22106512

International Baccalaureate®
Baccalauréat International
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PHYSICS
STANDARD LEVEL
PAPER 3

Tuesday 11 May 2010 (morning)

1 hour

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet.

Option A — Sight and wave phenomena

A1. This question is about the eye and sight.

(a) State, by reference to human vision, what is meant by accommodation. *[2]*

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(b) Explain how accommodation is achieved in the human eye. *[3]*

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(c) The light output from two particular lamps is described as "warm-white" and as "cold-white". Both lamps emit the full spectrum of colours. State how the visual impression of temperature difference may be achieved. *[2]*

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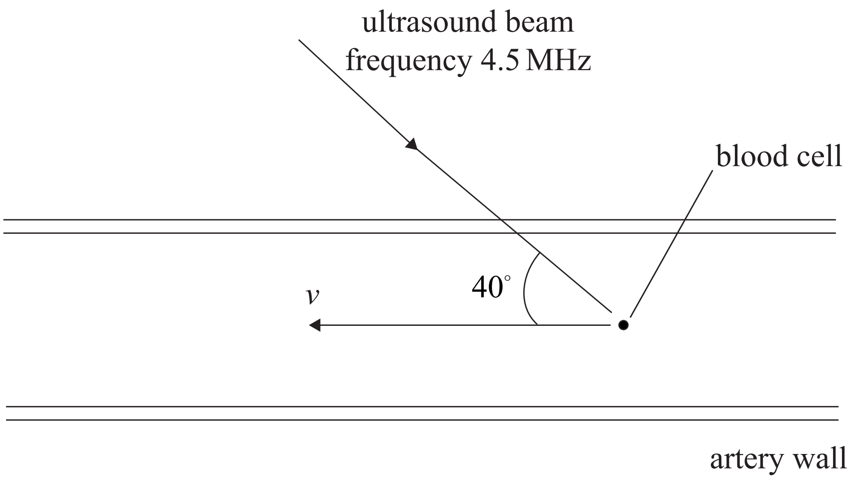
A2. This question is about the Doppler effect.

At one point in an artery, blood cells flow along the axis of the artery with speed v, as shown.



(This question continues on the following page)

(Question A2 continued)

A parallel beam of ultrasound of frequency 4.5 MHz is incident on the artery at an angle of 40°.
The speed of ultrasound in the body tissues is $c = 1.5 \times 10^3\,\mathrm{m\,s^{-1}}$.
The ultrasound detected after reflection from the blood cells is found to be Doppler-shifted in frequency by 740 Hz.
The expression for the Doppler shift Δf of the ultrasound of frequency f may be assumed to be

$$\Delta f = \frac{(2 f v \cos\theta)}{c}.$$

(a) For this stated expression, explain the inclusion of

(i) the factor of 2. *[2]*

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(ii) the factor $\cos\theta$. *[1]*

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(b) Determine a value for the speed of the blood cells in the artery. *[2]*

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A3. This question is about polarization.

(a) State what is meant by *polarized* light. *[2]*

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(b) Describe and explain how polarization may be used in stress analysis. You may draw a diagram if you wish. *[6]*

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Option B — Quantum physics and nuclear physics

B1. This question is about the wave nature of matter.

(a) Describe the de Broglie hypothesis. *[2]*

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(b) Outline an experiment to verify the de Broglie hypothesis. *[3]*

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(c) Show that the de Broglie wavelength of electrons accelerated from rest through a potential difference of 150 V is 1.0×10^{-10} m. *[3]*

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B2. This question is about alpha (α) particle scattering.

An experiment is carried out in which alpha (α) particles of initial kinetic energy 5.0 MeV are fired at a piece of gold foil. The proton number of gold is 79.

Determine the distance of closest approach of an alpha (α) particle to a gold nucleus. *[4]*

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B3. This question is about β^+ (positron) decay.

(a) In a β^+ decay, a positron is emitted along with a neutrino, and a γ-ray photon. Although the energy spectrum for γ-rays involved is discrete, the energy spectrum for the positrons is continuous.

