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PHYSICS
STANDARD LEVEL
PAPER 3

Candidate session number

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Friday 11 May 2012 (morning)

1 hour

Examination code

2	2	1	2	–	6	5	1	2

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]*.

0136

Option A — Sight and wave phenomena

A1. This question is about colour vision.

(a) State which type of receptor cell in the eye is responsible for detection of colour. *[1]*

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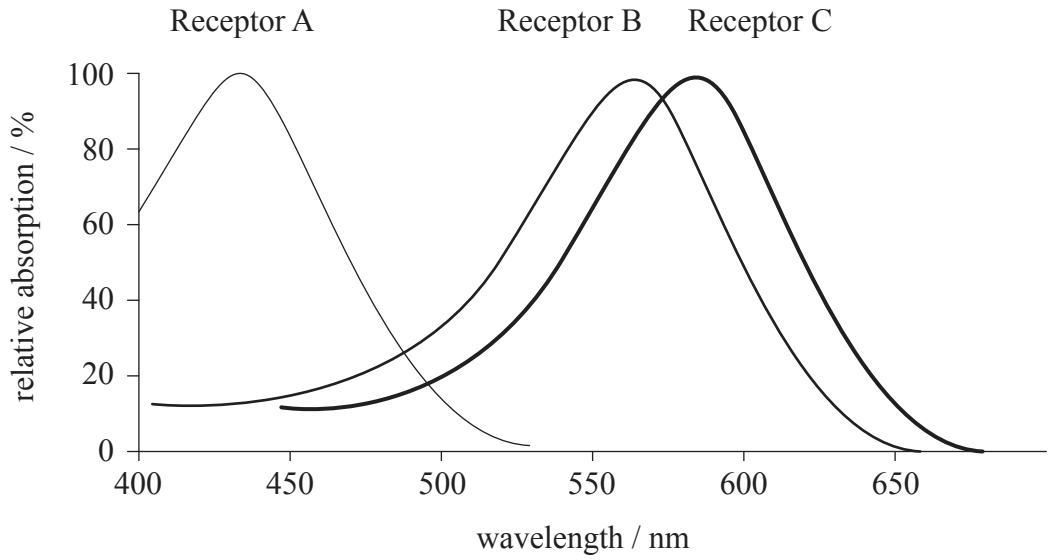
(b) The graph below shows how absorption varies with wavelength for the three types of colour receptor.



(i) Identify the colours that the receptors are sensitive to. *[1]*

Receptor A: . . . . . .

Receptor B: . . . . . .

Receptor C: . . . . . .

(This question continues on the following page)

(Question A1 continued)

(ii) Red-green colour blindness is more common than red-blue colour blindness. Using the information on the graph suggest why this is the case. *[2]*

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(iii) State which of the receptors absorb yellow light. *[1]*

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A2. This question is about standing waves on strings.

(a) A string is fixed at one end and the other free end is moved up and down. Explain how a standing wave can be formed on the string. *[3]*

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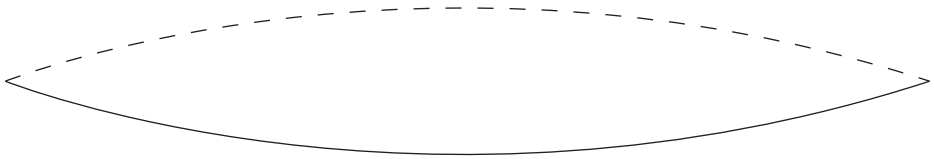
(b) The diagram shows a string vibrating in its fundamental (first harmonic) mode. Both ends of the string are fixed.



(i) Label an antinode on the diagram. *[1]*

(ii) The length of the string is 0.85 m and its fundamental frequency is 73 Hz. Calculate the speed of the waves on the string. *[2]*

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(This question continues on the following page)

(Question A2 continued)

(iii) Sketch how the string will appear if it is vibrated at a frequency three times that of the fundamental frequency. *[1]*

(iv) State the speed of the wave when the string is vibrated at a frequency three times that of the fundamental frequency. *[1]*

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A3. This question is about the Doppler effect.

(a) Describe the Doppler effect. *[3]*

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(b) A spectral line from a source on Earth has a frequency of 4.672×10^{14} Hz. When this same line is observed from a distant galaxy it is found to have shifted to 4.669×10^{14} Hz.

