IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M05/4/PHYSI/SP3/ENG/TZ1/XX+

22056512

PHYSICS
STANDARD LEVEL
PAPER 3

Friday 20 May 2005 (morning)

1 hour

Candidate session number

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INSTRUCTIONS TO CANDIDATES

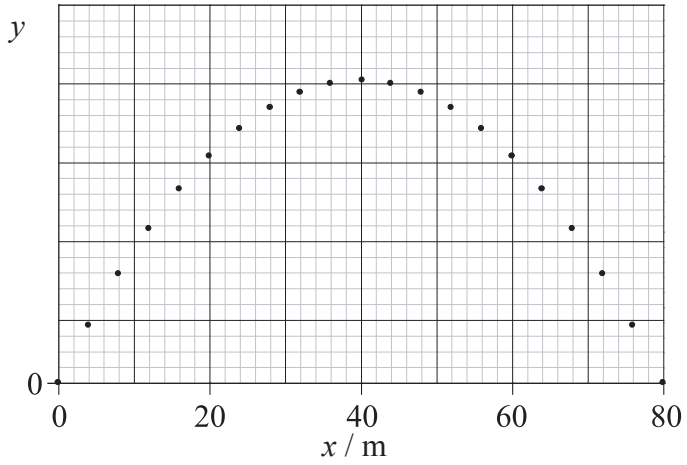
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover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

0132

Option A — Mechanics Extension

A1. This question is about parabolic motion.

A projectile is launched from the surface of a planet. The initial vertical component of velocity is $40\,\text{m}\,\text{s}^{-1}$. The diagram below shows the positions of the projectile in 0.20 s intervals. Note that no scale has been given on the vertical axis.



(a) Calculate

(i) the horizontal velocity of the projectile. *[2]*

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(ii) the acceleration of free fall at the surface of the planet. *[3]*

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(iii) the maximum height reached by this projectile. *[2]*

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(Question A1 continued)

(b) Determine the angle to the horizontal at which the projectile is launched. *[2]*

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(c) The projectile is launched with the same velocity from the surface of a planet where the acceleration of free fall is twice that calculated in (a) (ii). Draw the path of this projectile on the graph opposite. *[3]*

A2. This question is about gravitation.

(a) Define *gravitational potential* at a point. *[2]*

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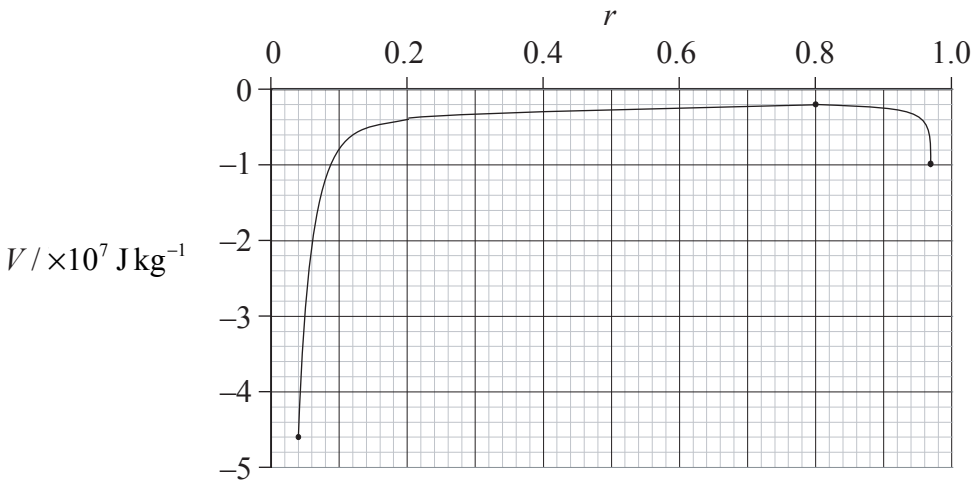
(b) The diagram below shows the variation of gravitational potential V of a planet and its moon with distance r from the centre of the planet. The unit of separation is arbitrary. The centre of the planet corresponds to $r = 0$ and the centre of the moon to $r = 1$. The curve starts at the surface of the planet and ends at the surface of the moon.



