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PROGRAMME DU DIPLÔME DU BI
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N07/4/PHYSI/SP3/ENG/TZ0/XX+

88076506

PHYSICS
STANDARD LEVEL
PAPER 3

Friday 9 November 2007 (morning)

1 hour

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

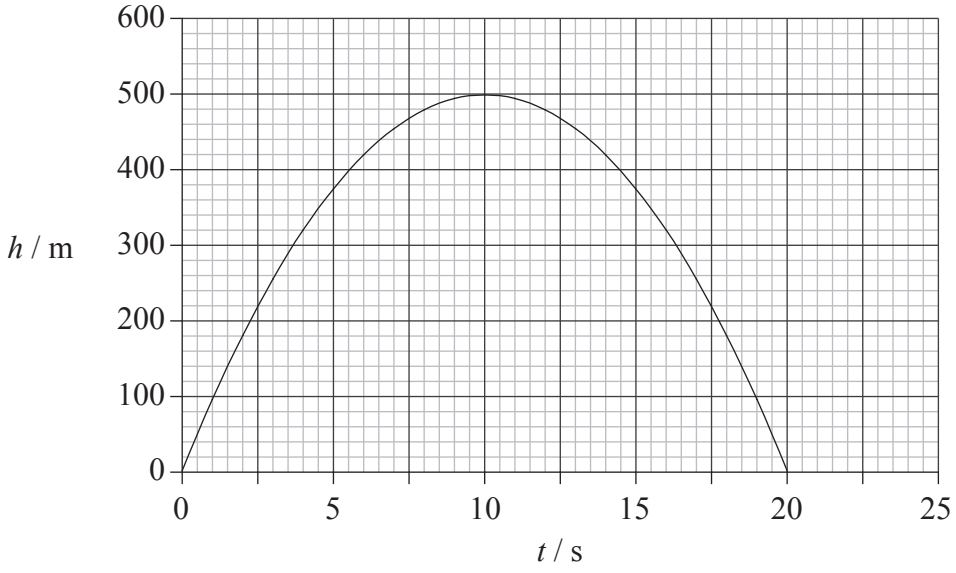
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover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

0129

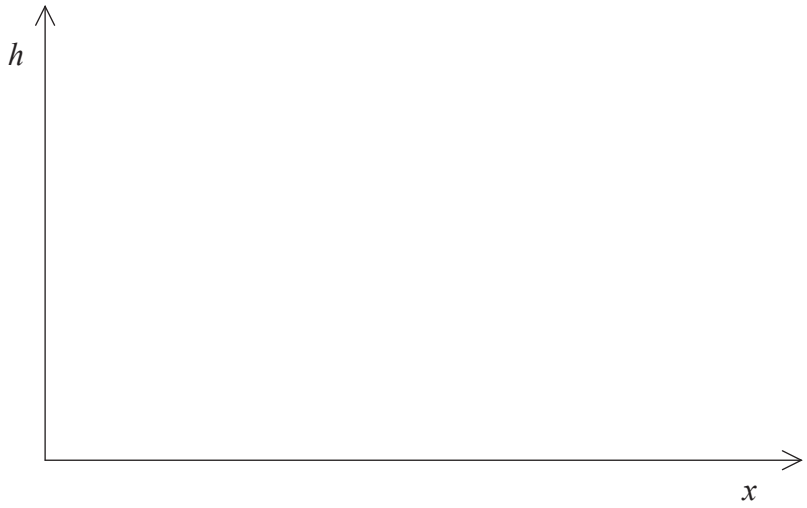
Option A — Mechanics Extension

A1. This question is about projectile motion.

The barrel of a rifle is held at an angle θ to the horizontal. A bullet fired from the rifle leaves the barrel at time $t = 0$ with a speed $200\,\text{m}\,\text{s}^{-1}$. The graph below shows the variation with time t of the vertical height h of the bullet.



(a) Using the axes below, draw a sketch graph to show the variation of h with the horizontal distance x travelled by the bullet. *(**Note**: this is a sketch graph; you do not have to add any values to the axes.)* *[2]*



(This question continues on the following page)

(Question A1 continued)

(b) State the expression for the initial vertical component of speed V_v in terms of the initial speed of the bullet and the angle θ. *[1]*

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(c) Use data from the graph to deduce that the angle $\theta = 30^\circ$. (The acceleration for free fall $g = 10\,\text{m s}^{-2}$) *[3]*

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A2. This question is about gravitational field strength and gravitational potential.

