22136518

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
STANDARD LEVEL
PAPER 3

Candidate session number

0	0							

Tuesday 7 May 2013 (afternoon)

1 hour

Examination code

2	2	1	3	–	6	5	1	8

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.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[40 marks]*.

Option A — Sight and wave phenomena

A1. This question is about depth of vision.

(a) State what is meant by depth of vision for the human eye. *[1]*

. . . . . .
. . . . . .

(b) State and explain the effect on the depth of vision when the intensity of light is increased. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

A2. This question is about standing waves.

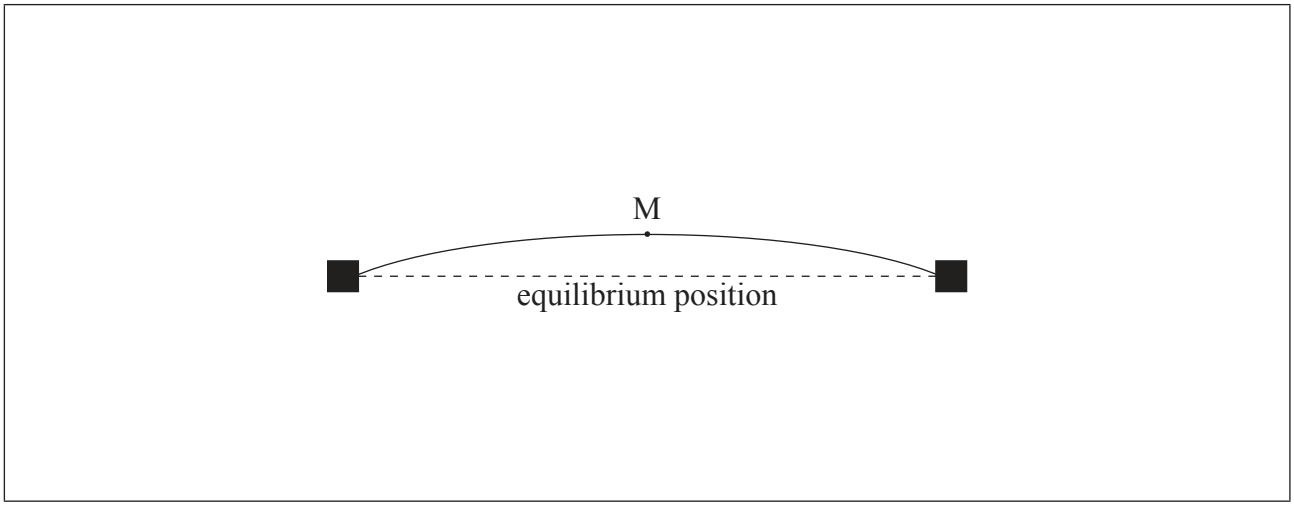
(a) State **one** difference between a standing wave and a travelling wave. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question A2 continued)

(b) A string fixed at both ends oscillates in its fundamental (first harmonic) mode. The diagram shows the displacement of the string at time $t = 0$. Point M is the point at the middle of the string.



At $t = 0$ point M is moving upwards. The frequency of oscillation is 250 Hz. On the diagram, draw

(i) an arrow to indicate the direction of acceleration of point M. *[1]*

(ii) a line to show the position of the string at a time of 2.0 ms. *[2]*

(c) Describe how the string in (b) was made to oscillate in its fundamental mode. *[1]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(d) State the frequency of oscillation of the string when it oscillates in its second harmonic. *[1]*

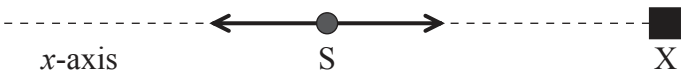
. . . . . .
. . . . . .

A3. This question is about the Doppler effect.

(a) Describe what is meant by the Doppler effect. *[1]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) A source S of sound emits sound of frequency 1.20 kHz. S executes simple harmonic oscillations along the *x*-axis. An observer X is situated on the *x*-axis as shown.

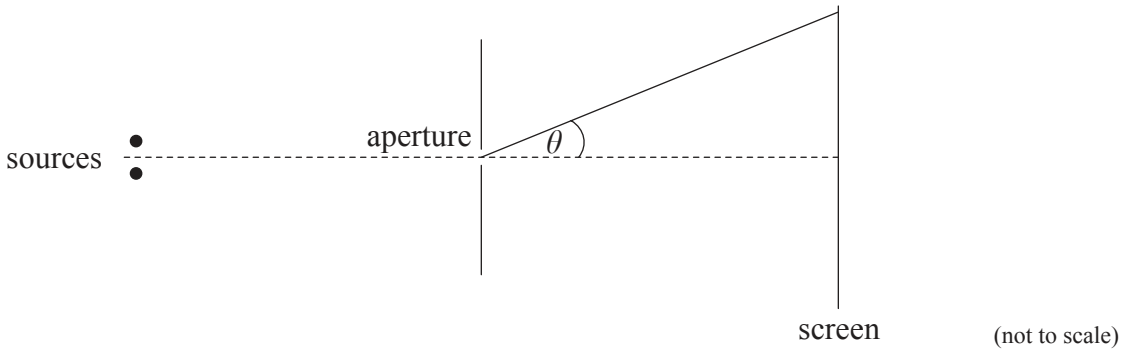


The maximum speed of S is $45\,m\,s^{-1}$. The speed of sound is $340\,m\,s^{-1}$. Determine the range of frequencies heard by the observer. *[3]*

