INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

M01/430/S(3)

PHYSICS
STANDARD LEVEL
PAPER 3

Wednesday 16 May 2001 (morning)

1 hour

Name

Number

INSTRUCTIONS TO CANDIDATES

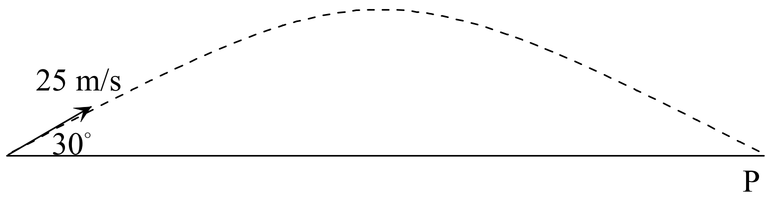
- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the boxes below.

OPTIONS ANSWERED	EXAMINER	TEAM LEADER	IBCA
	/20	/20	/20
	/20	/20	/20
	TOTAL /40	TOTAL /40	TOTAL /40

OPTION A — MECHANICS

A1. *This question is about a projectile.*

A projectile is projected with a speed of 25 $m\,s^{-1}$ at an angle of 30° to the horizontal as shown in the diagram.



You may ignore air resistance.

(a) At the maximum height reached by the projectile, show on the diagram the direction of

(i) the acceleration of the projectile. *[1]*

(ii) the velocity of the projectile. *[1]*

(b) What is the value of the horizontal component of the projectile velocity at the moment of launch? *[1]*

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(c) What is the value of the horizontal component of the projectile velocity at the instant it reaches point P? *[1]*

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(d) The projectile lands at point P. How far is point P from the point of launch? *(You may take the acceleration of free fall (g) to be equal to 10 $m\,s^{-2}$).* *[3]*

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A2. *This question is about the vector nature of momentum.*

Two ice pucks are connected by a spring and are set into motion on a flat horizontal ice bed. The spring compresses and expands and this produces a complex motion. The mass of the spring can be ignored and so can any friction between the pucks and the ice bed.

Diagram 1 below shows the position and directions of motion of the two pucks at a particular instant when the spring is stretched.

The vector in **Diagram 2** represents the total momentum of the two pucks at this instant.

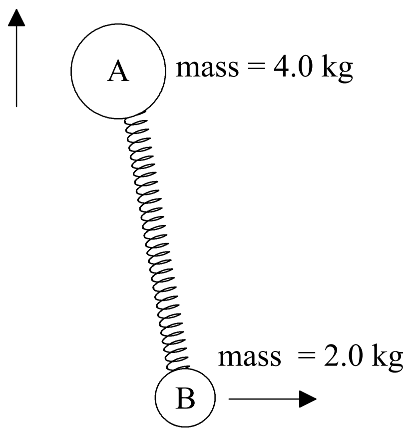

Diagram 1

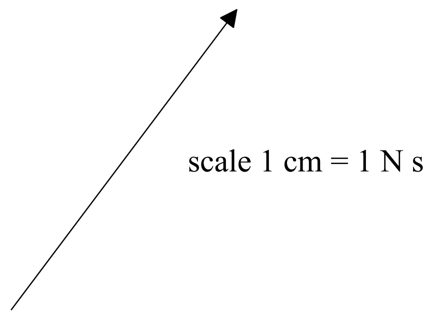

Diagram 2

Puck A has a mass of 4.0 kg and puck B has a mass of 2.0 kg. At the instant shown in **Diagram 1** the speed of the puck B is $1.5\,\mathrm{m\,s^{-1}}$.

(a) What is the magnitude of the momentum of puck B? *[1]*

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(b) Use **Diagram 2** above to find the magnitude of the momentum of puck A. *[3]*

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(This question continues on the following page)

(Question A2 continued)

(c) At some time later puck B is momentarily stationary.

(i) In what direction will A be moving at this instant? Explain. *[2]*

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(ii) What will be the speed of A at this instant? *[2]*

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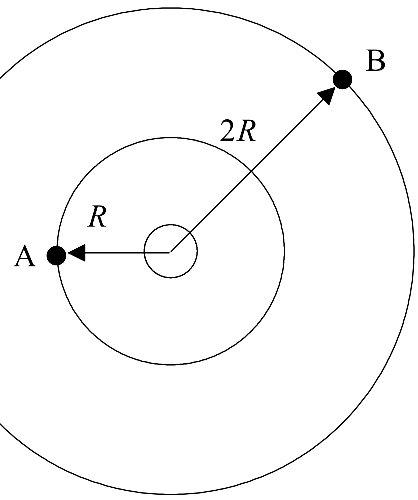
A3. *This question is about orbiting satellites.*

Two satellites A and B move in circular orbits about the Earth. Satellite A has an orbital radius R as measured from the centre of the Earth and satellite B has an orbital radius $2R$.