(a) Define *gravitational field strength*. *[2]*

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(b) State an expression for the magnitude of the gravitational field strength g_h at a point height h above a planet in terms of the mass of the planet M, its radius R and the gravitational constant G. *[1]*

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(c) The radius of Mars is 3.4×10^6 m and the magnitude of the gravitational field strength at a height of 1.2×10^6 m above its surface is $1.8\,\text{N kg}^{-1}$. Use your answer to (b) to deduce that the magnitude of the gravitational **potential** at height of 1.2×10^6 m above the surface of Mars is $8.3\times10^6\,\text{J kg}^{-1}$. *[3]*

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(d) A lump of rock is moving with speed v, towards Mars. Its closest distance of approach to Mars is at distance 1.8×10^6 m above the surface of Mars. Deduce that the lump of rock will go into circular orbit about Mars if the speed v is less than $3.0\times10^3\,\text{m s}^{-1}$. *[2]*

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A3. This question is about rotational equilibrium.

(a) State the condition for a body to be in rotational equilibrium. *[1]*

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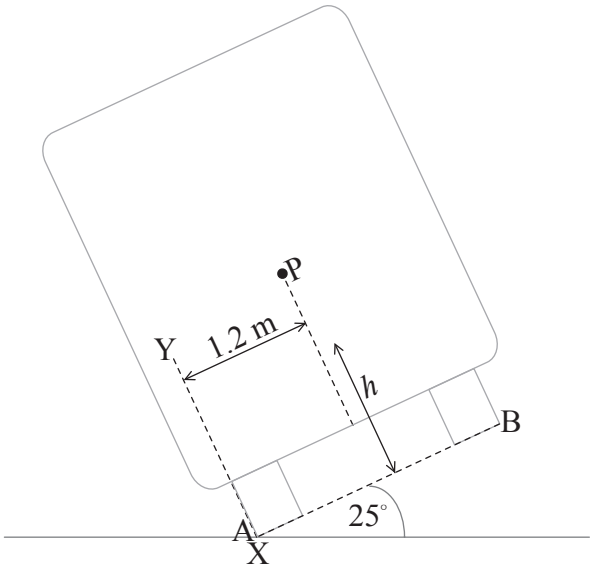
(b) For safety reasons, a bus when full with passengers must be able to tilt to an angle with the horizontal of 25° without toppling over. The diagram below (not to scale) shows the bus in this position. If the angle of 25° is increased, the bus will topple over.



Wheel A is in contact with the ground at point X. The centre of gravity of the bus is at point P. The perpendicular distance between P and the line XY is 1.2 m. The weight of the bus and passengers is W.

On the diagram above, draw arrows to show the line of action of the component of the weight of the bus parallel to the line AB (label this arrow W_P) and the component of the weight of the bus perpendicular to the line AB (label this arrow W_R). *[1]*

(c) Determine the distance h of the centre of gravity P of the bus from the line AB. *[4]*

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Option B — Quantum Physics and Nuclear Physics

B1. This question is about the photoelectric effect.

(a) Outline **two** observations associated with the photoelectric effect that cannot be accounted for by the wave model of light. *[2]*

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2. . . . . .
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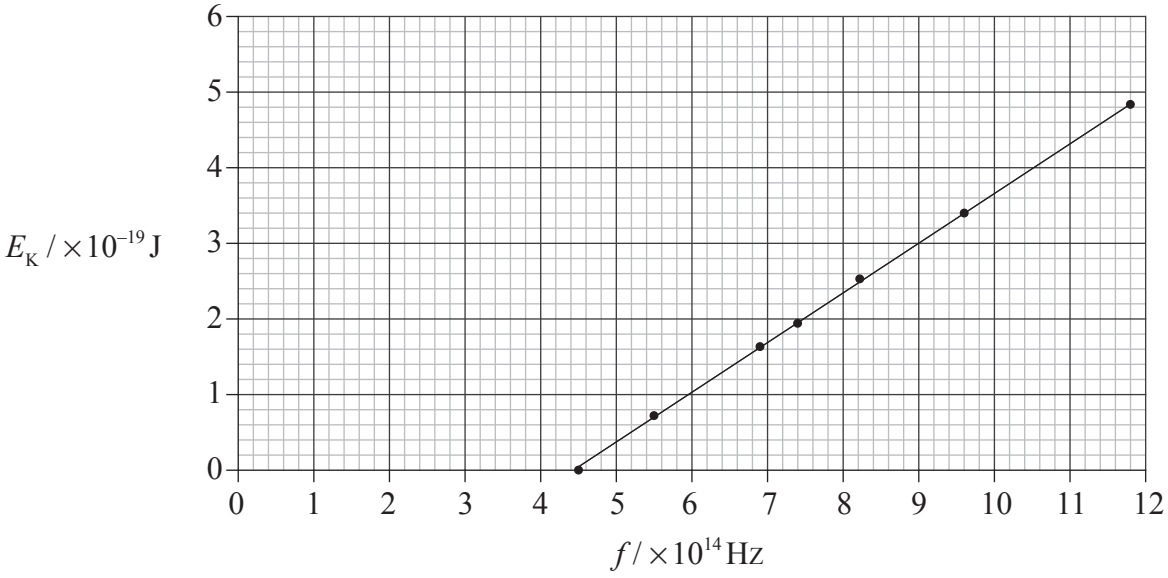
(This question continues on the following page)

