22116518

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
STANDARD LEVEL
PAPER 3

Candidate session number

0	0							

Thursday 12 May 2011 (morning)

1 hour

Examination code

2	2	1	1	–	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.

0132

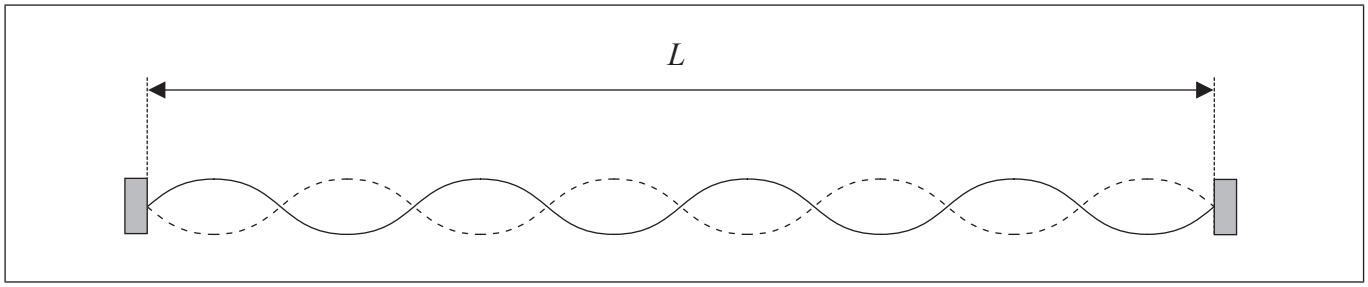
Please **do not** write on this page.

Answers written on this page
will not be marked.

Option A — Sight and wave phenomena

A1. This question is about standing (stationary) waves.

The diagram represents a standing wave of wavelength λ set up on a string of length L.



The string is fixed at both ends.

(a) For this standing wave

(i) state the relationship between λ and L. *[1]*

. . . . . .

(ii) label, on the diagram, **two** antinodes where the string is vibrating in phase. Label the antinodes with the letter A. *[2]*

(b) The standing wave has wavelength λ and frequency f. State and explain, with respect to a standing wave, what is represented by the product $f\lambda$. *[3]*

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

A2. This question is about the eye and resolution.

A student measures the aperture of the iris of one of her eyes as 2.0 mm in sunlight and 7.0 mm in moonlight. The intensity at her eye of sunlight is 10^6 times greater than the intensity of moonlight.

(a) (i) Determine the following ratio. *[3]*

$$\frac{\text{power of light entering the eye in sunlight}}{\text{power of light entering the eye in moonlight}}$$

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

(ii) Suggest why your answer in (a)(i) indicates that the change in diameter of the iris is not the principal mechanism by which the eye is able to adjust to different light intensities. *[1]*

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

(This question continues on the following page)

(Question A2 continued)

(b) (i) State the Rayleigh criterion. *[2]*

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

(ii) Suggest, with reference to the Rayleigh criterion, whether the ability of the eye to resolve the image of two objects is greater in sunlight **or** in moonlight. *[4]*

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

(c) Outline the different functions of the rods and the cones on the retina of the eye in their response to sunlight and to moonlight. *[4]*

Rods: . . . . . .
. . . . . .
. . . . . .
. . . . . .

Cones: . . . . . .
. . . . . .
. . . . . .
. . . . . .

Option B — Quantum physics and nuclear physics

B1. This question is about the photoelectric effect.

(a) State what is meant by the photoelectric effect. *[1]*

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

(b) Light of frequency $8.7 \quad 10^{14}$ Hz is incident on the surface of a metal in a photocell. The surface area of the metal is $9.0 \quad 10^{-6}\,m^2$ and the intensity of the light is $1.1 \quad 10^{-3}\,W\,m^{-2}$.