(i) At the position where $r = 0.8$, the gravitational field strength is zero. Determine the ratio

$$\frac{\text{mass of planet}}{\text{mass of moon}}.$$

[3]

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(ii) A satellite of mass 1500 kg is launched from the surface of the planet. Determine the **minimum** kinetic energy at launch the satellite must have so that it can reach the surface of the moon. *[3]*

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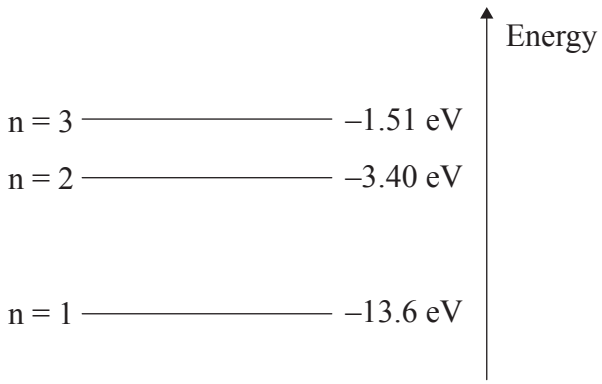
Option B — Quantum Physics and Nuclear Physics

B1. This question is about the Bohr model of the hydrogen atom.

(a) The diagram below shows the three lowest energy levels of a hydrogen atom as predicted by the Bohr model.



State **two** physical processes by which an electron in the ground state energy level can move to a higher energy level state. *[2]*

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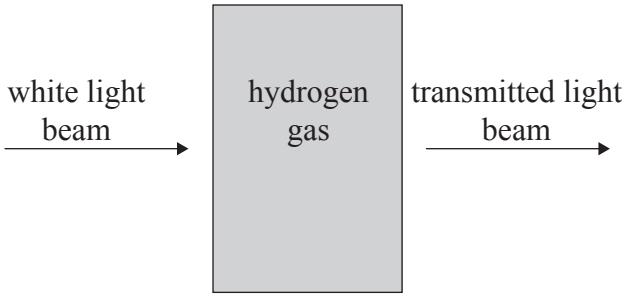
(Question B1 continued)

(b) A parallel beam of white light is directed through monatomic hydrogen gas as shown in the diagram below. The transmitted light is analysed.



White light consists of photons that range in wavelength from approximately 400 nm for violet to 700 nm for red light.

(i) Determine that the energy of photons of light of wavelength 658 nm is about 1.89 eV. *[2]*

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(ii) The intensity of light of wavelength 658 nm in the direction of the transmitted beam is greatly reduced. Using the energy level diagram in (a) explain this observation. *[3]*

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(iii) State **two** ways in which the Schrödinger model of the hydrogen atom differs from that of the Bohr model. *[2]*

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2. . . . . .

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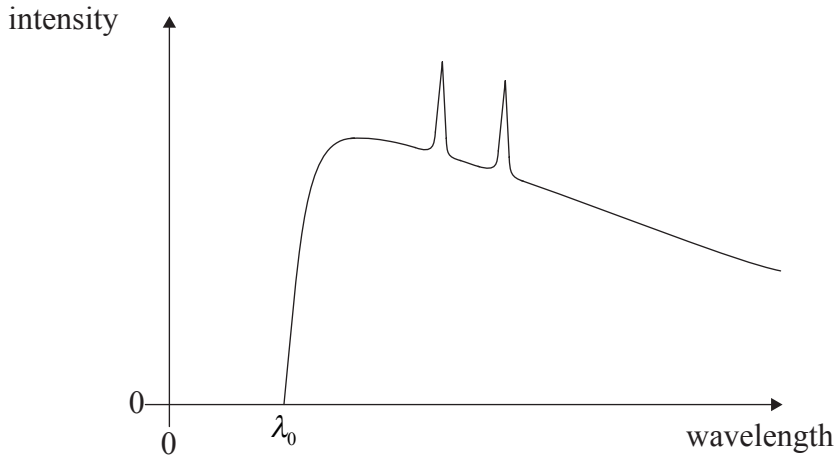
B2. This question is about X-rays.

The diagram shows an X-ray spectrum obtained when electrons, accelerated from rest through a potential difference of 20 kV are incident on a heavy metal target.