(a) Show that the speed of satellite A is greater than the speed of satellite B by a factor of $\sqrt{2}$. *[3]*

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(b) At which orbital radius is the gravitational potential due to the Earth the greatest? Explain. *[2]*

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OPTION B — ATOMIC AND NUCLEAR PHYSICS EXTENSION

B1. *This question is about nuclear processes.*

(a) Explain what is meant by the term *nuclear binding energy.* *[1]*

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(b) Use the following data to show that the nuclear binding energy per nucleon of the nuclide $^{4}_{2}\text{He}$ is 7.06 MeV. *[4]*

Mass of proton	= 1.00782 u
Mass of neutron	= 1.00867 u
Mass of $^{4}_{2}\text{He}$ nuclide	= 4.00260 u
1 u	= 930 MeV

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` (c) (i) State **two** advantages of using nuclear fusion as a source of energy as opposed to using nuclear fission. *[2]*

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(ii) Explain why sustained nuclear fusion is much harder to achieve in a laboratory than nuclear fission. *[2]*

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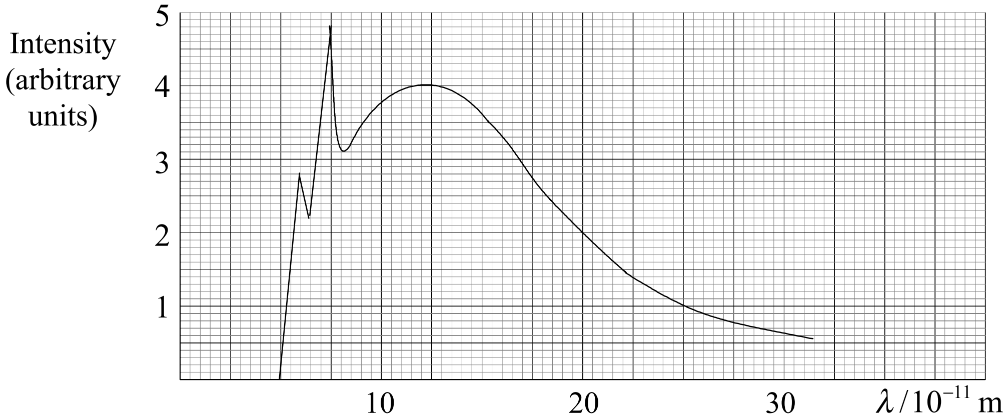
B2. *This question is about x-rays.*

Electrons are accelerated in an x-ray tube through a potential difference V. They strike a molybdenum target and the diagram below shows the resulting x-ray spectrum produced.



(a) Explain how the continuous part of the x-ray spectrum is produced. *[3]*

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(b) Use information from the graph to find

(i) the potential through which the electrons are accelerated. *[3]*

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(ii) the difference in energy between the ground state energy level and the first excited state energy level of the molybdenum atom. *[3]*

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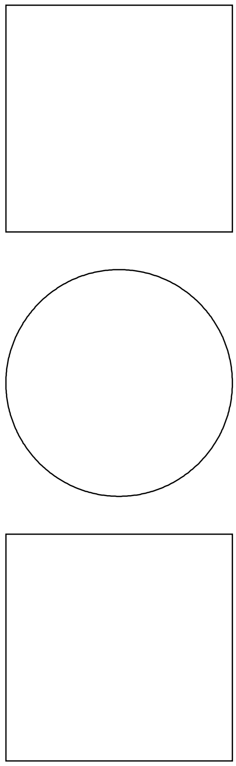
(c) On the graph sketch the x-ray spectrum that would be produced if the accelerating potential were halved. *[2]*

OPTION C — ENERGY EXTENSION

C1. *This question is about heat engines.*

A heat engine can be thought of as operating between a hot reservoir and a cold reservoir. During one cycle of the engine Q_H units of energy are transferred from the hot reservoir to the engine and Q_C units of energy are transferred from the engine to the cold reservoir. During the cycle the engine performs an amount of work *W*.

(a) The diagram below can be used to represent the system.