(i) Deduce that the maximum possible photoelectric current in the photocell is 2.7 nA. *[3]*

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

(ii) The maximum kinetic energy of photoelectrons released from the metal surface is 1.2 eV. Calculate the value of the work function of the metal. *[1]*

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

B2. This question is about the de Broglie hypothesis.

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

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

(b) Determine the de Broglie wavelength of a proton that has been accelerated from rest through a potential difference of 1.2 kV. *[2]*

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

(c) Explain why a precise knowledge of the de Broglie wavelength of the proton implies that its position cannot be observed. *[2]*

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

B3. This question is about radioactive decay.

Nitrogen-13 $\left({}^{13}_{7}\mathrm{N}\right)$ is an isotope that is used in medical diagnosis. The decay constant of nitrogen-13 is 1.2 $10^{-3}\,\mathrm{s}^{-1}$.

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

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

(ii) A sample of nitrogen-13 has an initial activity of 800 Bq. The sample cannot be used for diagnostic purposes if its activity becomes less than 150 Bq. Determine the time it takes for the activity of the sample to fall to 150 Bq. *[2]*

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

(b) (i) Calculate the half-life of nitrogen-13. *[1]*

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

(This question continues on the following page)

(Question B3 continued)

(ii) Outline how the half-life of a sample of nitrogen-13 can be measured in a laboratory. *[3]*

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

(c) Nitrogen-13 undergoes β^+ decay. Outline the experimental evidence that suggests another particle, the neutrino, is also emitted in the decay. *[2]*

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

Option C — Digital technology

C1. This question is about digital sampling.

(a) A compact disc stores music in digital form. The music is sampled at a frequency of 44.1 kHz. Each sample consists of two 16-bit words.

(i) State what is meant by digital form. *[1]*

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

(ii) The disc stores music that takes one hour for playback. Determine the minimum number of bits that are stored on the disc. *[2]*

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

(b) A page from a book has 45 lines of writing. Each line of the book has, on average, 65 letters and spaces. The text of the book is to be stored on compact disc where each letter or space on a line is represented by an eight-bit number. Determine the number of pages of text that can be stored on a compact disc similar to that in (a). *[2]*

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

C2. This question is about a digital camera.

(a) By reference to what is meant by a pixel, describe the structure of a charge-coupled device (CCD). *[3]*

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

(b) The CCD in a camera has an area of $16\,cm^2$ and is divided into 5.6 megapixels. The camera is used to take a photograph with a linear magnification of 0.030.

(i) Calculate the separation of pixels on the CCD. *[2]*

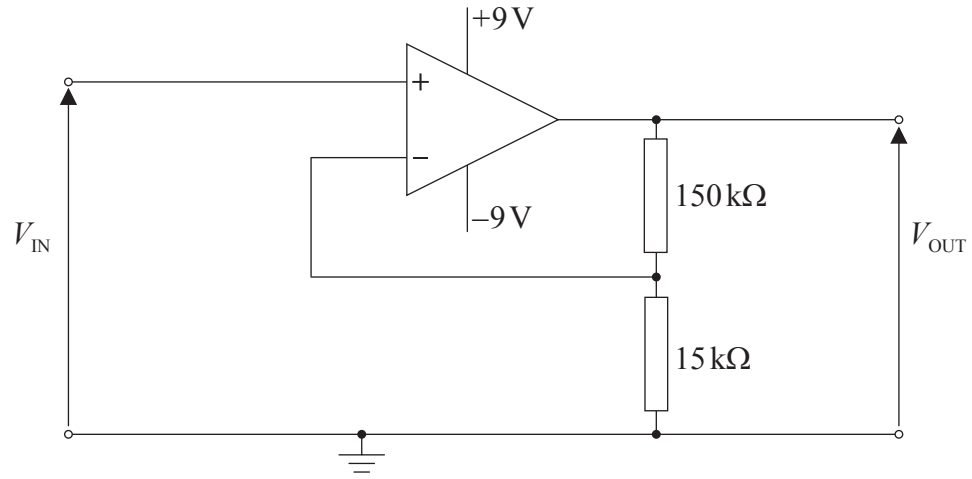
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(ii) Determine the minimum separation of two points on an object such that they may be seen separately on the image. Diffraction effects at the lens may be ignored. *[2]*

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

C3. This question is about an operational amplifier (op-amp) circuit.