(Question B1 continued)

(b) In 1916, Millikan carried out an experiment to verify Einstein's photoelectric theory. In the experiment, Millikan arranged for light of different frequencies f to be incident on the surface of a sodium cathode. By appropriate measurements, he determined the maximum kinetic energy E_K of electrons emitted from the surface for the different values of f. The results of his experiment are shown in the graph below.



Use the above graph to determine, explaining your working,

(i) the threshold frequency of sodium. *[2]*

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(ii) the Planck constant. *[4]*

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B2. (a) Describe the de Broglie hypothesis. *[2]*

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(b) The de Broglie wavelength of the electron in the ground state of the hydrogen atom is 3.3×10^{-10} m. Calculate the kinetic energy of the electron. *[3]*

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B3. This question is about radioactive decay.

(a) State the radioactive decay law. *[1]*

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(b) A nucleus of the isotope Zirconium-81 (Zr-81) decays into a nucleus of the isotope Yttrium (Y). The atomic number of Yttrium is 39. Complete the nuclear equation below for the decay of Zr-81. *[3]*

$$^{81}_{40}\text{Zr} =$$

(c) A freshly prepared sample of Zr-81 contains 1.6×10^{16} atoms. The initial activity of the sample is 7.4×10^{14} Bq. Determine the half-life of Zr-81. *[3]*

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Option C — Energy Extension

C1. This question is about the first law of thermodynamics and state changes in an ideal gas.

(a) In a state change of an ideal gas at constant pressure, work is done. From the first law of thermodynamics, the work done W can be expressed as

$$W = Q - \Delta U$$

where,

ΔU = change in internal energy of the gas

Q = non-mechanical energy transfer involved in the state change of the gas.

Explain whether for the compression of a gas at constant pressure

(i) ΔU is positive, zero or negative. *[3]*

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(ii) Q is zero, transferred from the gas or transferred to the gas. *[2]*

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(b) An ideal gas in a cylinder of volume $5.0 \times 10^{-4}\,m^3$ is at a pressure of $3.2 \times 10^{6}\,Pa$. The gas is compressed at constant pressure to a volume of $2.5 \times 10^{-4}\,m^3$. As a result of the compression, the decrease in temperature of the gas is 150 K. Determine the non-mechanical energy transfer involved in this compression. The thermal capacity of the gas $= 12\,J\,K^{-1}$. *[4]*

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C2. This question is about power generation in nuclear power stations.

(a) State **one** example of a renewable source and **one** example of a non-renewable source of thermal energy. *[2]*

Renewable: . . . . . .

Non-renewable: . . . . . .

(b) The production of electrical energy in a power station involves the conversion of thermal energy into mechanical energy. The mechanical energy is then converted into electrical energy. State the means by which the mechanical energy is converted into electrical energy. *[1]*

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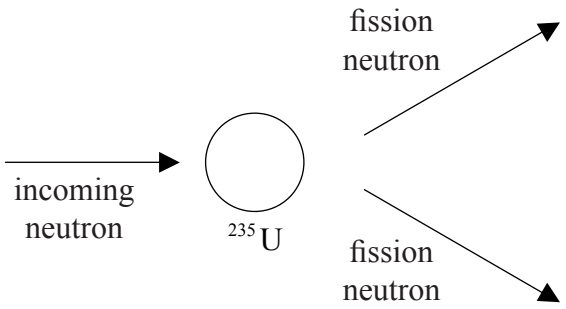
(c) In a nuclear power station, the source of the thermal energy is nuclear fission. The diagram below represents the fission of a uranium nucleus in which two neutrons are produced. (The fission nuclei produced are not shown.)