(i) State the direction of the motion of the galaxy relative to Earth. *[1]*

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(ii) Deduce the speed of the galaxy relative to Earth. *[3]*

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Option B — Quantum physics and nuclear physics

B1. This question is about plutonium as a power source.

Plutonium $\left({}^{238}_{94}\text{Pu}\right)$ decays by alpha emission. The energy of the alpha particle emitted is 8.8×10^{-13} J. The decay constant of plutonium-238 is $8.1 \times 10^{-3}\ \text{yr}^{-1}$.

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

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(b) Plutonium-238 is to be used as a power source in a space probe.

(i) Determine the initial activity of plutonium such that the power released by plutonium is 6.0 W. *[2]*

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(ii) The power source becomes useless when the power released decreases to 4.0 W. Determine the time, in years, for which the power source can be used in the space probe. *[4]*

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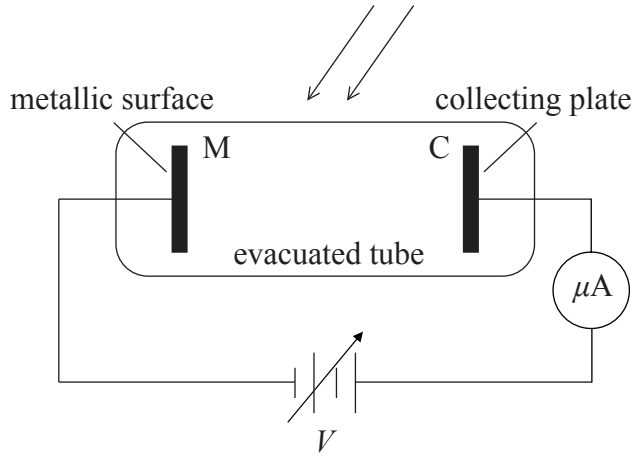
B2. This question is about the photoelectric effect.

The diagram shows apparatus used to investigate the photoelectric effect.



(a) When red light is incident on the metallic surface M the microammeter registers a current. Explain how a current is established in this circuit even though nothing joins M to C inside the tube. *[2]*

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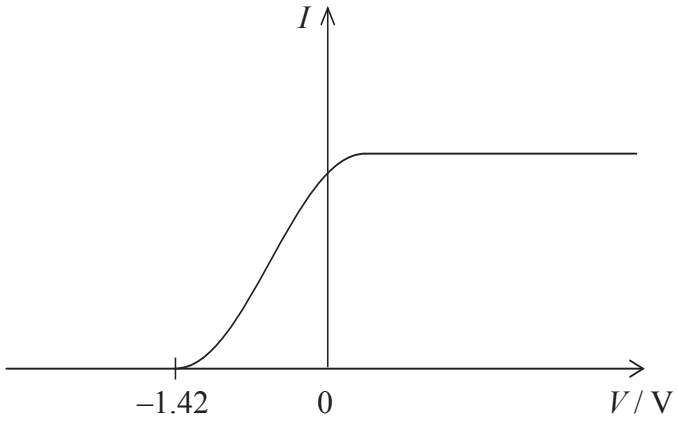
(b) The graph shows the variation with voltage V of the current I in the circuit.



(This question continues on the following page)

(Question B2 continued)

The work function of the metallic surface M is 0.48 eV.

(i) Define *work function*. *[1]*

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(ii) State the maximum kinetic energy of an electron immediately after it has been emitted from M. *[1]*

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(iii) Calculate the energy of a photon incident on M. *[1]*

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(iv) The red light incident on M is now replaced by blue light. The number of photons incident on M per second is the same as in (b).

On the axes opposite, sketch a graph to show the variation with V of the current I. *[2]*

B3. This question is about electron diffraction.

(a) A beam of electrons is accelerated from rest by a potential difference of 750 V. Calculate the de Broglie wavelength of the accelerated electrons. *[3]*

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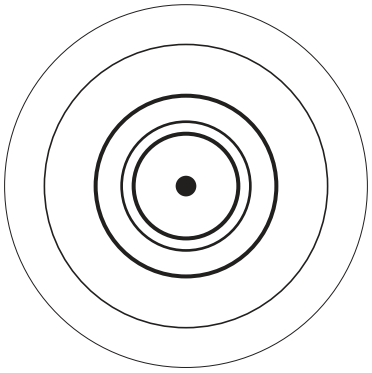
(b) The beam of electrons is incident on crystalline material. The diagram shows the electron intensity pattern after scattering from the material.