(i) State the difference between a discrete energy spectrum and a continuous energy spectrum. *[1]*

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(ii) Explain how the existence of the neutrino accounts for the continuous nature of the positron energy spectrum. *[2]*

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(This question continues on the following page)

(Question B3 continued)

(b) Sodium-22 is a radioisotope used in nuclear medicine that undergoes β^+ decay.
The half-life of sodium-22 is 2.6 years.
A sample of sodium-22 has an initial activity of 6.2×10^9 Bq.

(i) Define *decay constant.* *[1]*

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(ii) Calculate the decay constant of sodium-22. *[1]*

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(iii) Calculate the activity of the sample of sodium-22 after 8.0 years. *[3]*

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Option C — Digital technology

C1. This question is about storing information.

Information may be stored either in analogue form or in digital form.

(a) Distinguish between analogue information and digital information. *[2]*

Analogue: . . . .

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Digital: . . . .

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(b) State **one** method by which information may be stored in

(i) analogue form. *[1]*

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(ii) digital form. *[1]*

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(c) State and explain **two** reasons why, for many purposes, digital storage of information is replacing analogue storage. *[4]*

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2: . . . .

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(d) Suggest **two** possible implications for society of the ever-increasing capability of data storage. *[2]*

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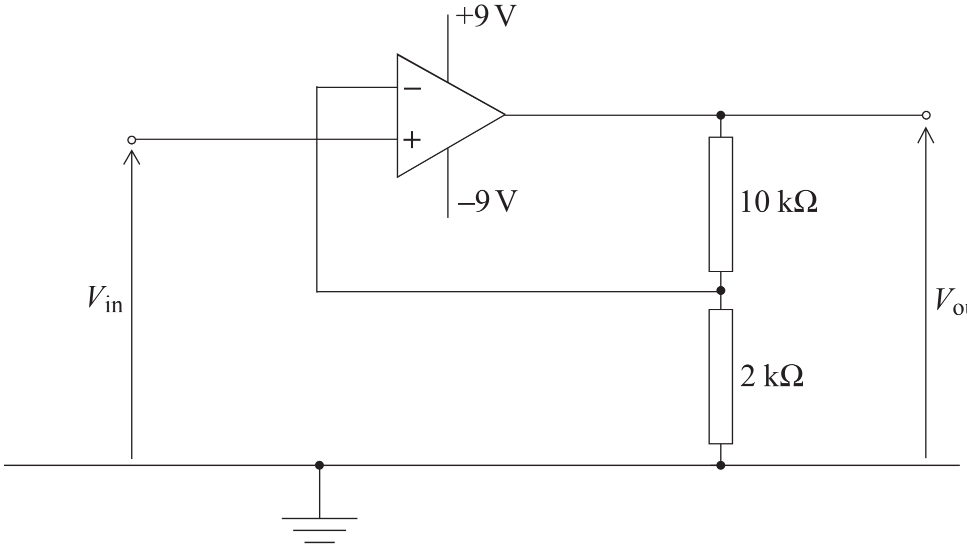
C2. This question is about an amplifier circuit.

The diagram below shows an amplifier circuit incorporating an ideal operational amplifier (op-amp).



The operational amplifier uses a +9 V / 0 / –9 V supply.

(a) Calculate the gain of the amplifier circuit. *[2]*

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(b) Determine the output potential V_{out} for values of input potential V_{in} equal to

(i) – 0.9 V. *[2]*

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(ii) + 2.0 V. *[1]*

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C3. This question is about a mobile phone network.

Describe the role of base stations and a cellular exchange when a mobile phone is switched on and before a call is made. *[5]*

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Option D — Relativity and particle physics

D1. This question is about relativistic kinematics.

(a) Define *inertial frame of reference*. *[2]*

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(b) Ann and Sue are twins. Sue remains on Earth. Ann travels to the star Sirius in a spaceship moving at a speed of 0.80 c, as measured by Sue. The distance between Earth and Sirius is 8.8 ly, as measured by Sue.