(i) On the diagram label the two reservoirs and the engine. Also draw and label appropriate arrows to represent the energy transfers quantities Q_H, Q_C and *W*. *[2]*

(ii) Write down the relation between Q_H, Q_C and *W*. *[1]*

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(iii) Name the law of physics, which relates the quantities Q_H, Q_C and *W*. *[1]*

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(This question continues on the following page)

(Question C1 continued)

(b) For a particular engine Q_H is provided at the rate of 3.0 kW and Q_C by a water cooling system. The data for the cooling system is given below.

rate of water flow	= 0.05 kg s^{-1}
temperature of cold water in	= 280 K
temperature of water out	= 285 K
specific heat capacity of water	= 4200 J kg^{-1} K^{-1}

(i) At what rate is energy carried away from the engine? *[2]*

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(ii) Determine the maximum theoretical mechanical power output of the engine and the maximum theoretical efficiency of the engine. *[3]*

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(c) A certain electrical power station uses water from a river to carry away the excess heat. Ignoring any variations in the flow rate of the river, explain why the power station is generally more efficient in winter than in summer. *[2]*

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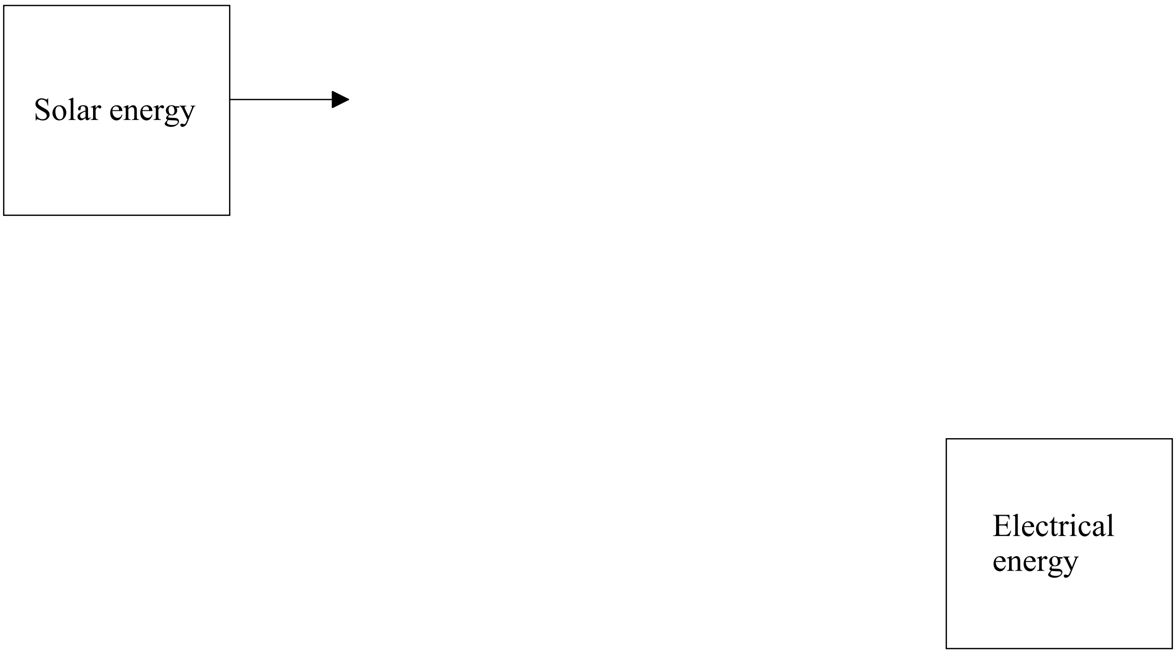
C2. *This question is about energy transformations.*

The energy possessed by the waves in the sea can be used to produce electrical energy.
Construct below an energy-flow diagram that shows the energy transformations by which solar energy is transformed to wave energy and then to electrical energy. *[4]*



C3. *This question is about photovoltaic devices.*

(a) What class of materials is usually used in a photovoltaic device? *[1]*

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(b) Why will a photovoltaic device not operate unless the frequency of the incident radiation is above a certain threshold value? *[3]*

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(c) One disadvantage of a photovoltaic device is that it will not operate at night. Suggest a way in which the energy generated by the device during the day may be used at night. *[1]*

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OPTION D — BIOMEDICAL PHYSICS

D1. *This question is about blood pressure.*

When a nurse takes the blood pressure of a particular patient the systolic reading is 140 mm of mercury and the diastolic reading is 80 mm of mercury.