Use the diagram above to describe what is meant by a chain reaction. *[2]*

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(This question continues on the following page)

(Question C2 continued)

(d) Neutrons that collide with nuclei of uranium-235 can either produce fission of the nuclei or be captured by the nuclei. Outline, in a nuclear power station, the method used to ensure that the majority of nuclei colliding with nuclei of uranium-235 produce fission of the nuclei. *[2]*

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(e) Outline how the energy liberated in fission is converted into mechanical energy. A labelled sketch could assist your answer. *[4]*

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Option D — Biomedical Physics

D1. This question is about scaling.

The length of a human baby is 50 cm and its mass is 3.4 kg.

(a) Estimate, using scaling, the mass of an adult of height 1.8 m. *[2]*

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(b) State **two** assumptions you have made in your estimate in (a). *[2]*

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(c) Explain, by reference to your assumptions, whether your answer in (a) is reasonable. *[3]*

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D2. This question is about hearing.

A sound wave of intensity $3.2 \times 10^{-4}\,\text{W m}^{-2}$ produces a pressure variation on the eardrum.

(a) Calculate the sound intensity level of the sound wave at the eardrum. *[2]*

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(b) Describe how the sound pressure is amplified in the middle ear. *[3]*

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D3. This question is about X-rays and imaging techniques.

(a) State **two** mechanisms by which an X-ray beam is attenuated in matter. *[2]*

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2. . . . . .

(b) Define the term *half-value thickness*. *[1]*

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(c) When a particular X-ray beam passes through fatty tissue, the intensity of the beam is reduced to a quarter of its initial intensity. Determine the fraction of the incident intensity of this beam when it is transmitted through the same thickness of muscle. The half-value thickness of muscle is 4.0 mm and that of fatty tissue is 6.0 mm. *[3]*

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(d) State the difference between an X-ray image and a CT image. *[2]*

X-ray image: . . . . . .

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CT image: . . . . . .

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Option E — The History and Development of Physics

E1. This question is about the work of Galileo and Newton.

(a) State the difference between the Copernican model and the Ptolemaic model of the universe. *[1]*

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(b) State **one** advantage of the Copernican model of the solar system. *[1]*

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(c) Galileo discovered four moons orbiting Jupiter. Outline how this discovery supports the Copernican model of the solar system. *[3]*

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(d) Galileo is said to have dropped objects of different masses from the top of the Leaning Tower of Pisa.

(i) Describe how the results of his observations were inconsistent with the Aristotelian view of falling objects. *[2]*

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(ii) Outline how Newtonian mechanics accounts for the result of Galileo's observations. *[2]*

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E2. This question is about the relation between magnetism and electricity.

Oersted observed that an electric current in a wire causes a compass needle to deflect.

(a) State the reason for the deflection of the compass needle. *[1]*

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(b) Ampere extended Oersted's work by experimenting with two current-carrying wires. Outline the results of his experiments. *[3]*

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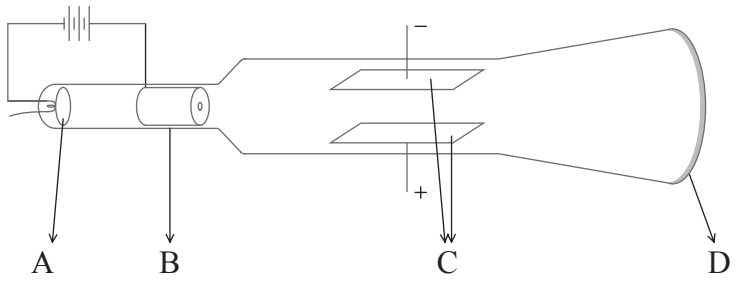
E3. This question is about the discovery of the electron.

(a) In 1897, J J Thomson measured the charge to mass ratio $\left(\frac{e}{m}\right)$ for electrons.

The diagram below illustrates a modern version of part of the apparatus he used.



State the name, and explain the purpose, of the parts of the apparatus labelled above.