(i) Calculate the time elapsed, as measured by Sue, between Ann leaving Earth and reaching Sirius. *[1]*

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(ii) State and explain whether Ann or Sue measures the proper time between Ann leaving Earth and arriving at Sirius. *[2]*

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(iii) Calculate the time taken for the spaceship to reach Sirius, as measured by Ann. *[2]*

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(iv) As Ann approaches Sirius, she sends a radio message back to Sue. The distance between Sirius and Earth, as measured by Ann, is 5.28 ly. Determine the time, as measured by Ann, that it takes for the signal to reach Sue. *[3]*

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D2. This question is about fundamental interactions.

(a) State an exchange particle for

(i) the weak interaction. *[1]*

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(ii) the electromagnetic interaction. *[1]*

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(b) Comment, with reference to the mass of the exchange particles, on the range of the weak and electromagnetic interactions. *[2]*

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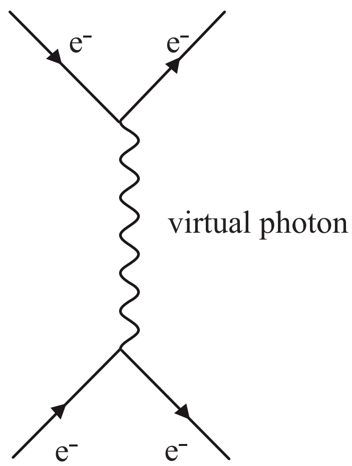
(c) Describe the process represented by the Feynman diagram below. *[1]*



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(d) State what is meant by a virtual particle. *[1]*

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(This question continues on the following page)

(Question D2 continued)

(e) Explain how the Heisenberg uncertainty principle for energy and time applies to the interaction in (c). *[2]*

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(f) The uncertainty in the time for the electromagnetic interaction between two electrons is $1.6\times10^{-16}\,\text{s}$. Determine the uncertainty in the energy of the virtual photon. *[2]*

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Option E — Astrophysics

E1. This question is about determining some properties of the star Wolf 359.

(a) The star Wolf 359 has a parallax angle of 0.419 arcseconds.

(i) Describe how this parallax angle is measured. *[4]*

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(ii) Calculate the distance in light-years from Earth to Wolf 359. *[2]*

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(iii) State why the method of parallax can only be used for stars at a distance of less than a few hundred parsecs from Earth. *[1]*

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(This question continues on the following page)

(Question E1 continued)

(b) The ratio

$$\frac{\text{apparent brightness of Wolf 359}}{\text{apparent brightness of the Sun}} \text{ is } 3.7\times10^{-15}.$$

Show that the ratio

$$\frac{\text{luminosity of Wolf 359}}{\text{luminosity of the Sun}} \text{ is } 8.9\times10^{-4}. \quad (1\,\text{ly}=6.3\times10^{4}\,\text{AU}).$$

[4]

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(c) The surface temperature of Wolf 359 is 2800 K and its luminosity is 3.5×10^{23} W. Calculate the radius of Wolf 359. *[2]*

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(d) By reference to the data in (c), suggest why Wolf 359 is neither a white dwarf nor a red giant. *[2]*

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E2. This question is about the density of the universe.

(a) Define *critical density*. *[1]*

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(b) Explain how the future of the universe may be predicted by comparing the estimated density of the universe to the critical density. *[3]*

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(c) Explain why the existence of dark matter makes it difficult to measure the density of the universe. *[1]*

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Option F — Communications

F1. This question is about modulation.

(a) A carrier wave may be amplitude modulated or frequency modulated.

State

(i) what is meant by modulation. *[1]*

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(ii) why carrier waves are modulated. *[1]*

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(b) A sinusoidal carrier wave has a frequency of 500 kHz and an amplitude of 8.0 V. The carrier wave is frequency modulated by a sinusoidal information signal of frequency 2.5 kHz and amplitude 1.2 V. The frequency deviation of the carrier wave is 15 kHz V^{-1}. Describe quantitatively the variation with time of the carrier wave. *[4]*

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F2. This question is about optic fibre transmission.