(a) Explain the meaning of the terms *systolic* and *diastolic*. *[2]*

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(b) Show that a blood pressure reading of 80 mm of mercury is equivalent to 11 kPa.
(Density of mercury = 1.36×10^4 kg m^{-3}, acceleration due to gravity = 10 m s^{-2}.) *[2]*

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(c) Explain why blood pressure readings are usually taken at the upper arm. *[2]*

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(d) If the height of the patient is 1.8 m and his systolic blood pressure reading at the upper arm is 140 mm, estimate the blood pressure reading if it were to be taken at the patient's ankle while he was standing upright.

State **one** assumption that you have made in your calculation. *[4]*

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D2. *This question is about scaling.*

Toby has a mass of 70 kg and Susie has a mass of 50 kg.

(a) Estimate the ratio of thermal energy loss from Toby to that from Susie. *[4]*

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(b) State **one** assumption that you have made in your estimate. *[1]*

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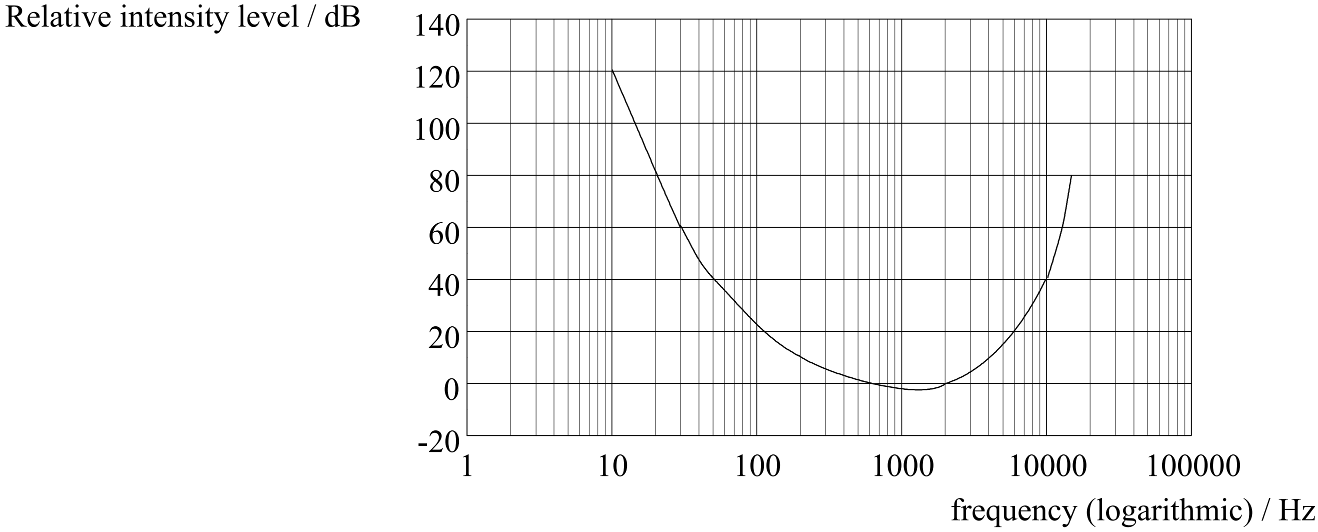
D3. *This question is about hearing.*

The graph below shows how the minimum intensity of sound that is required to be just heard (threshold of hearing) varies with frequency for the average human ear.



Use the graph to find

(a) the frequency range over which a sound of intensity 10^{-8} W m^{-2} can just be heard. *[2]*

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(b) the frequency at which the ear is most sensitive. *[1]*

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(c) how much less intense a sound of 200 Hz must be than a sound of intensity 10 000 Hz if it is to be just heard. *[2]*

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OPTION E — HISTORICAL PHYSICS

E1. *This question is about different views on the nature of motion.*

Here are two simple observations.

Observation 1. If you are holding a book in your hand and release it, it falls to the ground.

Observation 2. In order to make a book move along a flat surface you have to exert a force on the book continuously.

(a) Complete the table below in respect of the different views that Aristotle and Galileo had about aspects of these observations.

Aspect of the observations	**Aristotle's view**	**Galileo's view**
The time for books of different mass to reach the ground when dropped from the same height.	. . . .	. . . .
The relationship between a constant force applied to a book and the velocity of the book.	. . . .	. . . .

[4]

(b) How did the methods by which Galileo and Aristotle reached their conclusions differ? *[1]*

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(c) In what way did Newton extend Galileo's view of the effect of the force on the motion of the book? *[1]*

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E2. *This question is about the physics of Kepler and Newton.*

Kepler's third law states that the square of the orbital period of rotation of a planet around the Sun is proportional to the cube of the average radius of orbit.