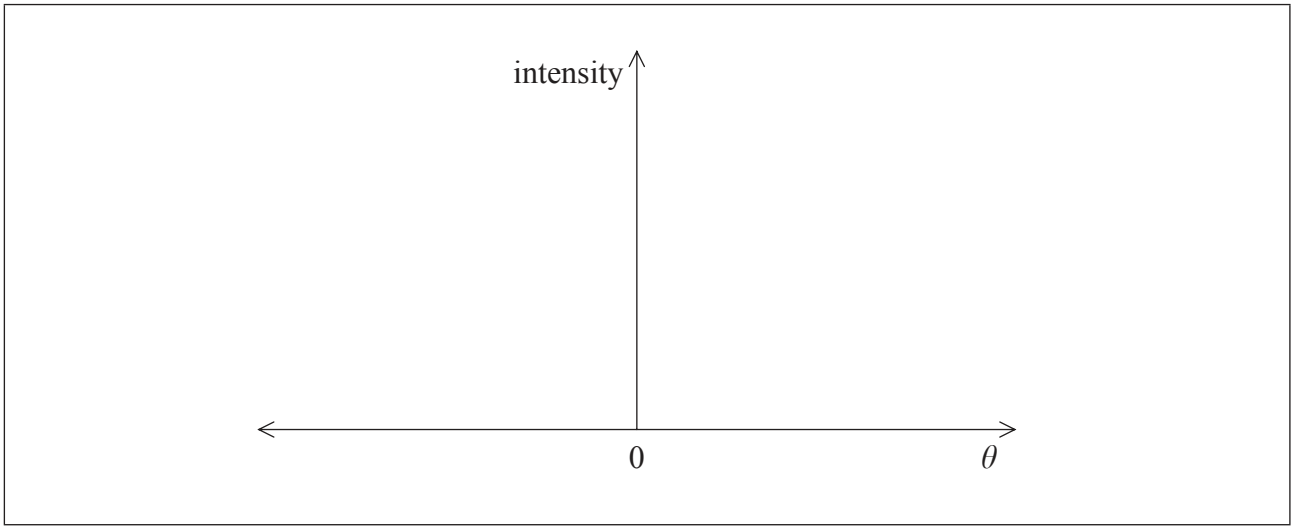
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

A4. This question is about resolution.

(a) Monochromatic light from two point sources is incident on a circular aperture. After passing through the aperture, the light is observed on a screen far from the aperture.



On the axes below, draw a graph to show the variation with angle θ of the intensity of light on the screen when the two sources are just resolved. (You do not have to put numbers on the axes.) *[2]*



(This question continues on the following page)

(Question A4 continued)

(b) Two small blue ink dots whose centres are 3.0 mm apart are made on white paper. The dots are small compared to their separation. The wavelength of blue light is 480 nm. The diameter of the pupil of a human eye is 2.1 mm.

(i) Determine the maximum distance between the eye and the paper at which the two dots are just resolved by the eye. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

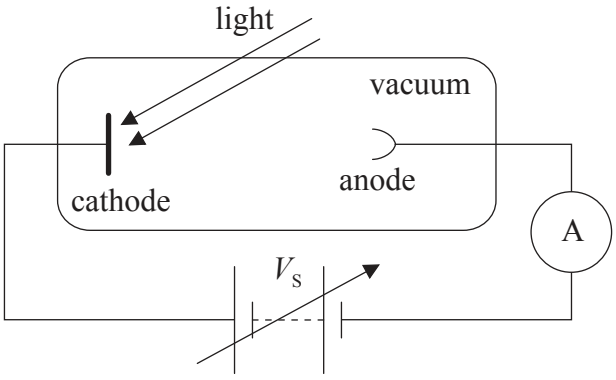
(ii) The two blue dots are now replaced by two similar red dots. Their separation is the same as that of the blue dots and the paper is held at the same distance as in (b)(i). Determine whether the dots will still be resolved. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

Option B — Quantum physics and nuclear physics

B1. This question is about the photoelectric effect.

In an investigation of the photoelectric effect, light of frequency f is incident on a metallic surface in vacuum.



It is observed that the light causes the almost simultaneous emission of electrons from the surface.