(i) State the reason why it is necessary for the material to be crystalline. *[1]*

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(This question continues on the following page)

(Question B3 continued)

(ii) Dark regions denote large numbers of incident electrons. Describe how the diagram opposite provides evidence for the wave nature of electrons. *[2]*

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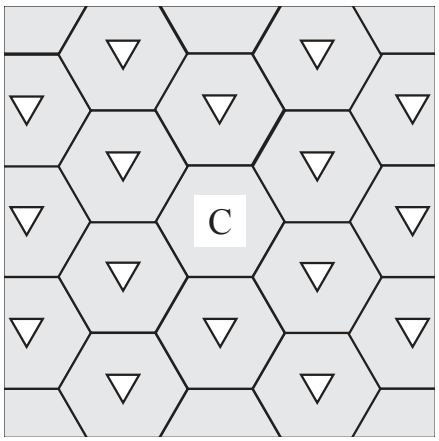
Option C — Digital technology

C1. This question is about mobile phones.

(a) The diagram shows the cell network used in a mobile phone system.



(i) A mobile phone is in cell C. State how the strength of the signal from the transmitter in this cell compares with the signals from surrounding cells. *[1]*

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(ii) Explain why mobile phone companies must use a specified range of frequencies within each cell. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(iii) The range of frequencies used allows approximately 800 signals to be transmitted simultaneously. However, a maximum of 400 connections can be made. State why this is the case. *[1]*

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(b) Suggest **two** reasons why the general public may be concerned about the use of mobile phones. *[2]*

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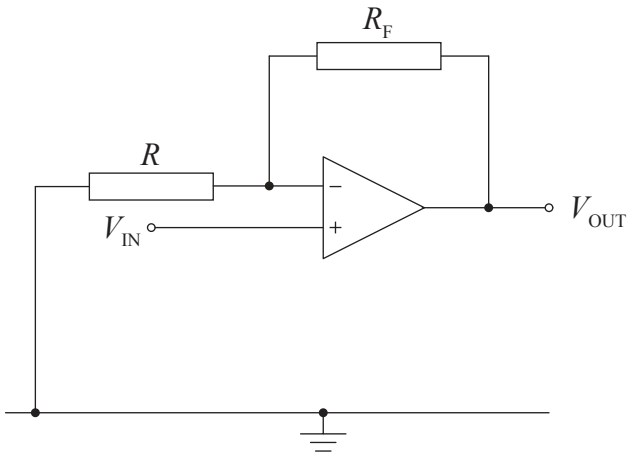
C2. This question is about operational amplifiers.

(a) State the properties of an ideal operational amplifier by using the words "zero" or "infinite" in the table below. *[2]*

input impedance (resistance)	
output impedance (resistance)	
(open loop) gain	

(b) The circuit below shows a non-inverting amplifier.



Show that the gain of this amplifier is given by $G = 1 + \frac{R_F}{R}$. *[3]*

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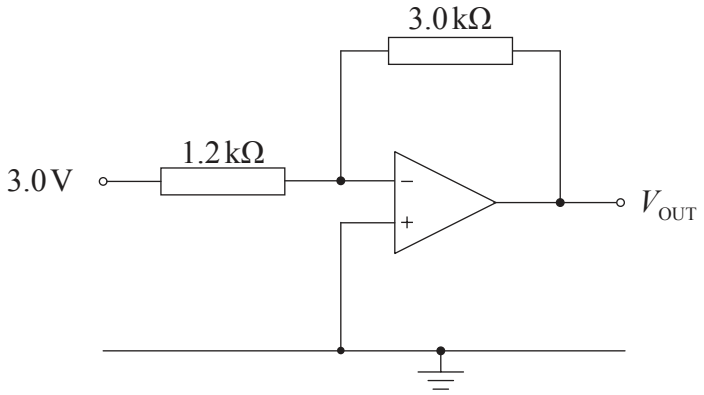
(Question C2 continued)

(c) The circuit below shows an inverting amplifier.



Calculate the output voltage V_{OUT}. *[2]*

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C3. This question is about compact discs (CDs).

(a) A CD consists of a single spiral track of pits of digital data. Each pit is 1.25×10^{-7} m deep.