(a) Explain the mechanism by which the continuous spectrum of wavelengths is produced. *[4]*

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(b) Calculate the minimum wavelength λ_0 of the emitted X-rays. *[2]*

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(c) The accelerating voltage is now increased to 30 kV. State what, if anything, will happen to the position of

(i) the minimum wavelength λ_0. *[1]*

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(ii) the characteristic lines. *[1]*

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B3. This question is about particle physics.

A neutron can decay into a proton, an electron and an antineutrino according to the reaction

$$n \rightarrow p + e + \bar{\nu}_e.$$

(a) Deduce the value of the electric charge of the antineutrino. *[1]*

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(b) State the name of the fundamental interaction (force) that is responsible for this decay. *[1]*

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(c) State how an antineutrino differs from a neutrino. *[1]*

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Option C — Energy Extension

C1. This question is about nuclear power and thermodynamics.

(a) A fission reaction taking place in the core of a nuclear power reactor is

$$^{1}_{0}\text{n} + ^{235}_{92}\text{U} \rightarrow ^{144}_{56}\text{Ba} + ^{89}_{36}\text{Kr} + 3\,^{1}_{0}\text{n}.$$

(i) State **one** form in which energy is released in this reaction. *[1]*

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(ii) Explain why, for fission reactions to be maintained, the mass of the uranium fuel must be above a certain minimum amount. *[2]*

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(iii) The neutrons produced in the fission reaction are fast moving. In order for a neutron to fission U – 235 the neutron must be slow moving. Name the part of the nuclear reactor in which neutrons are slowed down. *[1]*

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(iv) In a particular reactor approximately 8.0×10^{19} fissions per second take place. Deduce the mass of U – 235 that undergoes fission per year. *[3]*

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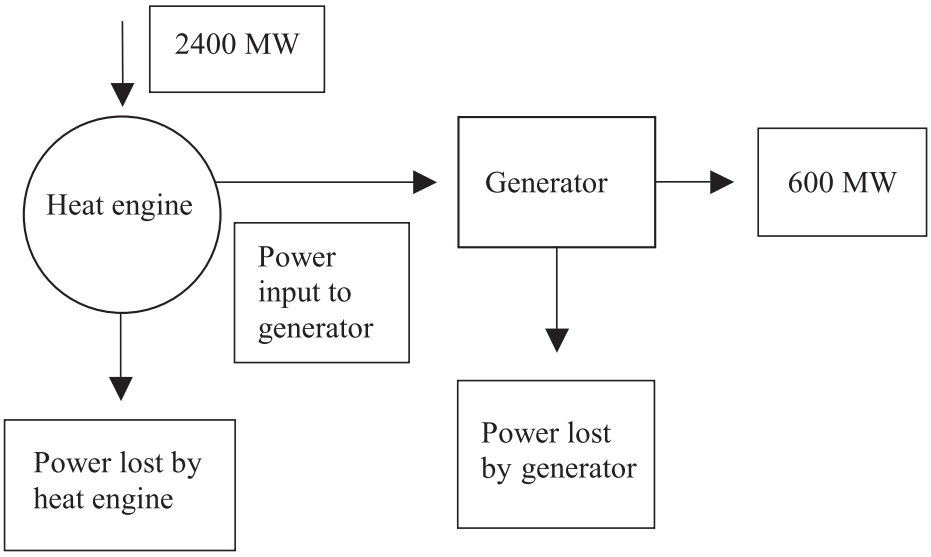
(This question continues on the following page)

(Question C1 continued)

(b) The thermal power from the reactor is 2400 MW and this is used to drive (operate) a heat engine. The mechanical power output of the heat engine is used to drive a generator. The generator is 75 % efficient and produces 600 MW of electrical power. This is represented by the energy flow diagram below.



(i) Calculate the power input to the generator. *[1]*

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(ii) Calculate the power lost from the generator. *[1]*

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(iii) Calculate the power lost by the heat engine. *[1]*

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(iv) State the name of the law of Physics which prohibits **all** of the 2400 MW of input thermal power from being converted into mechanical power. *[1]*

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(v) Deduce that that the efficiency of the heat engine is 33 %. *[1]*

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(This question continues on the following page)

(Question C1 continued)

(vi) The heat engine operates in a Carnot cycle with a low temperature reservoir of 300 K. Calculate the temperature of the hot reservoir. *[2]*

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C2. This question is about wind power.