(a) Suggest why this observation

(i) cannot be explained by the wave theory of light. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

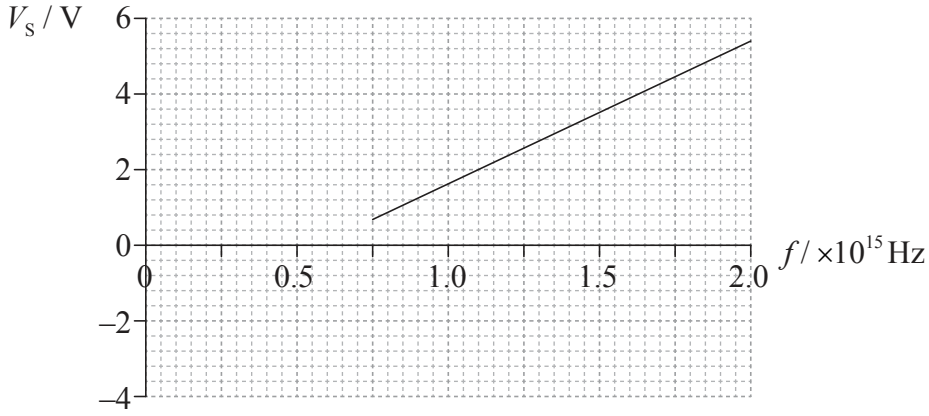
(ii) can be explained by the particle theory of light. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question B1 continued)

(b) For each frequency f of the incident light, V_S is adjusted until the current recorded is zero. The graph shows the variation of V_S with the frequency of light f.



Use the graph to calculate

(i) Planck's constant. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) the work function of the metal surface. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question B1 continued)

(iii) the de Broglie wavelength of the emitted electrons for light of frequency 1.4×10^{15} Hz. *[3]*

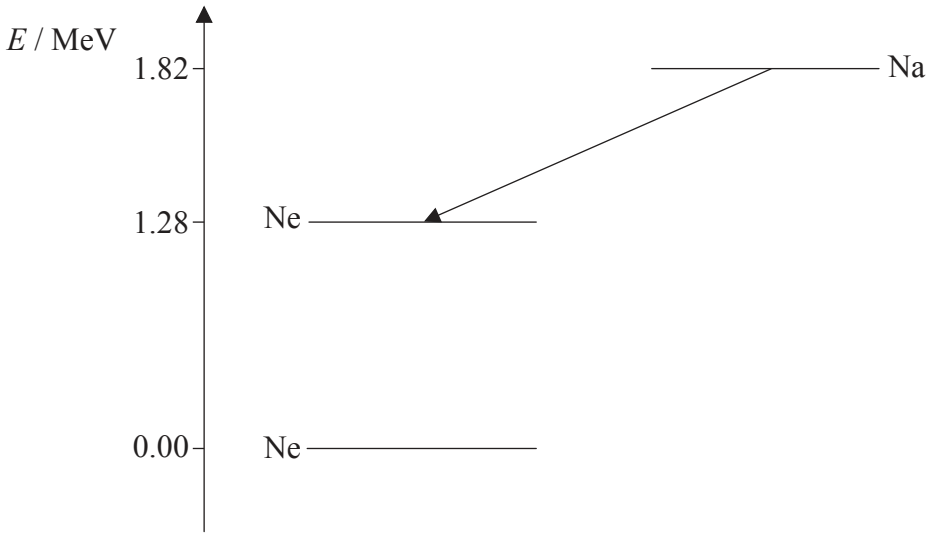
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

B2. This question is about nuclear energy levels and radioactive decay.

(a) State **one** piece of evidence that supports the existence of nuclear energy levels. *[1]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) The nuclide sodium-22 isotope undergoes beta plus (β^+) decay to the isotope neon-22. The diagram shows nuclear energy levels for $^{22}_{10}\text{Ne}$ and $^{22}_{11}\text{Na}$.



(i) Determine the energy Q released for the decay shown by the arrow. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question B2 continued)

(ii) Explain why the positron energy is not always equal to Q. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) Suggest why a photon is also emitted in this decay. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(c) The half-life of $^{22}_{11}\text{Na}$ is 2.6 years. Calculate the time, in years, after which the activity of a sample of $^{22}_{11}\text{Na}$ is 80% of its initial activity. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

Option C — Digital technology

C1. This question is about the compact disc (CD) and the charge-coupled device (CCD).

(a) Outline how information, such as music, is stored digitally on a compact disc (CD). *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) State **two** advantages of storing information digitally. *[2]*

1. . . . . .
. . . . . .
. . . . . .

2. . . . . .
. . . . . .
. . . . . .

(c) Images formed with the CCD of a digital camera are also digitized. Outline how the image in a CCD is formed. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

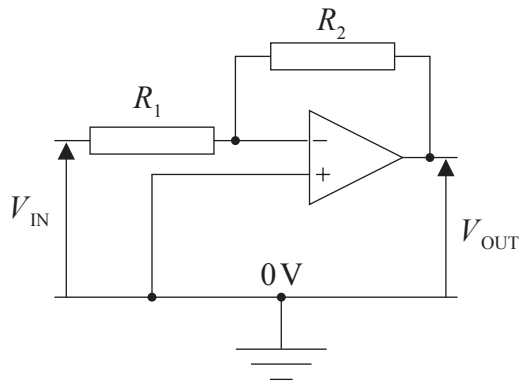
(Question C1 continued)

(d) The collecting area of a CCD has an area of $32\,mm^2$ and consists of 8.0×10^6 pixels. The magnification of the CCD is 2.4×10^{-3}. Determine whether the CCD can resolve the image of two objects that are separated by 1.2 mm. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

C2. This question is about the operational amplifier (op-amp).