(i) Part A: name: . . . . . *[1]*

purpose: . . . . . .

(ii) Part B: name: . . . . . *[1]*

purpose: . . . . . .

(iii) Part C: name: . . . . . *[1]*

purpose: . . . . . .

(iv) Part D: name: . . . . . *[1]*

purpose: . . . . . .

(b) Discuss the significance of this experiment in respect of the nature of electrons. *[3]*

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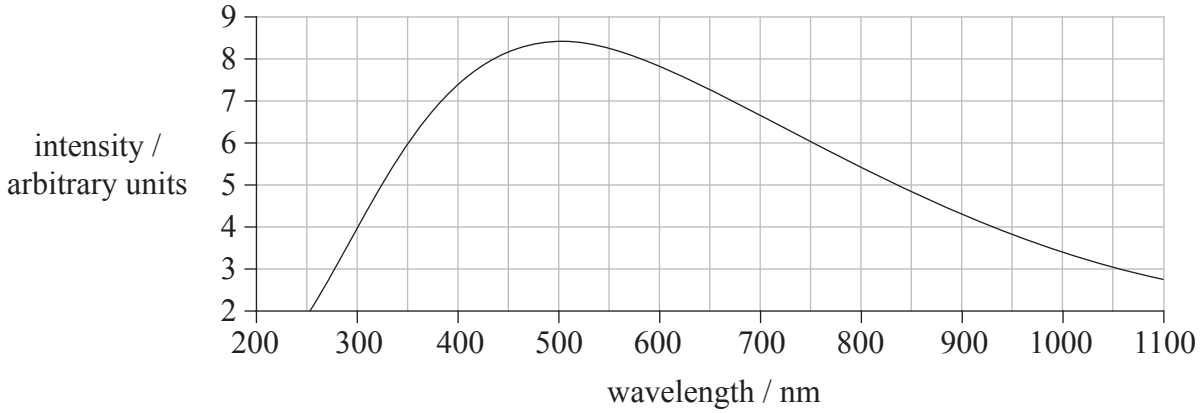
Option F — Astrophysics

F1. This question is about the Sun.

The black body spectrum of the Sun is shown below.



(a) Deduce that the surface temperature of the Sun is approximately 5800 K. *[2]*

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(b) The emission spectrum of the Sun is crossed by dark lines. Outline how these lines are used to determine the chemical composition of the Sun's atmosphere. *[3]*

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F2. This question is about the luminosity of stars.

(a) Define *luminosity*. *[1]*

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(b) Data for the surface temperature T and the radius R of two stars A and B are given in the table below.

	T / K	R / km
Star A	3.0×10^{3}	8.7×10^{11}
Star B	2.0×10^{4}	6.8×10^{7}

Using **only** data from the table, determine the ratio $\frac{\text{luminosity of A}}{\text{luminosity of B}}$. *[3]*

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F3. This question is about the Sun and the star Sirius A.

The table below gives data for the Sun and the star Sirius A.

Star	**Apparent brightness / W m^{-2}**	**Luminosity (relative units)**
Sun	1.4×10^{3}	1.0
Sirius A	1.1×10^{-7}	23

(a) Explain which star will have the greatest apparent magnitude. *[2]*

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(b) Using the data from the table, deduce that the distance of Sirius from Earth is 5.4×10^{5} AU. *[3]*

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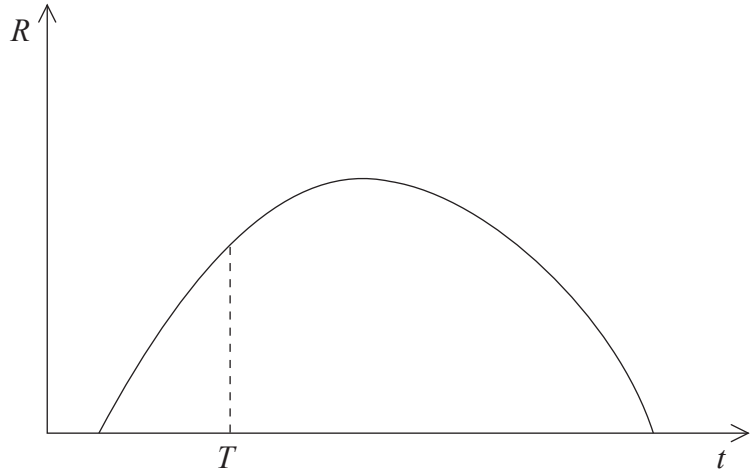
F4. This question is about the development of the universe.