(a) A wind turbine produces 15 kW of electric power at a wind speed v.

(i) Assuming a constant efficiency for the wind turbine, determine the power output of the turbine for a wind speed of $2v$. *[2]*

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(ii) Suggest **two** reasons why all the kinetic energy of the incident wind cannot be converted into mechanical energy in the turbine. *[2]*

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2. . . . . .

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(b) State and explain **one** advantage of using wind power to generate electrical energy as compared to using fossil fuels. *[2]*

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Option D — Biomedical Physics

D1. This question is about scaling and thermal energy loss.

An adult of height 1.80 m and a child of height 1.20 m are stranded during a hiking trip and must spend the cold night outdoors.

(a) Estimate the value of the ratio $\frac{Q_{adult}}{Q_{child}}$

where $Q = \frac{\text{total rate of thermal energy loss}}{\text{mass}}$. *[4]*

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(b) Using your answer in (a) explain whether the adult or the child is at greater risk from hypothermia (core body temperature significantly below normal). *[1]*

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D2. This question is about sound and hearing.

(a) State the approximate range of frequencies that are audible to a person with normal hearing. *[1]*

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(b) Outline the mechanism by which different frequencies are distinguished in the cochlea. *[3]*

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(c) A person with normal hearing can just hear a sound of intensity $10^{-12}\,\mathrm{W\,m^{-2}}$ at a frequency of 1000 Hz.

(i) A sound wave of frequency 1000 Hz incident on the ear drum has an intensity of $2.7\times10^{-5}\,\mathrm{W\,m^{-2}}$. Calculate the sound intensity level at the ear. *[2]*

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(ii) Explain why the response of the ear is measured as a change in sound intensity level rather than a change of intensity of sound. *[3]*

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D3. This question is about various diagnostic techniques.

(a) State and explain **one** situation, in each case, where the following diagnostic techniques would be used.

(i) X-rays *[1]*

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(ii) Ultrasound *[1]*

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(iii) Nuclear magnetic resonance *[1]*

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(b) Apart from health hazards, explain why different means of diagnosis are needed. *[3]*

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Option E — The History and Development of Physics

E1. This question is about models of the universe.

(a) In the course of one night, the stars appear to move across the sky. Outline how this observed motion is explained in

(i) the Ptolemaic model. *[2]*

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(ii) the Copernican model. *[2]*

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(b) Observations show that the brightnesses of the planets Venus and Mercury vary with time.

Explain why these observations

(i) cannot be explained in the Ptolemaic model of the universe. *[2]*

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(ii) can be explained in the Copernican model. *[2]*

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E2. This question is about force and motion.

(a) Two bodies are moving on a straight horizontal line with constant speed. Body A has double the speed of body B.

State and explain the net force on each body according to Aristotle and Galileo.

(i) Aristotle *[2]*

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(ii) Galileo *[2]*

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(b) A stone and a feather are dropped from rest from the same height. State why on the basis of Aristotle's theory the stone reaches the ground before the feather. *[2]*

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E3. This question is about theories of heat.

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

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(b) State and explain **one** experimental piece of evidence that convinced Lavoisier that the phlogiston did not exist. *[2]*

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(c) State and explain how Rumford reached the conclusion that heat is not a fluid. *[3]*

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Option F — Astrophysics

F1. This question is about eclipsing binary stars.

(a) In a particular binary star system, star A has apparent brightness 8.0×10^{-13} W m^{-2} and star B has apparent brightness 2.0×10^{-14} W m^{-2}.