The circuit diagram is for a non-inverting amplifier.



The operational amplifier is ideal.

Calculate the

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

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

(b) input potential V_{IN} at which the amplifier saturates. *[2]*

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

C4. This question is about a mobile phone network.

Describe the role of the cellular exchange during the making of a call from a mobile phone. *[4]*

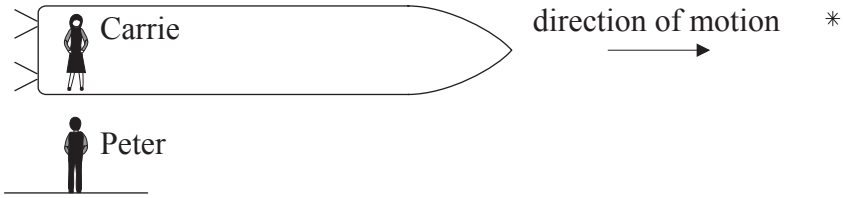
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

Option D — Relativity and particle physics

D1. This question is about relativity.

Carrie is in a spaceship that is travelling towards a star in a straight-line at constant velocity as observed by Peter. Peter is at rest relative to the star.

(a) Carrie measures her spaceship to have a length of 100 m. Peter measures Carrie's spaceship to have a length of 91 m.



(i) Explain why Carrie measures the proper length of the spaceship. *[1]*

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

(ii) Show that Carrie travels at a speed of approximately 0.4 c relative to Peter. *[2]*

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

(This question continues on the following page)

(Question D1 continued)

(b) According to Carrie, it takes the star ten years to reach her. Using your answer to (a)(ii), calculate the distance to the star as measured by Peter. *[2]*

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

(c) According to Peter, as Carrie passes the star she sends a radio signal. Determine the time, as measured by Carrie, for the message to reach Peter. *[3]*

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

D2. This question is about a light clock.

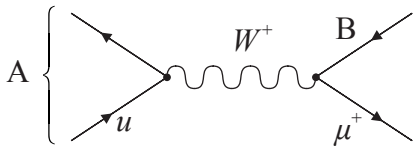
Describe the principle of a light clock. *[2]*

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

D3. This question is about quarks.

The quark content of a π^+ meson includes an up quark.

The Feynman diagram represents the decay of a π^+ meson.



(a) Identify the particles labelled A and B. *[2]*

A: . . . . . .

B: . . . . . .

(b) State, with reference to their properties, **two** differences between a photon and a W boson. *[2]*

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

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

(c) The approximate range of the weak interaction is 10^{-18} m. Determine, in kg, the likely mass of the W boson. *[2]*

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

D4. This question is about strangeness.

(a) Outline **two** properties of strangeness. *[2]*

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

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

(b) The following particle interaction is proposed.

$$p + \pi^- \rightarrow K^- + \pi^+$$

In this interaction, charge is conserved.

State, in terms of baryon and strangeness conservation, whether the interaction is possible. *[2]*

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

Option E — Astrophysics

E1. This question is about the properties of a star.

(a) Describe what is meant by a

(i) constellation. *[2]*

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

(ii) stellar cluster. *[1]*

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

(This question continues on the following page)

(Question E1 continued)

(b) Some data for the variable star Betelgeuse are given below.

Average absolute magnitude $= -5.1$
Average apparent magnitude $= +0.60$
Average apparent brightness $= 1.6 \quad 10^{-7}\,\text{W m}^{-2}$
Radius $= 790$ solar radii

The luminosity of the Sun is $3.8 \quad 10^{26}\,\text{W}$ and it has a surface temperature of 5700 K.