(a) Upon whose precise observations did Kepler base his law? *[1]*

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(b) Why did Kepler refer to the **average** radius of orbit? *[1]*

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(c) The asteroid called Ceres is on average three times further away from the Sun than the Earth. What is the orbital period, in years, of Ceres about the Sun? *[3]*

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(This question continues on the following page)

(Question E2 continued)

(d) Newton was able to explain Kepler's third law by proposing that there exists, between a planet and the Sun, a central force of attraction that varies as the inverse square of the planet's distance from the Sun.

(i) What did Newton mean by a *central force*? *[1]*

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(ii) In applying his law of gravitation to extended objects such as the Sun and planets, Newton made an assumption which he later proved mathematically. What was this assumption? *[2]*

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(iii) A consequence of Newton's ideas on mechanics and gravity is that the mass of the Sun can be found by observing the effect that the Sun has on the planets that orbit it. Use the following data to estimate the mass of the Sun.

Universal gravitational constant	$\approx 6 \times 10^{-11}$ N m^2 kg^{-2};
Average orbital radius of the Earth about the Sun	$\approx 1.5 \times 10^{11}$ m;
One year	$\approx 3 \times 10^{7}$ s.

[4]

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(iv) Newton's theory of mechanics and gravity is said to be *deterministic*. Explain what deterministic means. *[2]*

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OPTION F — ASTROPHYSICS

Note that there is only ***one*** *question in this Option.*

F1. *This question is about various aspects of the stars Sirius A and Sirius B.*

(a) Sirius A is at a distance of 2.64 pc from the Earth. With the aid of a diagram describe how the distance of Sirius A from the Earth can be determined. *[6]*

Diagram

Description

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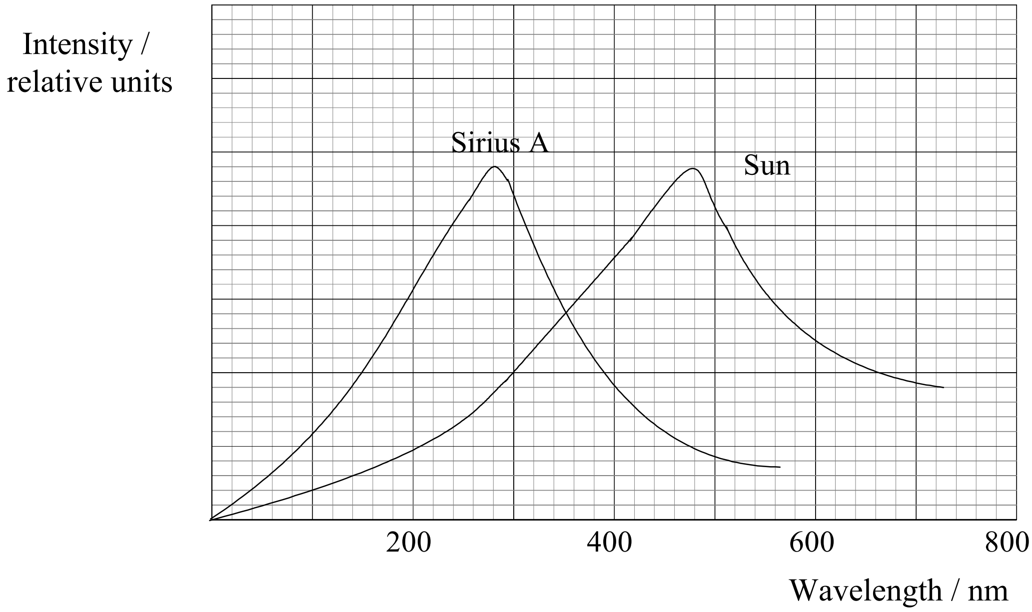
(This question continues on the following page)

(Question F1 continued)

In answering questions (b), (c), and (d) you will need the following data:

Distance of Sirius A from Earth	= 2.64 pc
Apparent brightness of Sirius A	= 1.42×10^{-5} W m^{-2}
Temperature of the Sun	= 6000 K
Apparent brightness of the Sun	= 1370 W m^{-2}
1 parsec	= 2.1×10^{5} AU

(b) The graph below shows the spectra of the Sun and the star Sirius A. *(The intensities have been 'normalised' such that both curves fit on the same graph.)*



Use the information from the graph to

(i) explain whether or not the temperature of Sirius A is higher than that of the Sun. *[2]*

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(ii) find the surface temperature of Sirius A. *[2]*

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(This question continues on the following page)

(Question F1 continued)

(c) Show that the distance from Earth to Sirius A is equivalent to 5.5×10^5 AU. *[1]*

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(d) Show that the luminosity of Sirius A is about 3.1×10^3 times that of the Sun. *[4]*

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(e) What factor other than temperature determines the luminosity of a star? *[1]*

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(f) Sirius A has a companion star Sirius B. Sirius A is a main sequence star whilst Sirius B is a white dwarf.