(i) Explain how it is possible to deduce that star A has a higher luminosity than star B. *[2]*

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(ii) The surface area of star B is 10 000 times smaller than that of star A. Calculate the ratio

$$\frac{\text{surface temperature of star B}}{\text{surface temperature of star A}}.$$ *[4]*

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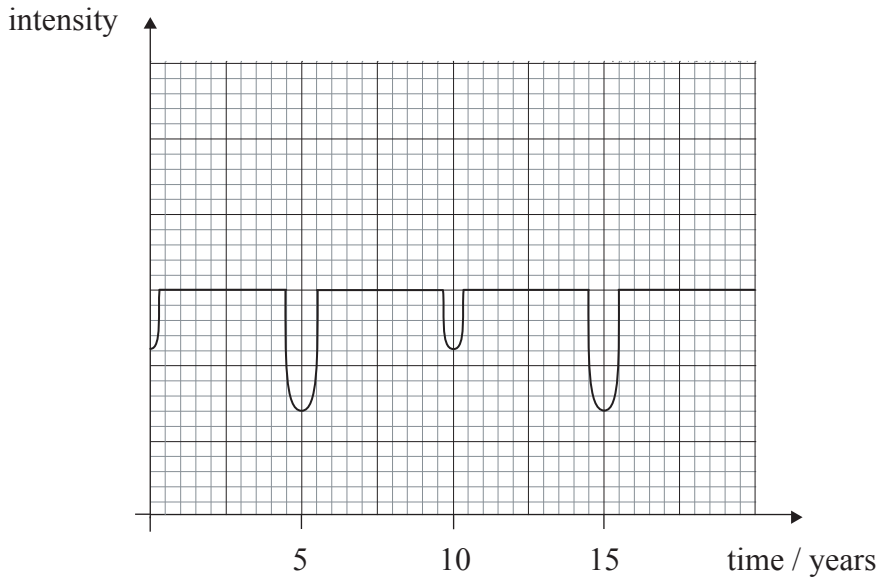
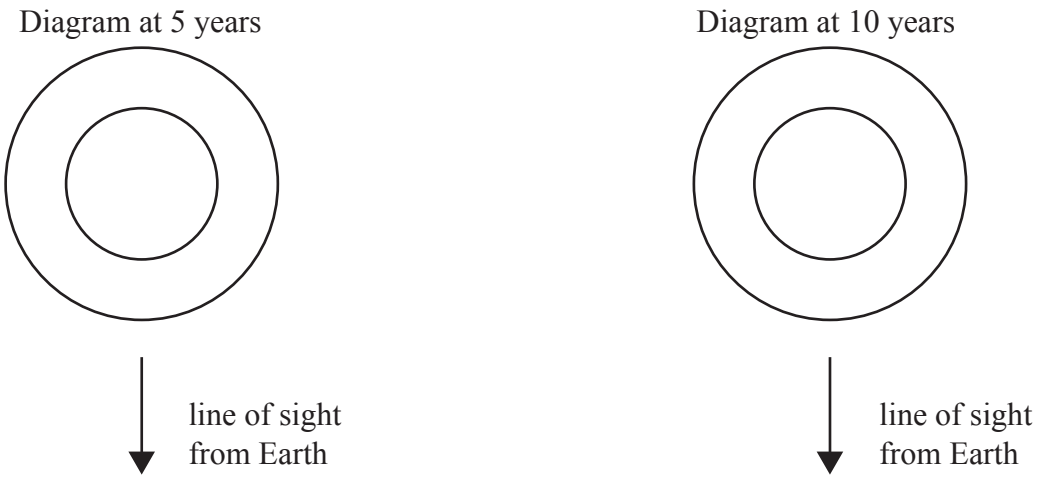
(This question continues on the following page)

(Question F1 continued)

(b) The graph below shows the variation with time of the intensity of light received on Earth from the two stars.



(i) The diagrams below each show the orbits of the two stars. Star A is in the inner orbit. Annotate the diagrams to show the relative positions of stars A and B as seen from Earth, that correspond to the intensity-time graph opposite at times of 5 and 10 years. *[2]*



(ii) State the period of this binary star system. *[1]*

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(iii) State what can be deduced from knowing the period of the binary and the separation of the stars. *[1]*

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F2. This question is about cosmology.

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

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(b) Recent measurements suggest that the mass density of the universe is likely to be less than the critical density. State what this observation implies for the evolution of the universe in the context of the Big Bang model. *[1]*

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(c) (i) Outline what is meant by *dark matter*. *[2]*

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(ii) Give **two** possible examples of dark matter.

1. . . . . *[1]*

2. . . . . *[1]*

F3. This question is about cosmic background radiation.