The diagram below shows the variation with time t of the radius R of the observable universe, based on a closed model of the universe. The point $t = T$ is the present time.



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

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(b) On the diagram above, draw the variation with time t of the radius R of the observable universe, based upon an open model of the universe. *[3]*

(c) Explain, by reference to your answer to (b), why the predicted age of the universe depends upon the model of the universe chosen. *[2]*

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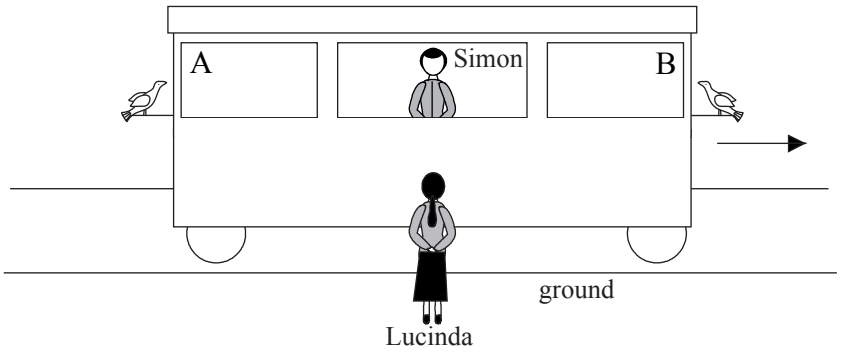
Option G — Relativity

G1. This question is about simultaneity.

In the diagram below, Simon is in a railway carriage that is travelling in a straight-line with uniform speed relative to Lucinda who is standing on the ground by the track. There is a window at each end A and B of the railway carriage. Simon determines his position to be at the midpoint of the railway carriage.

At the instant that Simon and Lucinda are opposite each other, a bird lands at end A of the carriage and another one lands at end B of the carriage. Lucinda determines that the two birds land simultaneously.



State, and explain, whether Simon will observe the landings of the birds to be simultaneous. *[4]*

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G2. This question is about time dilation.

The distance between a star and Earth is 5.0×10^{16} m as measured by an observer on Earth. An astronaut in a spaceship is moving from the Earth towards the star at a speed of 0.60c as measured by the observer on Earth.

(a) Calculate the time taken to travel from the Earth to the star as measured by

(i) the observer on Earth. *[2]*

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(ii) the astronaut. *[2]*

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(b) State, and explain, which of your answers in (a) is the proper time. *[2]*

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(c) At the time when the astronaut leaves the Earth, the astronaut and the observer on Earth are the same age. After reaching the star the astronaut returns to Earth. Explain any age difference between the astronaut and the observer on the astronaut's return to Earth. *[3]*

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G3. This question is about relativistic mass and energy.

(a) Outline why it is not possible for an object with rest mass to attain the speed of light. *[3]*

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(b) An electron is accelerated from rest through a potential difference of 6.00×10^6 V.

After acceleration,

(i) state the total energy of the electron in MeV. *[1]*

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(ii) deduce that the speed of the electron is 0.997c. *[3]*

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Option H — Optics

H1. This question is about refraction.

(a) Define *refractive index*. *[1]*

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(b) In a certain medium, the speed of light of a particular frequency is $2.1 \times 10^8 \, \text{m s}^{-1}$. Calculate the refractive index of the medium for this frequency. *[2]*

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(c) With reference to your answer in (b), describe what is meant by optical dispersion. *[3]*

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H2. This question is about image formation by a plane mirror.

(a) State the **two** laws of reflection of light. *[2]*

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2. . . . . .