(i) Explain why the wavelength of electromagnetic waves used to read the CD is 5.00×10^{-7} m. *[3]*

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(ii) The inner radius of the playing area is 25 mm and the outer radius is 58 mm. The effective width of the track is approximately 1.6 μm. Determine the length of the track on the CD. *[3]*

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(b) State **one** negative environmental impact of the increased use of CDs. *[1]*

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Option D — Relativity and particle physics

D1. This question is about relativistic kinematics.

In a thought experiment, a train is moving at a speed of 0.950c relative to the ground. A pendulum attached to the ceiling of the train is set into oscillation.

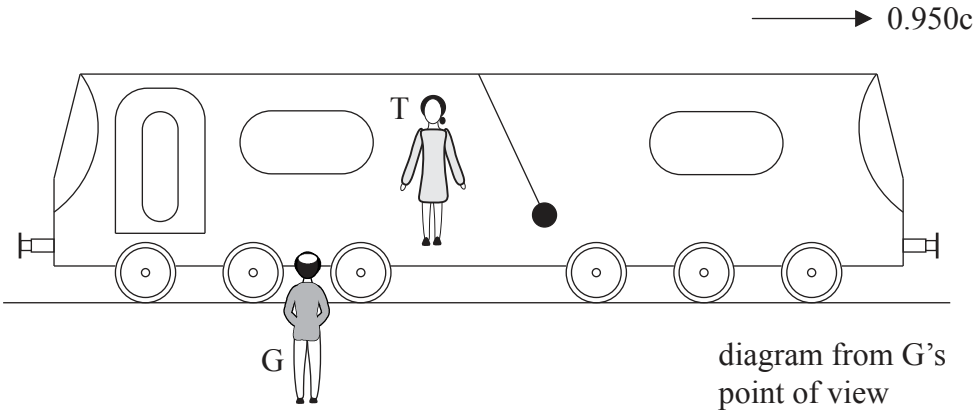

diagram from G's point of view

An observer T on the train and an observer G on the ground measure the period of oscillation of the pendulum.

(a) State and explain whether the pendulum period is a proper time interval for observer T, observer G **or** both T and G. *[2]*

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(b) Observer T measures the period of oscillations of the pendulum to be 0.850 s. Calculate the period of oscillations according to observer G. *[2]*

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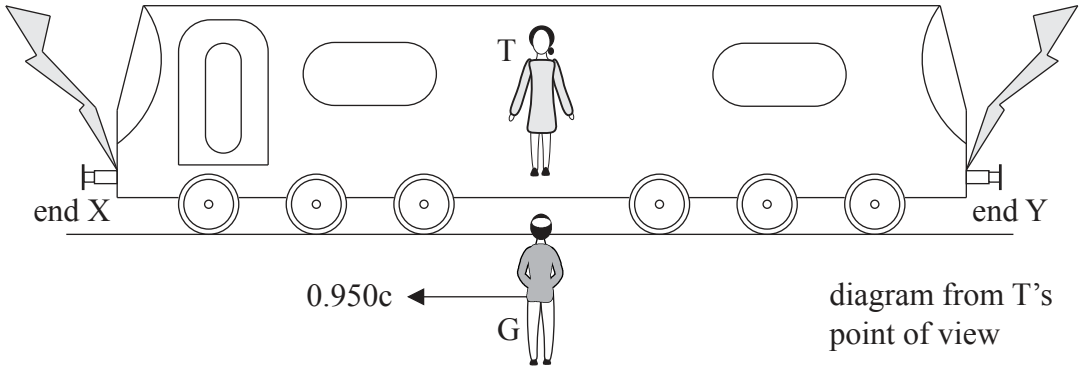
(Question D1 continued)

(c) Observer T is standing in the middle of the train. Two lightning strikes hit the ends of the train. The strikes are simultaneous **according to observer T**.



Light from the strikes reaches both observers.

(i) Explain why, according to observer G, light from the two strikes reaches observer T at the same time. *[2]*

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(ii) Using your answer to (i), explain why, according to observer G, end X of the train was hit by lightning first. *[2]*

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(This question continues on the following page)

(Question D1 continued)

(d) The lightning strikes in (c) make marks on both the train and the ground. The proper length of the train is 160 m.

Determine, according to observer G, the distance between the marks made on the ground. *[2]*

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D2. This question is about quarks and interactions.