(a) Describe what is meant by *cosmic background radiation*. *[2]*

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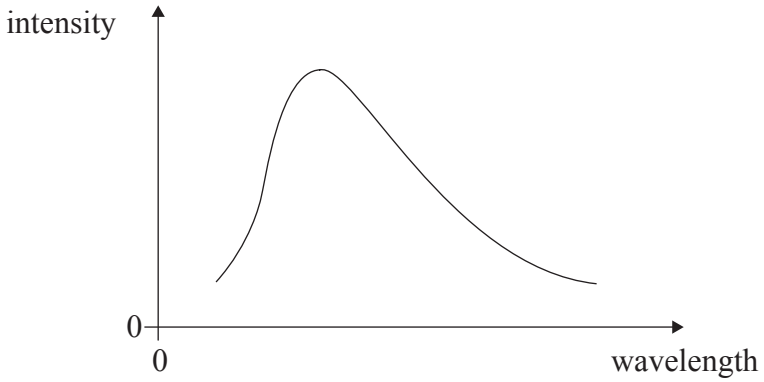
(b) The graph below shows the spectrum of the cosmic background radiation *i.e.* the variation, with wavelength, of the intensity of the cosmic background radiation.



There is evidence to suggest that the universe will expand forever. On the diagram above, sketch a graph to show the spectrum of the background radiation for the universe many millions of years from now. *[2]*

Option G — Relativity

G1. This question is about the postulates of special relativity.

(a) State the **two** postulates of the special theory of relativity. *[2]*

Postulate 1

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Postulate 2

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(i) Explain how this observation is consistent with the theory of special relativity. *[1]*

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(ii) Calculate the speed of one spacecraft relative to an observer in the other. *[3]*

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G2. This question is about relativistic kinematics.

(a) Muons are unstable particles that have an average lifetime of 2.2×10^{-6} s as measured in a reference frame in which they are at rest. Muons that are created at a height of 3.0 km above the Earth's surface move vertically downward with a speed of $0.98\,c$ as measured by an observer at rest on the Earth's surface.

(i) Calculate the average lifetime of a muon as measured by the observer on Earth. *[2]*

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(ii) Calculate the distance travelled by a muon during a time equal to the average lifetime of the muon according to the observer at rest relative to the Earth's surface. *[2]*

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(iii) Calculate the distance travelled by the Earth during a time equal to the average lifetime of the muon according to an observer at rest relative to the muon. *[2]*

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(This question continues on the following page)

(Question G2 continued)

(iv) Muons created at a height of 3.0 km above the Earth's surface are in fact detected on the surface of the Earth. Use your answers to (ii) and (iii) together with any other relevant calculations to explain this observation according to

1. the observer at rest on the surface of the Earth. *[2]*

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2. the observer at rest relative to the muon. *[3]*

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(b) The rest mass of the muon is 106 MeVc^{-2}. Calculate the potential difference through which a muon at rest in the lab must be accelerated in order to have a speed of 0.98 c. (The electric charge of the muon is identical to that of the electron.) *[3]*

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Option H — Optics

H1. This question is about light and the electromagnetic spectrum.

(a) Outline the electromagnetic nature of light. *[2]*

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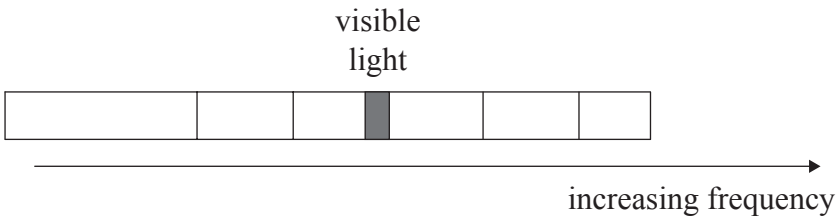
(b) The diagram below is a representation of the electromagnetic spectrum.



In the diagram the region of visible light has been indicated.