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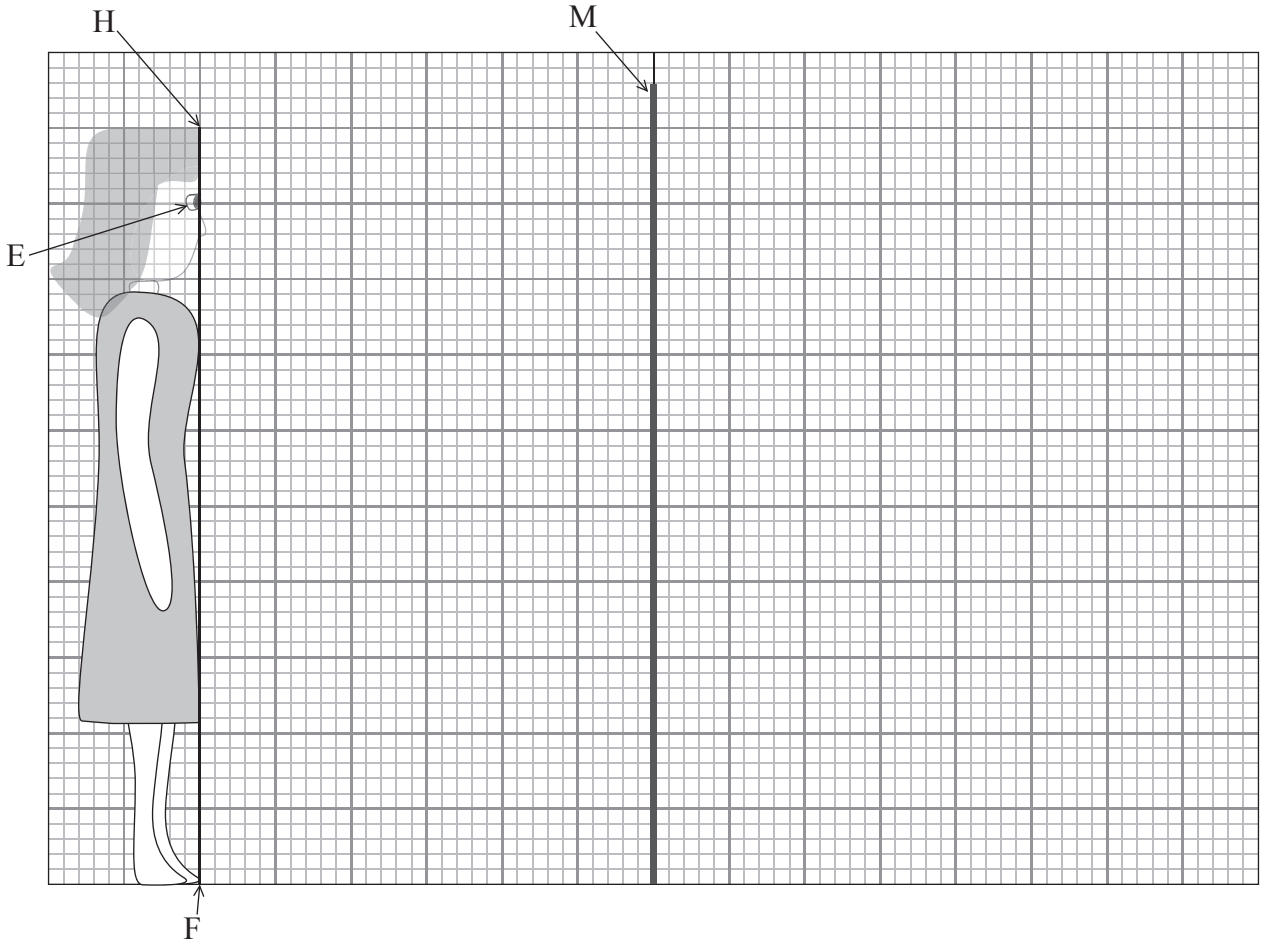
(b) In the diagram below, the line labelled HF represents a person standing in front of a vertical mirror labelled *M*. The position of the person's eye is labelled E.



On the diagram above draw

(i) the position of the image of the person formed by the mirror. *[2]*

(ii) a ray from the foot F, and a ray from the top of the head H, to show the reflection of these rays into the eye E. *[2]*

(This question continues on the following page)

(Question H2 continued)

(c) The height of the person is 1.50 m and her eye is 1.35 m above the floor. The length and height of the mirror above the floor are adjusted so that she can just see the whole of her image in the mirror.

