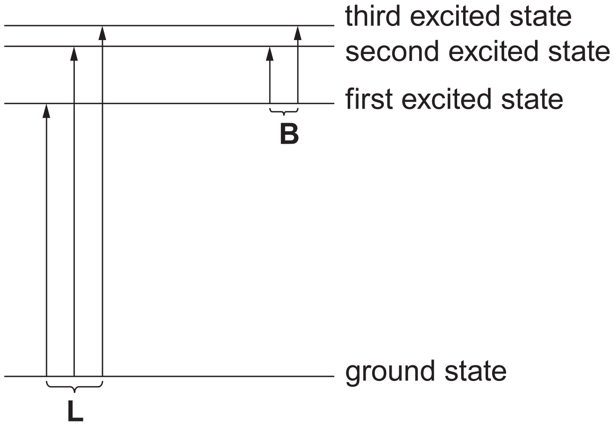
(c) The diagram shows the lowest energy levels of a hydrogen atom, and five possible transitions between these levels.



(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

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

$$p \quad + \quad p \longrightarrow p \quad + \quad n \quad + \quad \pi^+$$

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(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:

$$p \quad + \quad p \longrightarrow {}^{2}_{1}H^{+} \quad + \quad e^{+} \quad + \quad \nu_e$$

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${}^{2}_{1}H^{+}$ 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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