(a) The diagram shows the circuit of an inverting amplifier.



(i) State what is meant by an inverting amplifier. *[1]*

. . . . . .
. . . . . .

(ii) On the diagram above, label, with the letter V, the point in the circuit that is referred to as virtual earth. *[1]*

(iii) Show that the gain G of the amplifier is given by the expression $G = -\frac{R_2}{R_1}$. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question C2 continued)

(b) In the circuit in (a) the resistance of R_1 is 6.0 kΩ and the resistance of R_2 is 60 kΩ. The amplifier operates with a ±12 V supply. Calculate the value of the output voltage V_{OUT} for an input voltage V_{IN} of

(i) 0.30 V. *[1]*

. . . . . .
. . . . . .

(ii) 3.0 V. *[1]*

. . . . . .
. . . . . .

C3. This question is about the mobile phone system.

A person makes a phone call using a mobile phone. Explain the function of the base stations and the cellular exchange during the phone call. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

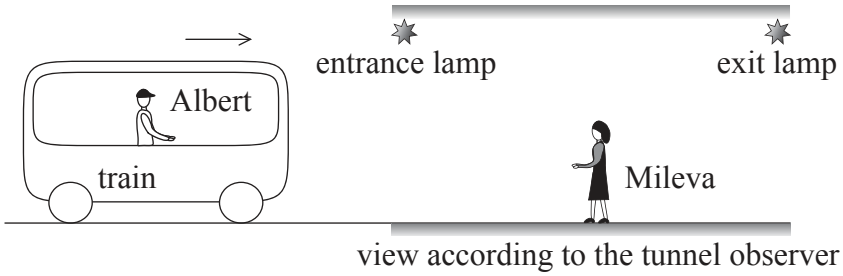
Option D — Relativity and particle physics

D1. This question is about relativistic kinematics.

(a) Define *proper length*. *[1]*

. . . . . .
. . . . . .

(b) Albert is at rest in a train approaching a tunnel. Mileva is in the tunnel mid-way between the entrance and exit lamps at the ends of the tunnel.



view according to the tunnel observer

The proper length of the train is 120 m and the proper length of the tunnel is 72 m. The train moves with speed 0.80c relative to the tunnel. Calculate the

(i) gamma factor for a speed of 0.80c. *[1]*

. . . . . .
. . . . . .

(ii) length of the train according to Mileva. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question D1 continued)

(iii) length of the tunnel according to Albert. *[1]*

. . . . . .
. . . . . .

(c) The lamps in the tunnel are switched on. According to Mileva the lamps switch on simultaneously. Explain why, according to Albert, the entrance lamp switches on after the exit lamp. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question D1 continued)

(d) The diagrams below show two events. In event 1 the train in (b) is about to exit the tunnel and in event 2 the train has just exited the tunnel. The proper length of the train is 120 m and the proper length of the tunnel is 72 m.

Event 1 Event 2

Determine the time between these two events according to

(i) Mileva. *[1]*

. . . . . .
. . . . . .
. . . . . .

(ii) Albert. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.

D2. This question is about quarks and interactions.

(a) Distinguish between the quark structure of a baryon and a meson. *[1]*

. . . . . .
. . . . . .

(b) Calculate the magnitude of the smallest non-zero spin that a particle can have. *[1]*

. . . . . .
. . . . . .

(c) (i) State the Pauli exclusion principle. *[1]*

. . . . . .
. . . . . .

(ii) The hadron Δ^{++} consists of three u quarks and has spin $\frac{3}{2}$.

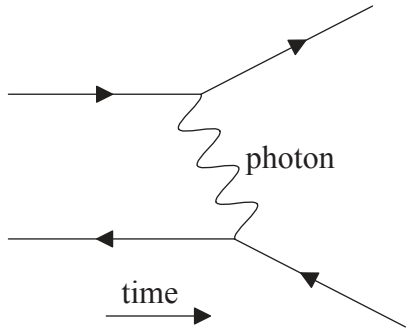
Explain how it is possible for the quarks in Δ^{++} not to violate the Pauli principle. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question D2 continued)

(d) The Feynman diagram represents the electromagnetic scattering of an electron and a positron.



(i) Identify a positron on the diagram by labelling it with e^+. *[1]*

(ii) State and explain the range of the interaction. *[2]*

. . . . . .

. . . . . .

(e) The following reactions have never been observed. For each reaction state **one** conservation law that would be violated if the reactions were to occur. *[2]*

$e^+ + e^+ \rightarrow p^+ + p^+$ . . . . . .

$e^- + \nu \rightarrow e^+ + \overline{\nu}$ . . . . . .

Option E — Astrophysics

E1. This question is about stars.

(a) Define *absolute magnitude*. *[1]*

. . . . . .
. . . . . .

(b) The table shows data for two stars, X and Y.