(i) Show that the distance from Earth to Betelgeuse is about $4 \quad 10^{18}\,\text{m}$. *[3]*

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

(ii) Determine, in terms of the luminosity of the Sun, the luminosity of Betelgeuse. *[2]*

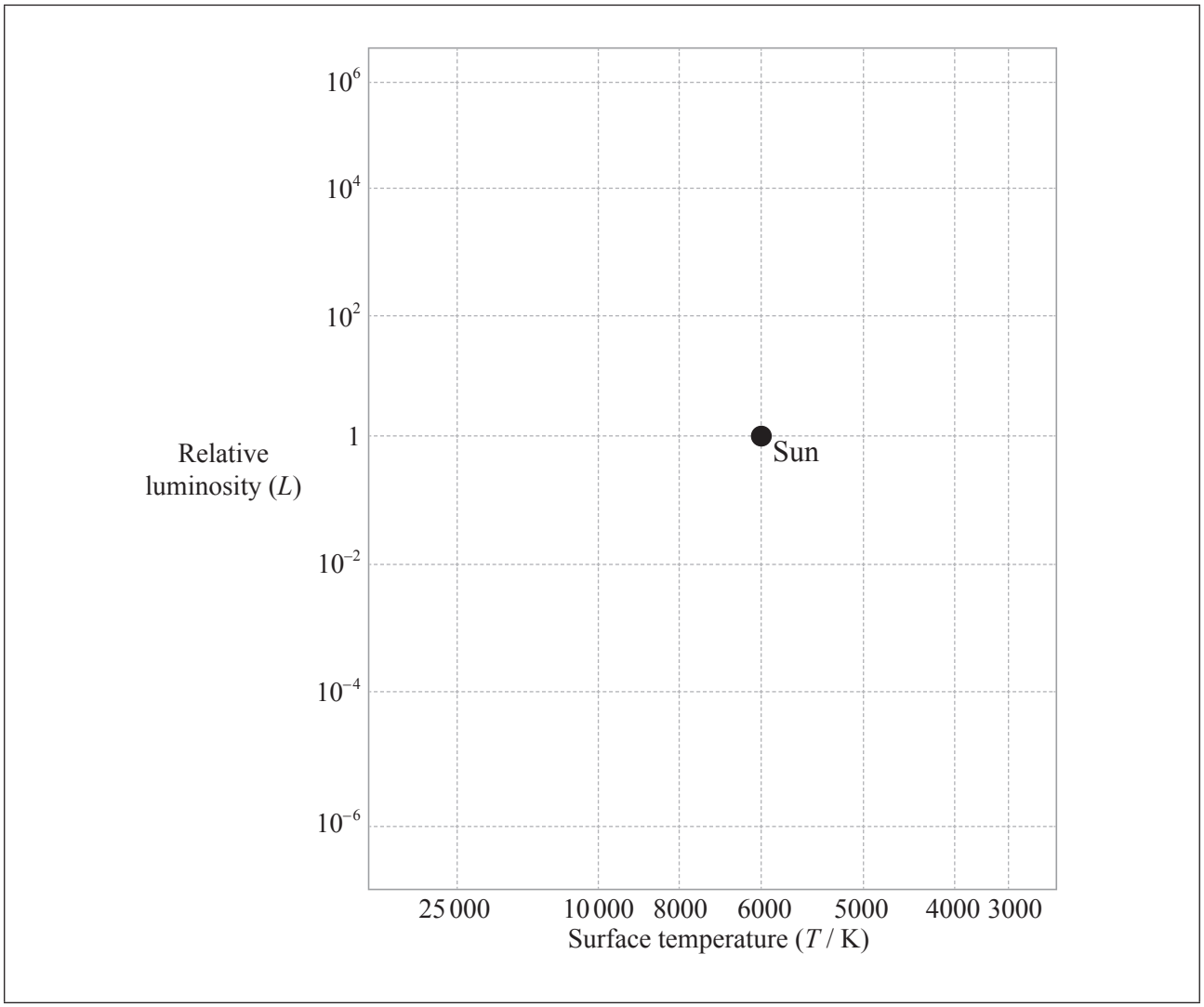
. . . . . .
. . . . . .
. . . . . .
. . . . . .