(a) Outline how interactions in particle physics are understood in terms of exchange particles. *[2]*

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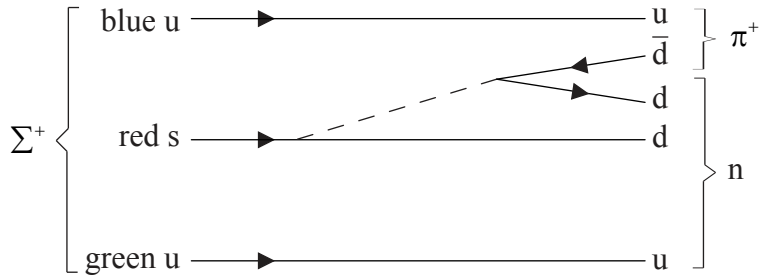
(b) The sigma ($\Sigma^+ = u\ u\ s$) decays into a positive pion ($\pi^+ = u\ \bar{d}$) and a neutron according to the following reaction.

$$\Sigma^+ \rightarrow n + \pi^+$$

The colour of each of the quarks in Σ^+ is indicated in the diagram below.



Deduce

(i) the colour of the $\bar{d}$ in π^+. *[1]*

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(ii) the electric charge of the particle represented by the dotted line. *[1]*

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(This question continues on the following page)

(Question D2 continued)

(c) Determine whether or not strangeness is conserved in this decay. *[2]*

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(d) The total energy of the particle represented by the dotted line is 1.2 GeV more than what is allowed by energy conservation. Determine the time interval from the emission of the particle from the s quark to its conversion into the d $\bar{d}$ pair. *[2]*

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(e) The pion is unstable and decays through the weak interaction into a neutrino and an anti-muon.

Draw a Feynman diagram for the decay of the pion, labelling all particles in the diagram. *[2]*

Option E — Astrophysics

E1. This question is about the star Naos (Zeta Puppis).

The following data are available for the star Naos.

Surface temperature $= 4.24 \times 10^4$ K
Radius $= 7.70 \times 10^9$ m
Apparent magnitude $= +2.21$
Parallax angle $= 3.36 \times 10^{-3}$ arcseconds

(a) State the spectral class of Naos. *[1]*

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(b) State what is meant by apparent magnitude. *[1]*

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(c) Determine, for Naos, its

(i) distance from Earth, in parsec. *[1]*

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(ii) absolute magnitude. *[2]*

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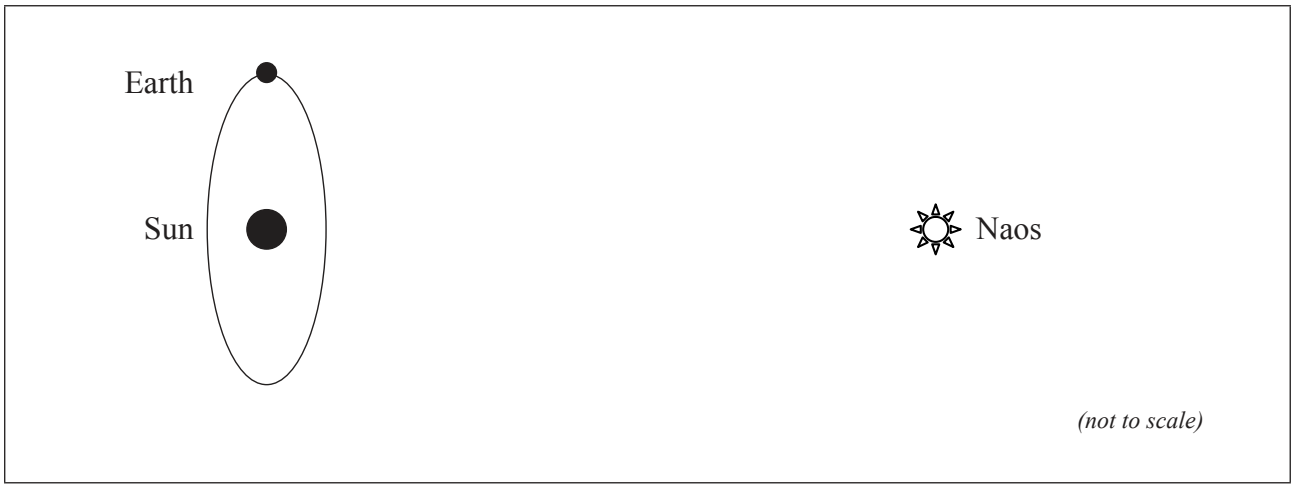
(This question continues on the following page)

(Question E1 continued)

(d) The distance to Naos may be determined by the method of stellar parallax. The diagram shows the star Naos and the Earth in its orbit around the Sun.