	Apparent brightness / W m^{-2}	**Absolute magnitude**
Star X	2.5×10^{-8}	–5.4
Star Y	8.1×10^{-9}	–6.3

Use the data to explain which star

(i) appears brighter from Earth. *[1]*

. . . . . .
. . . . . .

(ii) is closer to Earth. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question E1 continued)

(c) The luminosity of star X is 4.9×10^{30} W and its spectral class is M.

(i) Determine the distance of star X from Earth. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Estimate the radius of star X. *[3]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) Suggest the type of star X. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question E1 continued)

(d) Outline how a study of the spectrum of star X gives information about its chemical composition. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

E2. This question is about cosmology.

(a) Cosmic microwave background radiation was discovered by Penzias and Wilson in 1964. State **two** characteristics of the cosmic microwave background radiation. *[2]*

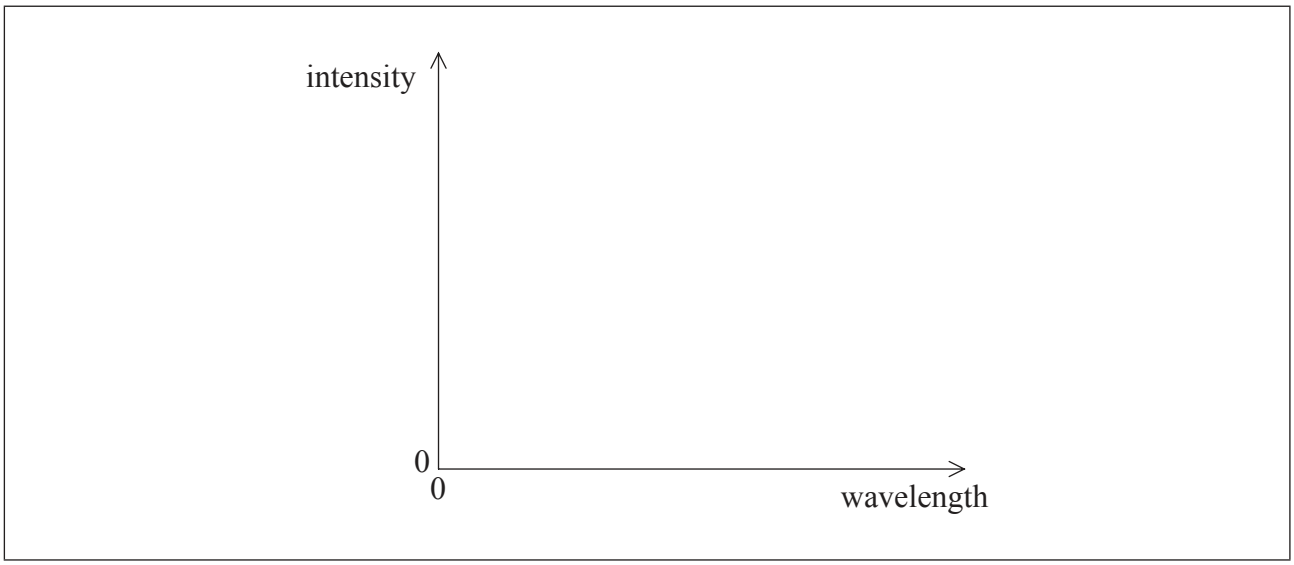
1. . . . . .
. . . . . .

2. . . . . .
. . . . . .

(This question continues on the following page)

(Question E2 continued)

(b) (i) Using the axes below, sketch a graph to show the variation with wavelength of the intensity of the cosmic background radiation. *[2]*



(ii) Explain how the graph may be used to determine the temperature of the cosmic background radiation. *[2]*

. . . . . .
. . . . . .

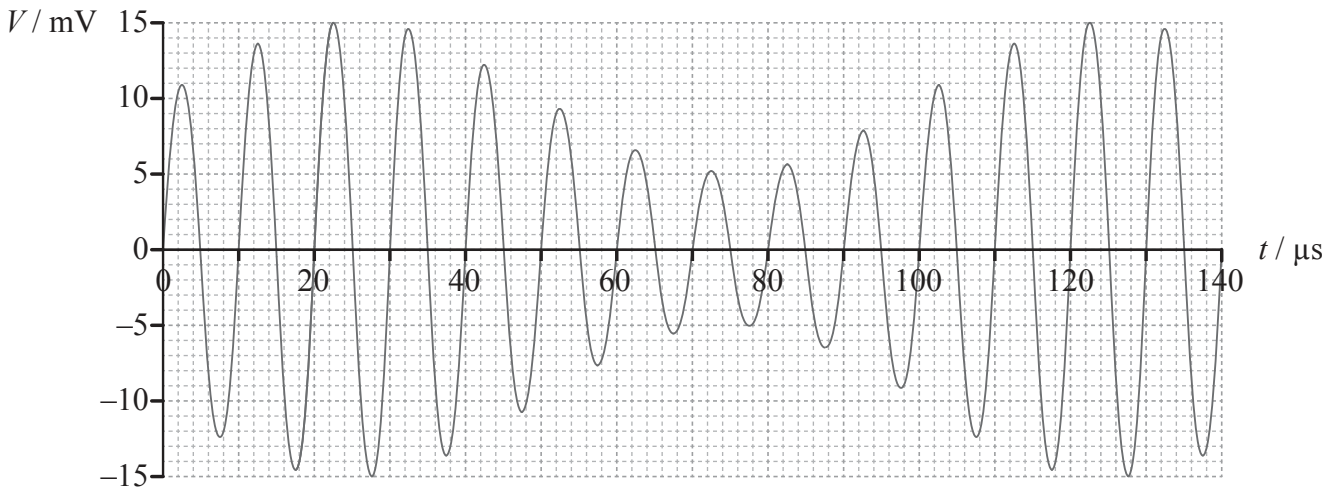
(iii) Discuss how the discovery of the cosmic background radiation provides evidence for the Big Bang. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