(iii) Calculate the surface temperature of Betelgeuse. *[2]*

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

(This question continues on the following page)

(Question E1 continued)



(c) On the Hertzsprung–Russell diagram above,

(i) label the position of Betelgeuse with the letter B. *[1]*

(ii) sketch the position of main sequence stars. *[1]*

(This question continues on the following page)

(Question E1 continued)

(d) Some stars, such as Betelgeuse, are in combination with a companion star forming a spectroscopic binary system. Describe and explain the characteristics of a spectroscopic binary system. *[3]*

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

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

(a) Explain, with reference to the possible fate of the universe, the significance of the critical density of matter in the universe. *[3]*

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

(b) Suggest **one** reason why it is difficult to estimate the density of matter in the universe. *[2]*

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

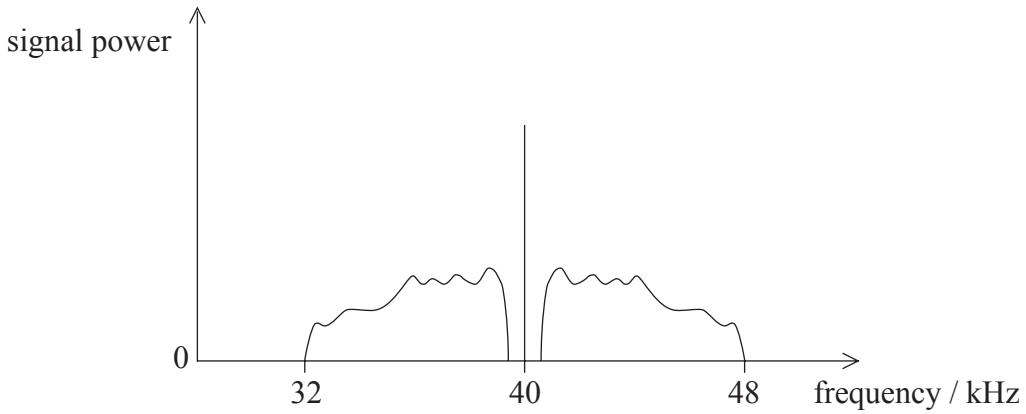
Option F — Communications

F1. This question is about modulation.

(a) Outline what is meant by the modulation of a wave. *[2]*

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

(b) The frequency spectrum of the signal from a radio transmitter is shown below.



(i) State the name of this form of radio transmission. *[1]*

. . . . . .