(i) Draw lines on the diagram above in order to indicate the parallax angle of Naos. *[1]*

(ii) Outline how the parallax angle of Naos may be measured. *[2]*

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(This question continues on the following page)

(Question E1 continued)

(e) Determine, using the data given,

(i) the luminosity of Naos. *[2]*

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(ii) the wavelength at which Naos emits most of its energy. *[1]*

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(f) The star Mizar has the same apparent brightness as Naos and a much lower temperature. To the **naked eye** Naos does not appear as bright as Mizar.

By reference to your answer to (e)(ii), suggest an explanation of this fact. *[2]*

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E2. This question is about Olbers' paradox.

(a) State **two** postulates of the Newtonian model of the universe. *[2]*

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(b) Describe quantitatively how Olbers' paradox arises in the Newtonian model of the universe. *[3]*

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(c) Suggest how the paradox is resolved in the standard Big Bang model of the universe. *[2]*

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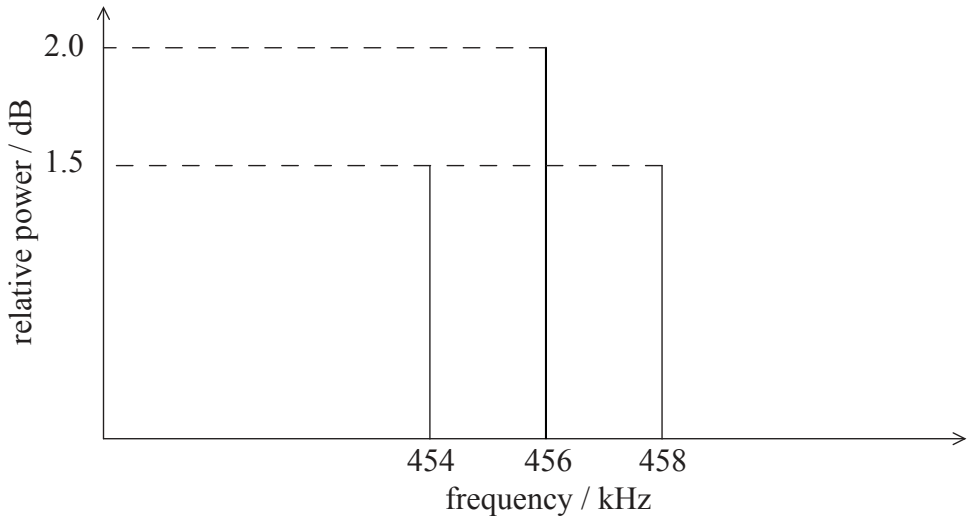
Option F — Communications

F1. This question is about radio transmission and reception.

(a) The diagram shows a power spectrum for an amplitude modulated (AM) radio signal.



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

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(ii) Calculate the frequency of the signal. *[1]*

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

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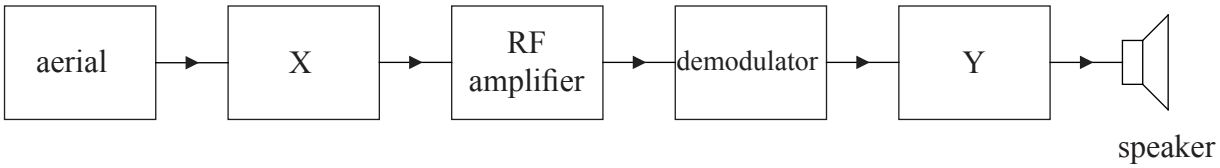
(Question F1 continued)

(b) The diagram below shows an incomplete block diagram for an AM radio receiver.



(i) Identify components X and Y. *[2]*

X: . . . . . .

Y: . . . . . .

(ii) Explain the function of components X and Y. *[2]*

X: . . . . . .

. . . . . .

Y: . . . . . .

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(c) Discuss an advantage and a disadvantage of using amplitude modulation compared with frequency modulation when transmitting and receiving a radio signal. *[3]*

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F2. This question is about the sampling of analogue signals.