State **two** characteristics of a white dwarf that are different to the characteristics of a main sequence star. *[2]*

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(g) Sirius A and Sirius B form a system known as a visual binary.

(i) Explain the term *visual binary*. *[1]*

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(ii) What property, other than separation of the stars, of a visual binary system is measured in order to find the mass of the system? *[1]*

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OPTION G — SPECIAL AND GENERAL RELATIVITY

G1. *This question is about time dilation.*

(a) One of the two postulates of the Special Theory of Relativity can be stated as *'the laws of physics are the same for observers in different inertial reference frames.'*

(i) What does the term *inertial reference frame* mean? *[1]*

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(ii) State the other postulate of Special Relativity. *[2]*

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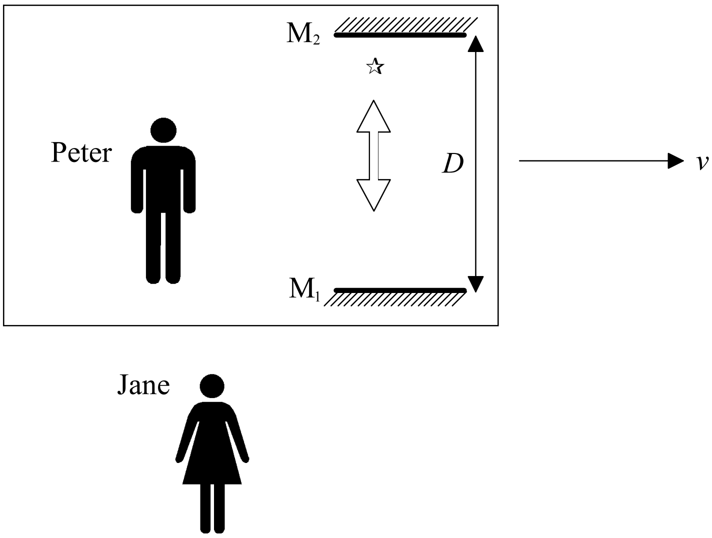
(This question continues on the following page)

(Question G1 (b) continued)

(b) In the diagram below Peter is moving with uniform velocity relative to Jane. A light pulse reflects between the two plane mirrors separated by a distance D as shown in the diagram. To Peter the pulse is seen to traverse a perpendicular path between the mirrors.



(i) Sketch a diagram to show how the path of the light pulse will appear to Jane as the pulse leaves M_1 strikes M_2 and travels back to M_1. Label the distance D on your diagram. *[2]*

(ii) Explain qualitatively with the aid of your diagram and the postulates of relativity why Peter and Jane will measure different times for the light pulse to travel between the mirrors. *[2]*

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(This question continues on the following page)

(Question G1 continued)

(c) Peter and Jane are each wearing a wristwatch with a second hand that takes one minute to make one complete revolution and Peter is moving at a speed of 0.9c with respect to Jane.

When Peter observes the second hand on his watch to have made one complete revolution, how many revolutions will Jane observe the second hand of her watch to have made? *[2]*

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(d) An experiment that demonstrates *time dilation* involves the decay of particles called *muons.*

(i) Outline how the observation of the decay of muons created in the upper atmosphere supports the phenomenon of time dilation. *[4]*

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(ii) Muons have a half-life of 3.1×10^{-6} s as measured in a reference frame in which the muons are at rest.

Suppose an accelerator creates a pulse of muons moving with a speed of 0.9c. How far will the pulse have travelled as measured by a laboratory observer when half the muons in the pulse will have decayed? *[3]*

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G2. *This question is about gravitational and inertial mass.*

One of the cornerstones of Einstein's General Theory of Relativity is that gravitational mass and inertial mass are equivalent.

In 1969 Neil Armstrong was the first man to stand on the surface of the Moon. In what has become a classic film, he is shown holding a hammer in one hand and a feather in the other. He released them at the same time and both reached the surface of the moon at the same time.

Explain how this demonstrates the equivalence of gravitational mass and inertial mass. *[4]*

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OPTION H — OPTICS

H1. *This question is about the refraction of light.*

The diagrams below show two different situations in which a monochromatic ray of light is incident on the boundary between two surfaces. In **Diagram 1** the boundary is between air and glass and in **Diagram 2** the boundary is between water and glass.