(ii) State the frequency of the carrier wave. *[1]*

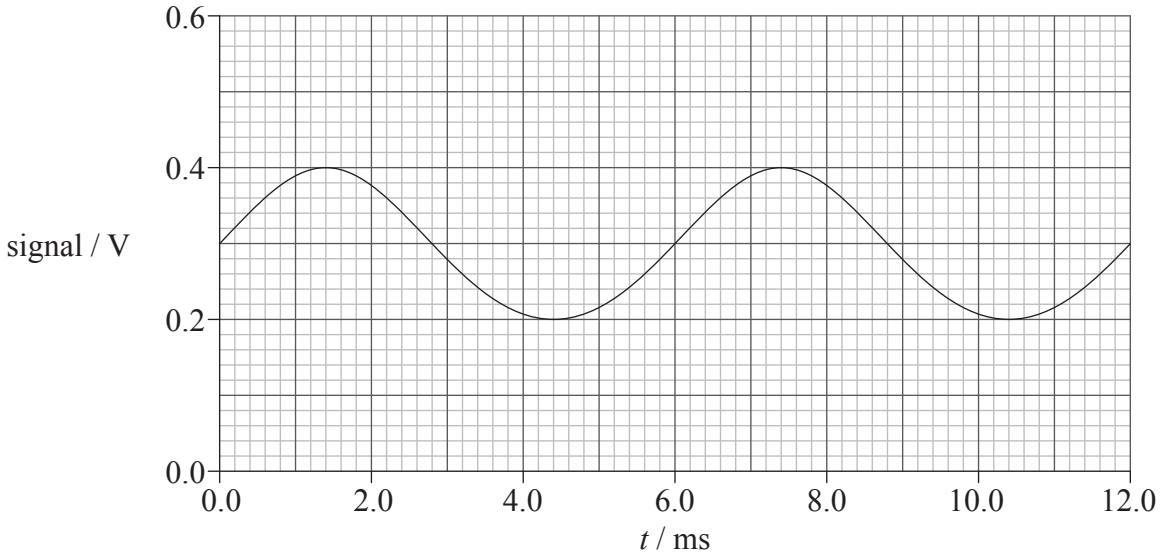
. . . . . .

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

. . . . . .

F2. This question is about the transmission of signals.

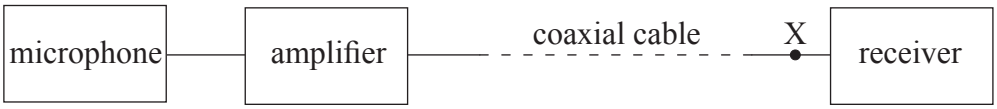
The signal from a microphone is amplified and then transmitted to a distant receiver. The variation with time t of the amplified signal before transmission is shown below.



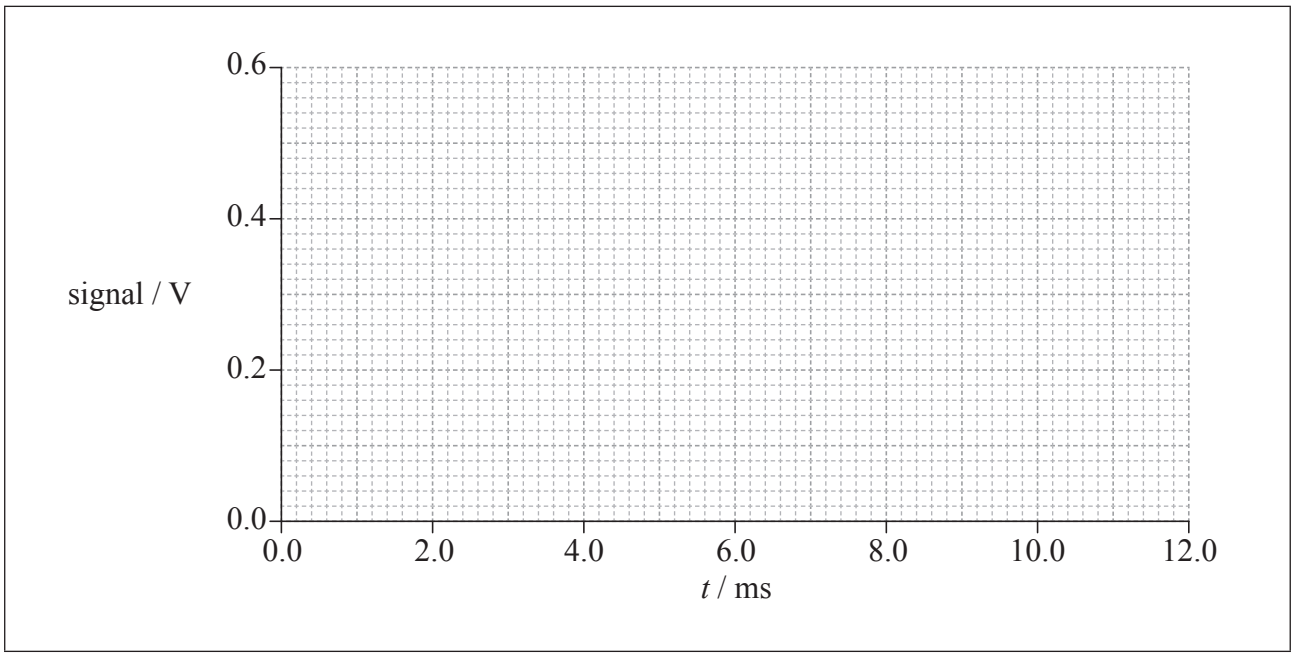
(This question continues on the following page)