Indicate on the diagram above the approximate position occupied by

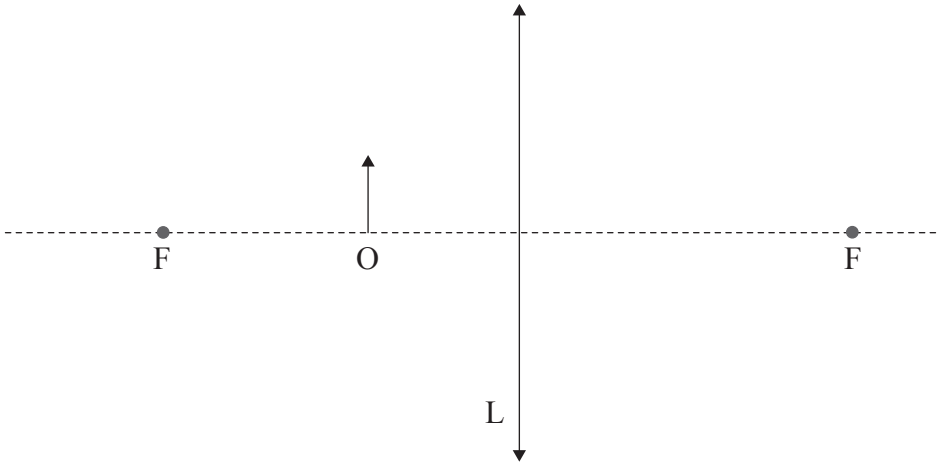
(i) infrared waves (label this I). *[1]*

(ii) microwaves (label this M). *[1]*

(iii) gamma rays (label this G). *[1]*

H2. This question is about converging lenses.

(a) The diagram shows a small object O represented by an arrow placed in front of a *converging* lens L. The focal points of the lens are labelled F.



(i) Define the *focal point* of a converging lens. *[2]*

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(ii) On the diagram above, draw rays to locate the position of the image of the object formed by the lens. *[3]*

(iii) Explain whether the image is real or virtual. *[1]*

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(This question continues on the following page)

(Question H2 continued)

(b) A convex lens of focal length 6.25 cm is used to view an ant of length 0.80 cm that is crawling on a table. The lens is held 5.0 cm above the table.

(i) Calculate the distance of the image from the lens. *[2]*

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(ii) Calculate the length of the image of the ant. *[2]*

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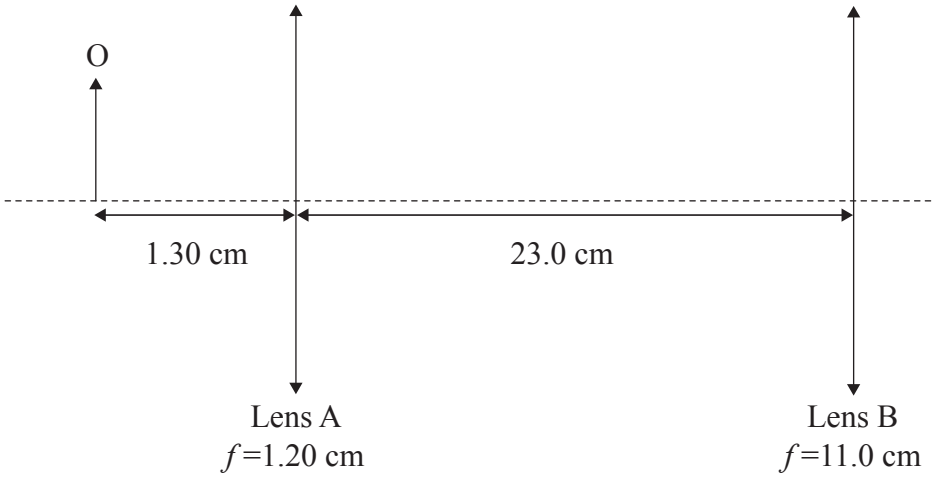
H3. This question is about a compound microscope.

A compound microscope consists of two convex lenses of focal lengths 1.20 cm (lens A) and 11.0 cm (lens B). The lenses are separated by a distance of 23.0 cm as shown below. (The diagram is not drawn to scale.)



An object O is placed 1.30 cm from lens A. An image of O in lens A is formed a distance of 15.6 cm from A.

(a) This image forms an object for lens B. Calculate the object distance for lens B. *[1]*

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(b) Calculate the distance from lens B of the image as produced by lens B. *[2]*

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(c) Calculate the magnification of the microscope. *[2]*

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