Option F — Communications

F1. This question is about modulation.

(a) The diagram shows the variation with time of the voltage of an amplitude modulated (AM) carrier wave.



Determine the

(i) frequency of the carrier wave. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) frequency of the signal (information) wave. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question F1 continued)

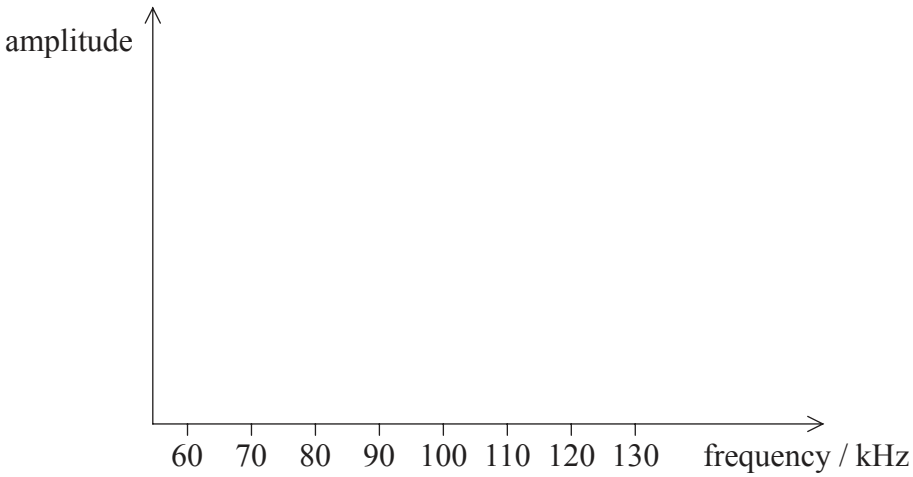
(iii) bandwidth of the signal. *[1]*

. . . . . .
. . . . . .

(iv) amplitude of the signal wave. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) Using the axes below, draw the power spectrum of the modulated carrier wave in (a). *[2]*



F2. This question is about digital transmission.

The sampling frequency in an analogue-to-digital converter (ADC) is 44 kHz.

(a) By reference to the reconstruction of an analogue signal, state and explain the maximum frequency that can be used by this system. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(b) The ADC produces a 32 bit parallel output. Calculate the

(i) bit rate of the transmission. *[1]*

. . . . . .

(ii) duration of one bit. *[1]*

. . . . . .

F3. This question is about attenuation.

(a) For a copper cable, state

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

. . . . . .
. . . . . .

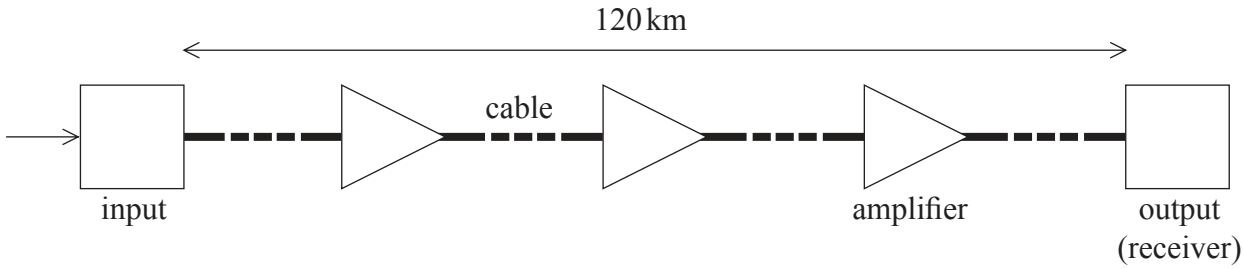
(ii) **one** cause of attenuation in the copper cable. *[1]*

. . . . . .
. . . . . .

(This question continues on the following page)

(Question F3 continued)

(b) A copper cable of length 120 km is used to transmit a signal. The attenuation per unit length of the cable is 15 dB km^{-1}. Amplifiers, each of gain 52 dB, are placed at equal intervals along the cable.



The power of the input signal is 240 mW. The output signal power must not fall below 12 mW.