(Question F2 continued)

(a) The amplified signal is transmitted using a coaxial cable as illustrated.



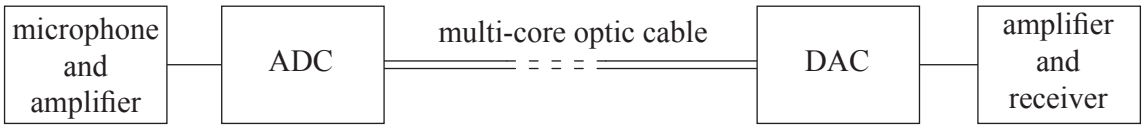
On the axes below, sketch the waveform of the signal at point X after transmission along the coaxial cable. *[3]*



(This question continues on the following page)

(Question F2 continued)

(b) A second transmission system, as shown below, uses a cable containing many separate fibres (multi-core optic cable).



(i) Suggest why a multi-core optic cable is required rather than a single-core optic fibre. *[1]*

. . . . . .

(ii) State what circuits should be included in the transmission system so that a single-core optic fibre may be used. *[1]*

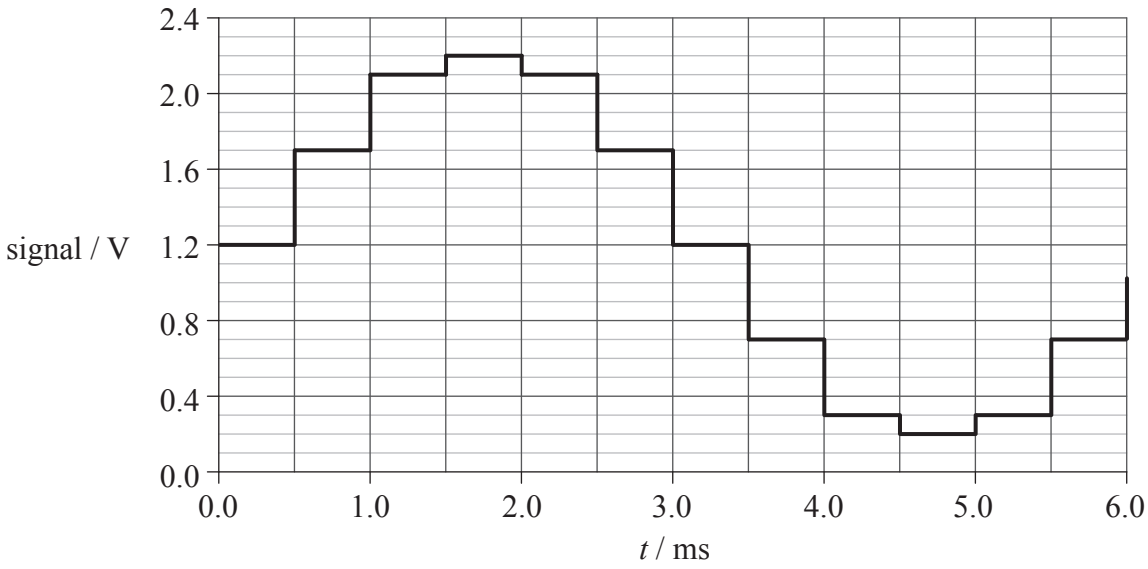
. . . . . .