(a) In a sound recording system a microphone is plugged into a computer sound card. Two possible sampling frequencies are 44.1 kHz and 8.0 kHz.

(i) Explain the advantage of using 44.1 kHz rather than 8.0 kHz as the sampling frequency. *[2]*

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(ii) Suggest the implication for storing the sampled data when using a sampling frequency of 44.1 kHz. *[1]*

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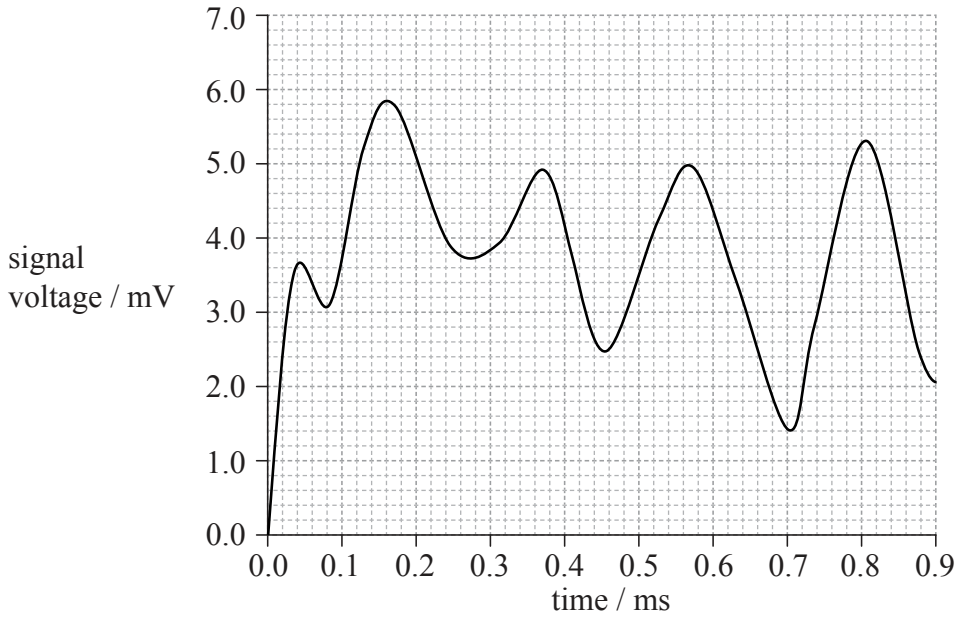
(This question continues on the following page)

(Question F2 continued)

(b) The graph shows an analogue signal which is to be sampled. The voltages of the sampled values are then recorded as binary numbers with 0000 representing the range from 0.00 to 0.99 mV, 0001 representing from 1.00 mV to 1.99 mV, *etc*.



(i) The first sample takes place at 0.0 ms and the sampling rate is 5.0 kHz. On the graph above, draw the points where the next **two** samples occur. Label these as S1 and S2. *[2]*

(ii) State the binary numbers representing these two samples. *[2]*

S1: . . . . . .

S2: . . . . . .

(This question continues on the following page)

(Question F2 continued)

(c) Explain how time-division multiplexing allows transmission of different signals on the same line. *[3]*

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Option G — Electromagnetic waves

G1. This question is about a magnifying glass.

(a) (i) Define the *angular magnification* of a magnifying glass. *[1]*

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(ii) Derive an equation for the angular magnification of a magnifying glass with the image at infinity. *[3]*

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(This question continues on the following page)

(Question G1 continued)

(b) An object is positioned 8.00 cm from a magnifying glass of focal length 15.0 cm.

(i) Calculate the position of the image. *[2]*

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(ii) Calculate the linear magnification. *[1]*

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(iii) The image is upright and magnified. State a further property of the image. *[1]*

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G2. This question is about lasers and diffraction gratings.

(a) (i) State **two** ways that laser light differs from light emitted by an ordinary filament lamp. *[2]*

1: . . . . . .

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2: . . . . . .

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(ii) Outline the main mechanisms in the production of laser light. *[4]*

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(This question continues on the following page)

(Question G2 continued)

(b) (i) Describe the pattern produced on a screen by a red laser beam incident on a diffraction grating. *[2]*

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(ii) Laser light of wavelength 632 nm is incident on a diffraction grating having 600 lines per mm. Determine the angular separation between the first and second order maxima. *[4]*

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