(i) Estimate the total number of amplifiers needed. *[4]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

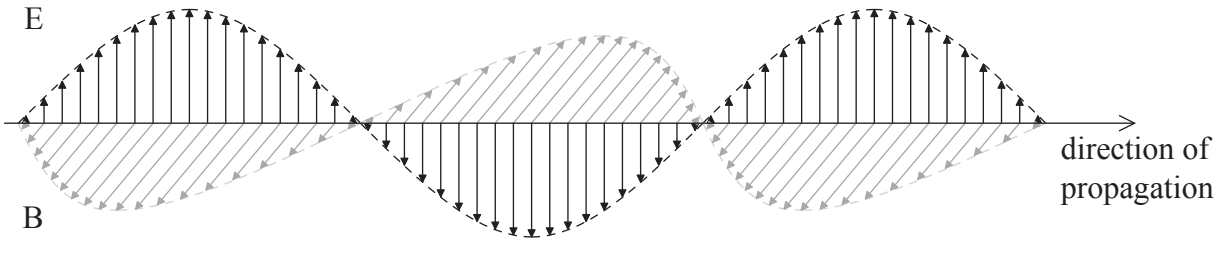
(ii) State **one** advantage in replacing the cable with an optic fibre. *[1]*

. . . . . .
. . . . . .

Option G — Electromagnetic waves

G1. This question is about light.

(a) The diagram is a representation of the oscillating electric (E) and magnetic (B) fields in an electromagnetic wave in vacuum. The fields are perpendicular to each other.



(i) State the change, if any, in the angle between E and B when the wave enters a transparent medium from vacuum. *[1]*

. . . . . .
. . . . . .

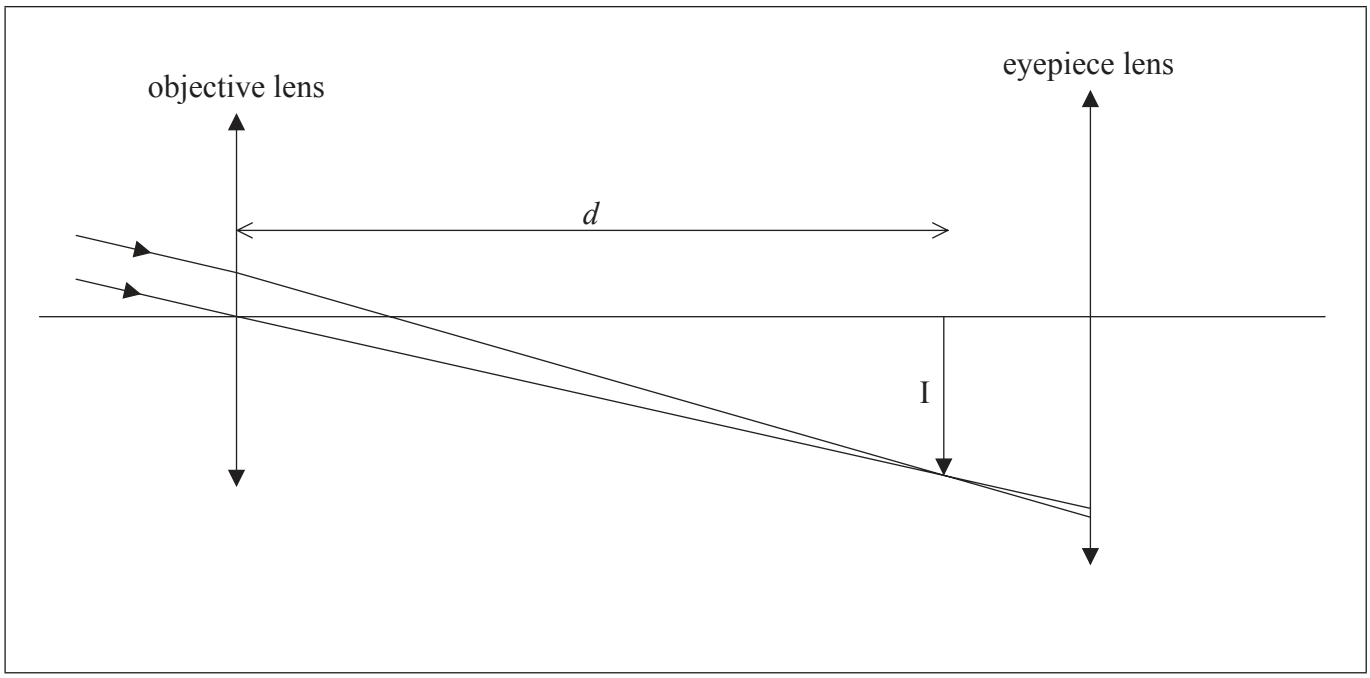
(ii) On the diagram, label a distance that is equal to one wavelength of this electromagnetic wave. *[1]*

(b) State **one** common property of all electromagnetic waves. *[1]*

. . . . . .
. . . . . .

G2. This question is about an astronomical telescope.

(a) The diagram is a partially completed ray diagram for an astronomical telescope.



The image I of a star is formed by the objective lens at a distance d from the objective lens. The final image of the star is formed at infinity.