By reference to your ray diagram in (b)(ii), deduce

(i) the minimum length of the mirror. *[1]*

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(ii) the height of the lower edge of the mirror above the floor. *[1]*

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(d) The person now stands further away from the mirror. State the effect, if any, that this has to your answers in (c)(i) and (ii). *[1]*

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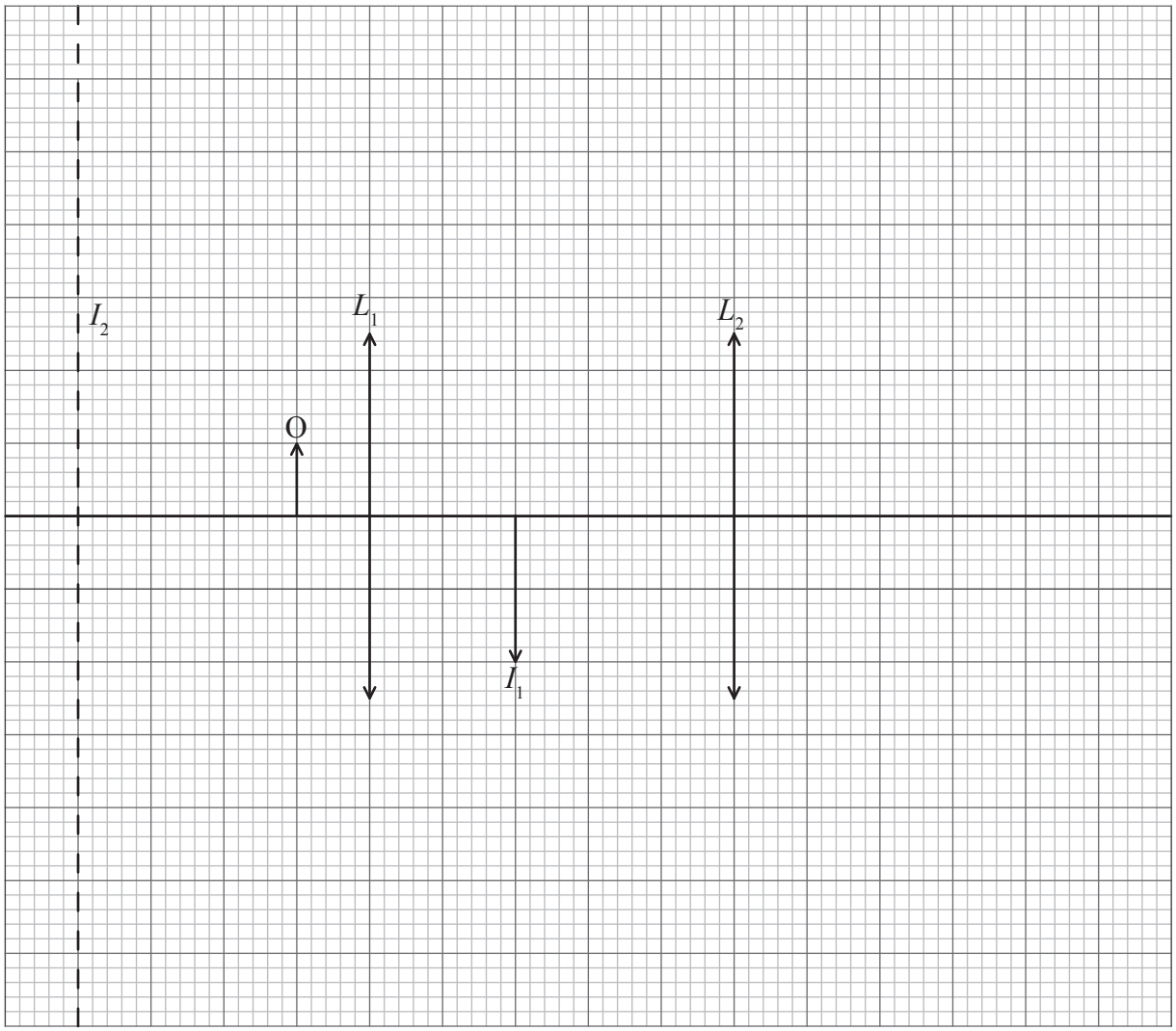
H3. This question is about a compound microscope.

The diagram below shows two lenses of a compound microscope. L_1 is the objective lens and L_2 is the eyepiece lens.



I_1 is the image of the object O formed by the objective lens L_1. The final image formed is in the plane shown by the dotted line labelled I_2.

(a) On the diagram above, construct a ray **or** rays to determine the position of the principal focus of the eyepiece. Label this position with the letter F. *[2]*

(This question continues on the following page)

(Question H3 continued)

(b) By using the grid, take measurements to determine the linear magnification of

(i) the objective lens. *[1]*

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(ii) the eyepiece. *[1]*

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(c) Use your answer to (b) to determine the total linear magnification of the microscope. *[1]*

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