. . . . . .

(This question continues on the following page)

(Question F2 continued)

(c) The received signal of the second transmission system is shown below.



Calculate the

(i) minimum number of output bits of the ADC. *[2]*

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

(ii) sampling frequency of the ADC. *[2]*

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

(This question continues on the following page)

(Question F2 continued)

(d) State **one** advantage and **one** disadvantage of the coaxial cable transmission as compared with the fibre optic cable. *[2]*

Advantage: . . . . . .

. . . . . .

Disadvantage: . . . . . .

. . . . . .

F3. This question is about signal power and attenuation.

An optic fibre in a telephone system has length 48 km. The noise power in the optic fibre is 2.5 10^{-18} W.

(a) The signal-to-noise ratio is not to fall below 25 dB. Show that the minimum signal power in the fibre is 7.9 10^{-16} W. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The attenuation per unit length of the signal in the fibre is 2.7 dB km^{-1}. Use the data in (a) to determine the power of the input signal to the fibre so that the signal-to-noise ratio does not fall below 25 dB. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option G — Electromagnetic waves

G1. This question is about properties of electromagnetic waves.

(a) State **two** properties that are common to all electromagnetic waves. *[2]*

1. . . . . .

2. . . . . .

(b) A single lens is used to form a magnified real image of an object. Explain, with reference to the dispersion of light, why the image has coloured edges. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Outline why a clear sky is blue in colour. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

G2. This question is about a converging lens.

(a) Define *angular magnification*. *[2]*

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

(b) A thin converging lens of focal length 4.5 cm is to be used as a magnifying glass. The observer places the lens close to her eye. The least distance of distinct vision is 24 cm.

(i) Show that the distance of the object from the lens is 3.8 cm. *[1]*

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

(ii) Determine the angular magnification produced by the lens. *[4]*

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

(This question continues on the following page)

(Question G2 continued)

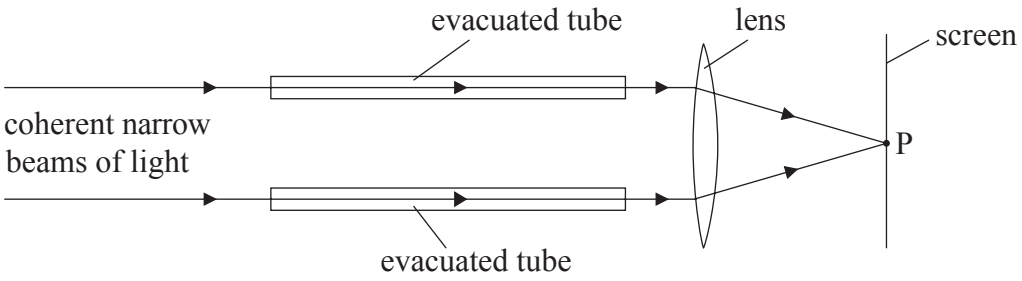
(c) Suggest **two** reasons why, for high magnifications, a combination of lenses is used rather than a single lens. *[2]*

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

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

G3. This question is about interference of light.

Two coherent narrow beams of light pass through two identical evacuated tubes, as shown below.



The two coherent narrow beams are brought to a focus at point P on a screen.

(a) State what is meant by coherence. *[1]*

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

(This question continues on the following page)

(Question G3 continued)

(b) State, with reference to the wavelength, the condition that must be satisfied for a bright fringe to be formed on the screen at point P. *[1]*

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

(c) Air is allowed to enter gradually into one of the evacuated tubes. The brightness of the light at point P is seen to decrease and then increase again repeatedly.

(i) State the effect on the wavelength of the light in the evacuated tube as the air is introduced. *[1]*

. . . . . .

(ii) Suggest why there is a variation in the brightness of the light at point P. *[1]*

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