(i) Show that the distance d is equal to the focal length of the objective lens. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) On the diagram, label the **two** focal points of the eyepiece lens with the letters F_1 and F_2 respectively. *[1]*

(iii) On the diagram, construct lines to show how the final image of the star is formed at infinity. *[3]*

(iv) The angular magnification of the telescope is defined as $M = \frac{\theta_2}{\theta_1}$. On the diagram, label the angles θ_1 and θ_2. *[1]*

(This question continues on the following page)

(Question G2 continued)

(b) In a particular astronomical telescope in normal adjustment, the focal length of the objective lens is 26 cm and the focal length of the eyepiece lens is 4.0 cm. The telescope is used to view a distant weather balloon whose angular diameter with a naked eye is 2.2°. Determine the angular diameter of the image of the weather balloon formed by the telescope. *[2]*

. . . . . .

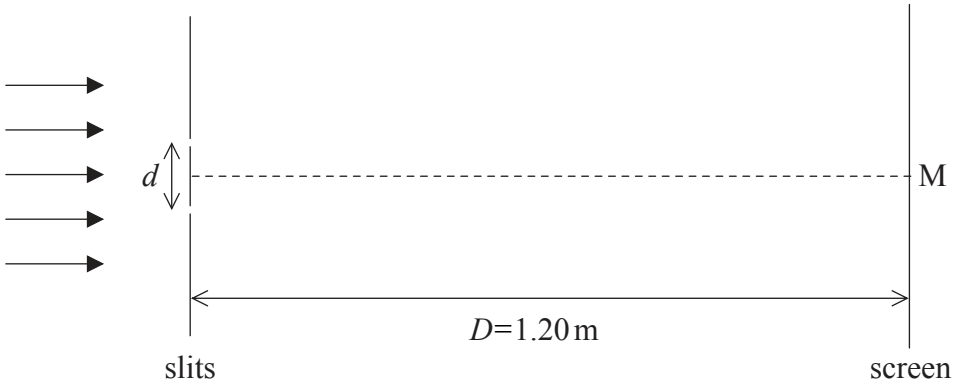
. . . . . .

. . . . . .

. . . . . .

G3. This question is about interference.

(a) Coherent monochromatic light is incident normally on two very narrow, parallel slits whose width is small compared to their separation. After the light passes through the slits it is incident on a screen. The mid-point of the screen is at M.



The distance D between the slits and the screen is 1.20 m. The slit separation d is 0.150 mm.

(i) Explain why the intensity of the light at M is a maximum. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .

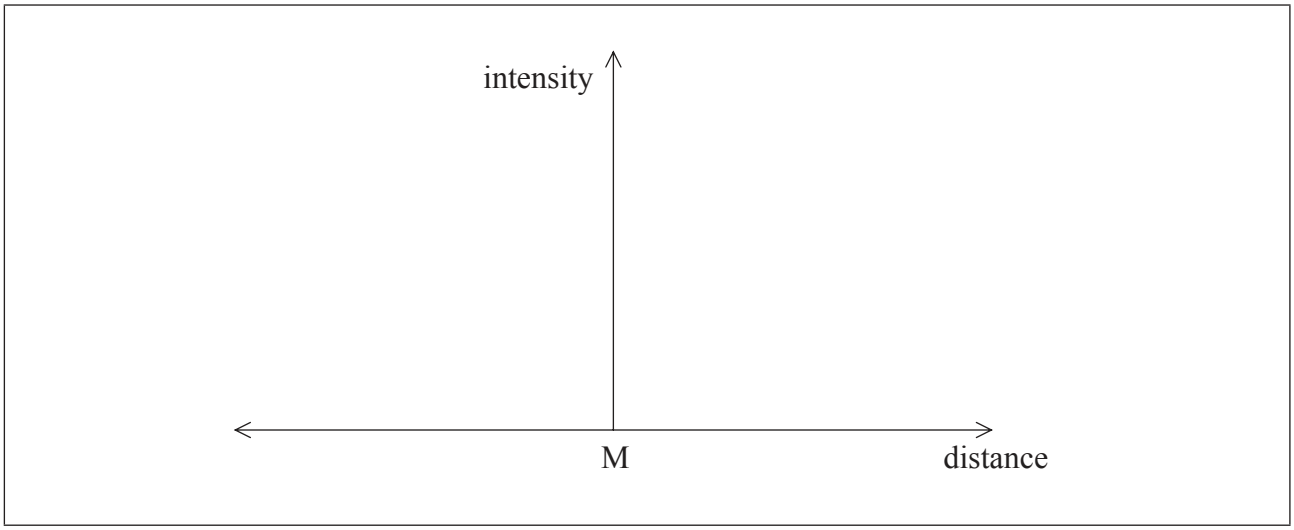
(ii) Point P is the closest point to M on the screen where the light intensity is a minimum. The distance MP is 2.62 mm. Calculate the wavelength of light. *[2]*

. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(This question continues on the following page)

(Question G3 continued)

(b) Using the axes below, sketch a graph to show the variation with distance along the screen of the light intensity. *[2]*



(c) The number of slits is greatly increased, each with the same separation as in (a). Describe the differences, if any, in the intensity distribution in (b). *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Please **do not** write on this page.

Answers written on this page
will not be marked.