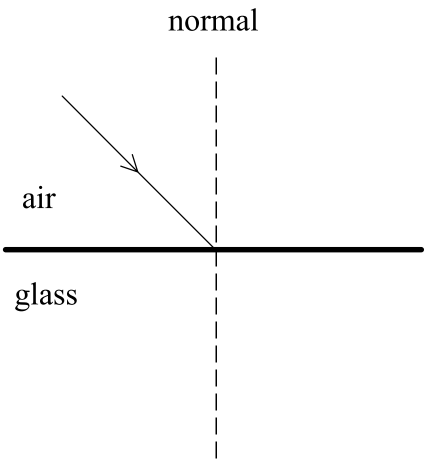

Diagram 1

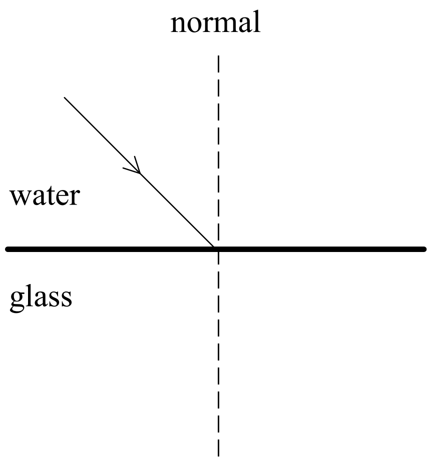

Diagram 2

The refractive index of glass is greater than that of water.

(a) On each diagram sketch the reflected and refracted rays. *[3]*

(b) The refractive index for glass is 1.5 and for water 1.3. Calculate the critical angle for the glass-water boundary. *[1]*

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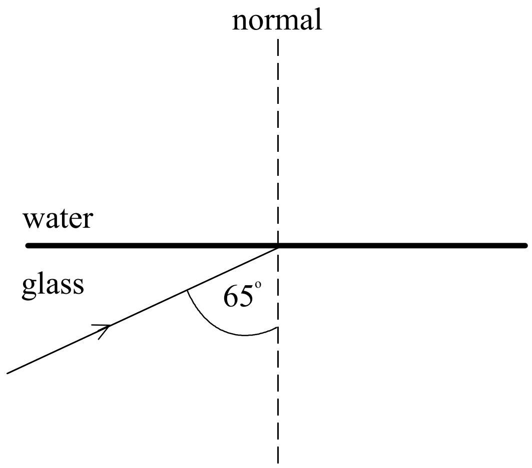
(This question continues on the following page)

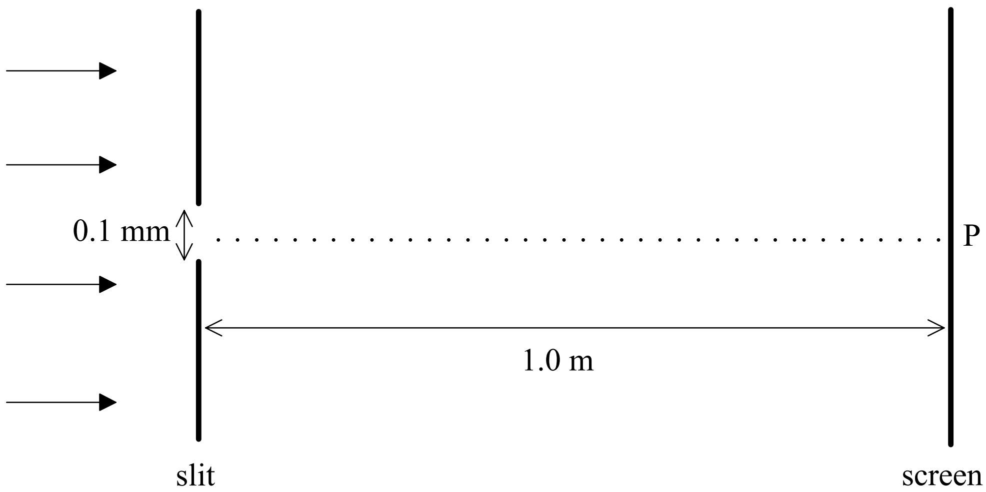
(Question H1 continued)

(c) A ray is incident at the glass-water boundary as shown on the diagram below. Sketch the subsequent path(s) of the ray. *[2]*