The variation with time t of the input power to an optic fibre is shown in Diagram 1. The variation with time t of the output power from the optic fibre is shown in Diagram 2.

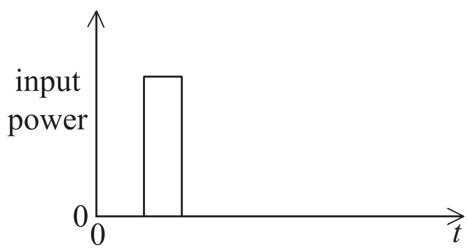

Diagram 1

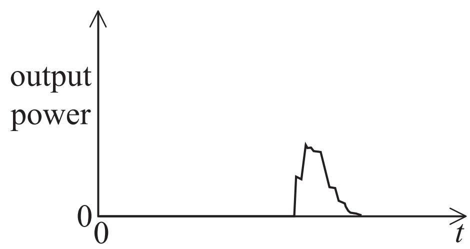

Diagram 2

The scales are the same on both diagrams.

(a) State and explain the feature of the graphs that shows that there is

(i) attenuation of the signal. *[2]*

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(ii) signal noise. *[2]*

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(b) The duration (time width) of the signal increases as it travels along the optic fibre.

(i) State **two** reasons for this increased time duration. *[2]*

1: . . . .

2: . . . .

(ii) Suggest why this increase in the width of the pulse sets a limit on the frequency of pulses that can be transmitted along an uninterrupted length of optic fibre. *[1]*

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F3. This question is about the use of satellites for communication.

(a) (i) State what is meant by a geostationary satellite. *[2]*

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(ii) Explain the advantages of the use of geostationary satellites for communication. *[2]*

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(b) Explain the advantages of the use of polar-orbiting satellites for communication. *[3]*

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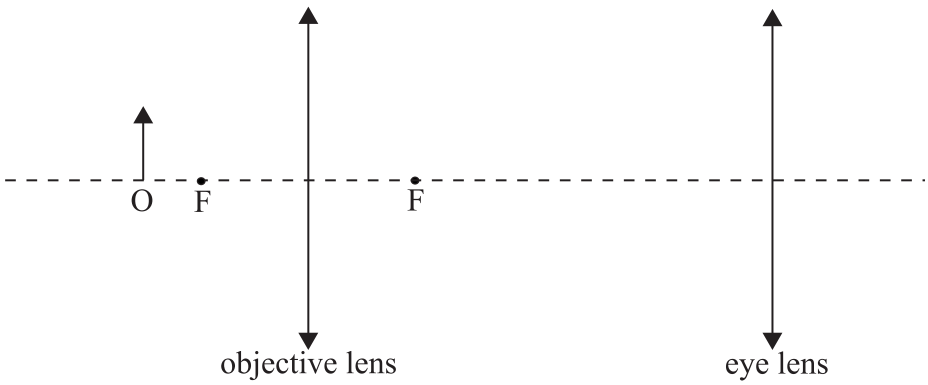
Option G — Electromagnetic waves

G1. This question is about a compound microscope, spherical aberration and chromatic aberration.

(a) An object O is placed in front of the objective lens of a compound microscope as shown below.



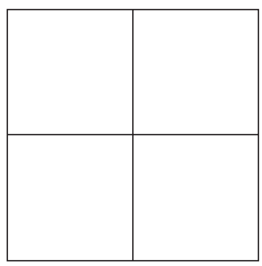
The focal points of the objective lens are at F. The microscope is in normal adjustment. Without drawing a ray diagram, label the approximate positions, on the principal axis, of

(i) the image produced by the objective lens (label this position X). *[1]*

(ii) the focal points of the eye lens (label these points E). *[1]*

(iii) the final image (label this image Y). *[1]*

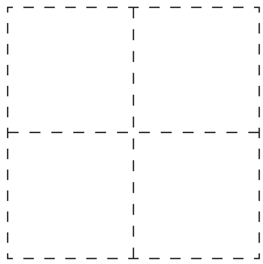
(b) An object is viewed through a convex lens that has been corrected for spherical aberration. For a particular object distance, the image of the object is as shown below.



(This question continues on the following page)

(Question G1 continued)

Another convex lens of the same focal length, but not corrected for spherical aberration, is now used to view the object. The object distance is unchanged.
In the space below, draw the image as it would be seen through this second lens.
The image as seen through the corrected lens is shown as a broken line. *[2]*



(c) Explain how chromatic aberration arises when an object is viewed through a single lens. *[2]*

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G2. This question is about the scattering of light.

(a) State an approximate wavelength for

(i) red light. *[1]*

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(ii) blue light. *[1]*

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(b) With reference to your answers in (a), discuss why the setting Sun appears reddish in colour. *[3]*

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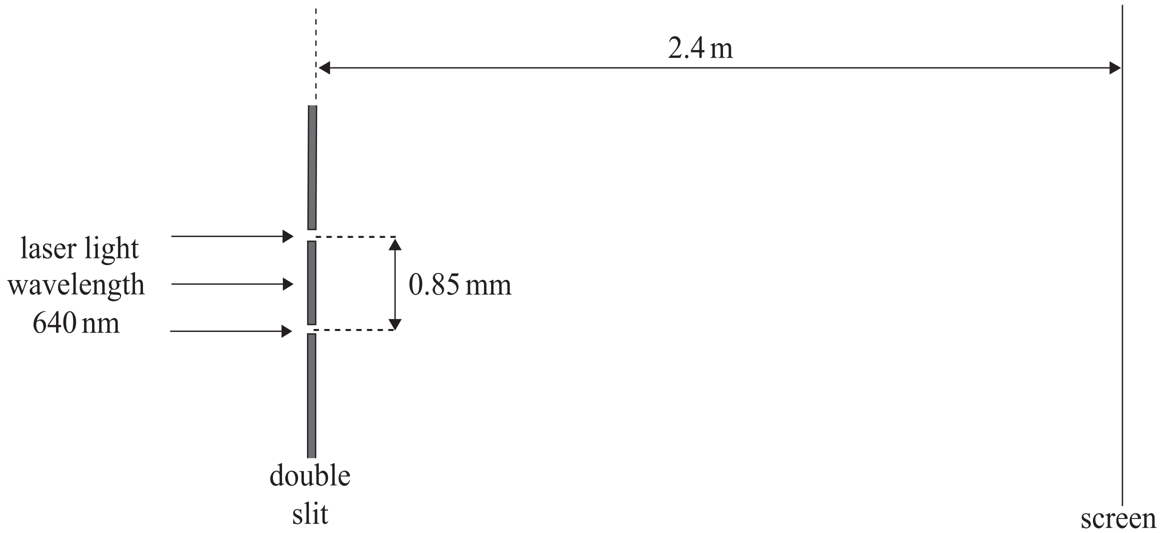
G3. This question is about two-source interference.

A double slit is arranged so that its plane is normal to a beam of laser light, as shown below.



The wavelength of the light is 640 nm. The slit separation in the double slit arrangement is 0.85 mm. Coherent light emerges from the slits and an interference pattern is observed on a screen. The screen is parallel to the plane of the double slits. The distance between the slits and the screen is 2.4 m.

(a) (i) State what is meant by coherent light. *[1]*

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(ii) Explain how an interference pattern is formed on the screen. *[3]*

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(b) Calculate the separation of the fringes in the interference pattern on the screen. *[2]*

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(This question continues on the following page)

(Question G3 continued)

(c) The interference pattern in (b) consists of a series of alternate light and dark fringes. The intensity of the light from one slit is now reduced. Suggest the effect on the appearance of the fringes. *[2]*

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