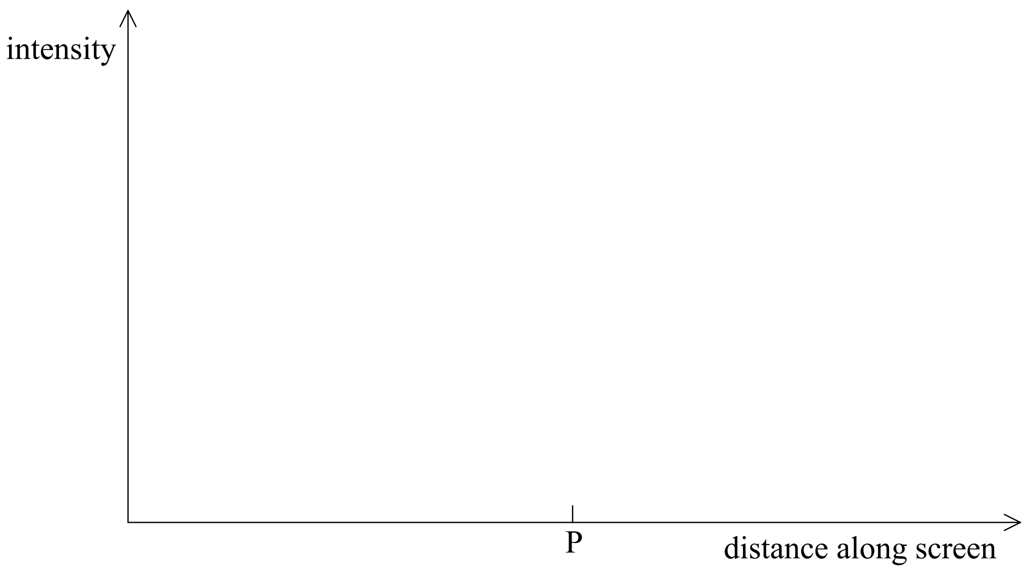


H2. *This question is about diffraction.*

In the diagram below (not to scale) a monochromatic beam of light of wavelength 500 nm is incident on a single slit of width 0.1 mm. After passing through the slit the light is brought to a focus (the focusing lens is not shown) on a screen placed at a distance of 1.0 m from the slit.



(a) On the axes below sketch a diagram showing how the intensity of the light varies at different points along the screen. *(Note that this is a sketch graph; no values are required).* *[3]*



(b) Calculate the width of the central maxima. *[3]*

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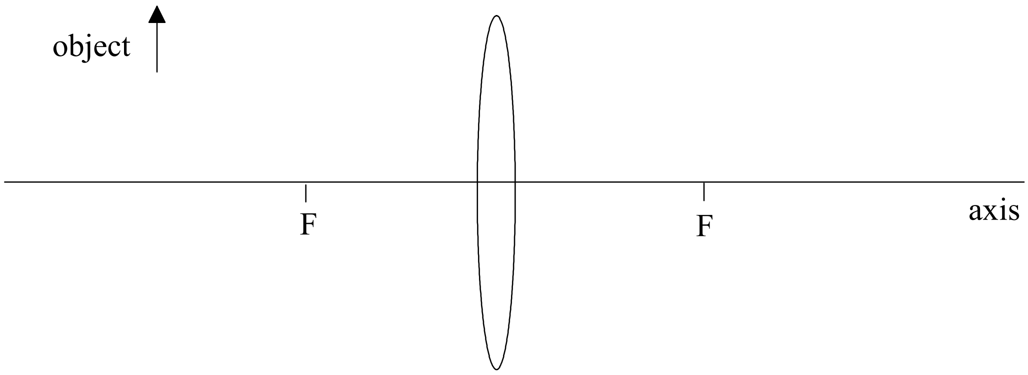
H3. *This question is about the compound microscope.*

(a) The diagram below shows a convex lens, the position of the principal foci (focal points), F, of the lens and an object, which is to be viewed by the lens.



(i) Redraw the object at an appropriate location on the principal axis such that the lens will form a **magnified, virtual image** of the object. *[1]*

(ii) Construct a ray diagram that enables the position of the image to be located. *[2]*

(iii) Mark on the diagram a position where the eye could be placed in order to view the image. *[1]*

(b) The lens above is to be used as the eyepiece of a compound microscope. The diagram below shows the **objective** lens, its two principal foci (focal points), F_o, and the object that is to be viewed.

Mark the following on the axis:

(i) the approximate position, X, of the image formed by the objective lens; *[1]*

(ii) the approximate position, C, of the **eyepiece** lens; *[1]*

(iii) the principal foci (focal points), F, of the eyepiece lens; *[1]*

(iv) the approximate position, Y, of the final image. *[1]*