IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M03/430/S(3)

PHYSICS
STANDARD LEVEL
PAPER 3

Candidate number

Tuesday 20 May 2003 (morning)

1 hour

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box 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. You may continue your answers on answer sheets. Write your candidate number on each answer sheet, and attach them to this examination paper using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

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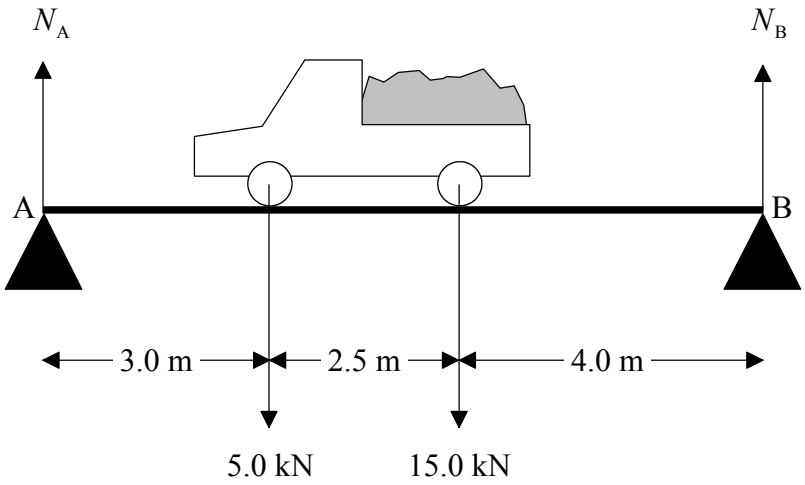
Option A – Mechanics extension

A1. This question is about forces acting on a bridge.

In the diagram below a loaded truck is parked (stationary) on a short bridge that is supported at the points A and B.



The load acting through the front axle is 5.0 kN and the load acting through the rear axle is 15.0 kN.

N_A and N_B are the vertical forces produced on the bridge by the two supports A and B respectively. (The weight of the bridge need not be considered)

(a) Write down the value of $(N_A + N_B)$. *[1]*

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(b) Calculate the value of the force N_A and the force N_B when the truck is in the position shown in the diagram. The relevant distances are shown on the diagram and you can assume that the bridge remains rigid. *[3]*

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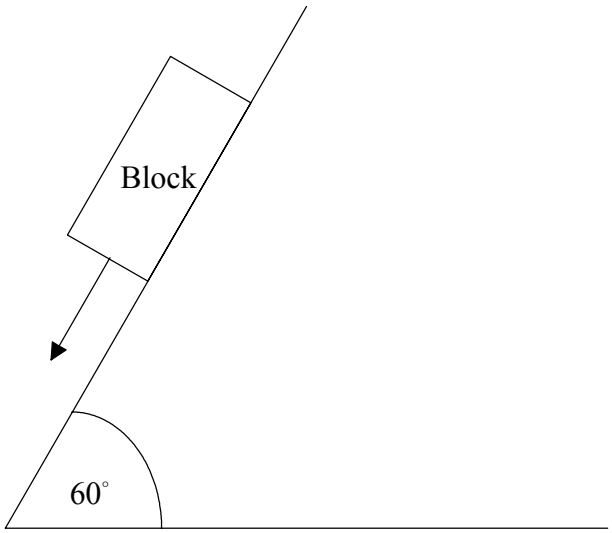
A2. This question is about a wooden block sliding down a rough inclined plane (slope).

The diagram below shows a wooden block sliding down a rough plane. In the position shown the block is accelerating.



(a) Draw a free-body diagram representing the forces acting on the block. *[4]*

(This question continues on the following page)

(Question A2 continued)

The plane makes an angle of 60° with the horizontal, the weight of the block is 5.0 N and the coefficient of kinetic (dynamic) friction between the block and the plane is 0.30.

(b) (i) Determine the magnitude of the frictional force acting on the block. *[2]*

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(ii) Determine the acceleration of the block down the plane. *[2]*

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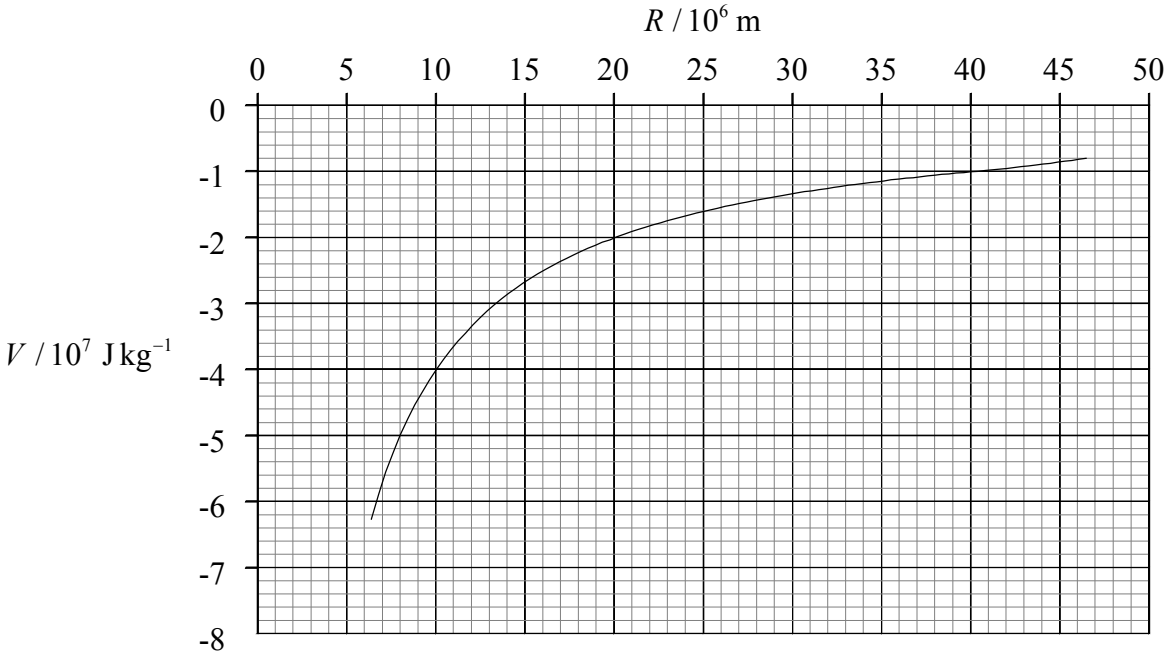
A3. This question is about gravitational potential energy.

The graph below shows the variation of gravitational potential V due to the Earth with distance R from the centre of the Earth. The radius of the Earth is 6.4×10^6 m. The graph does not show the variation of potential V within the Earth.



(a) Use the graph to find the gravitational potential

(i) at the surface of the Earth. *[1]*

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(ii) at a height of 3.6×10^7 m above the surface of the Earth. *[2]*

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(b) Use the values you have found in part (a) to determine the minimum energy required to put a satellite of mass 1.0×10^4 kg into an orbit at a height of 3.6×10^7 m above the surface of the Earth. *[3]*

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(This question continues on the following page)

(Question A3 continued)

(c) Give **two** reasons why more energy is required to put this satellite into orbit than that calculated in (b) above. *[2]*

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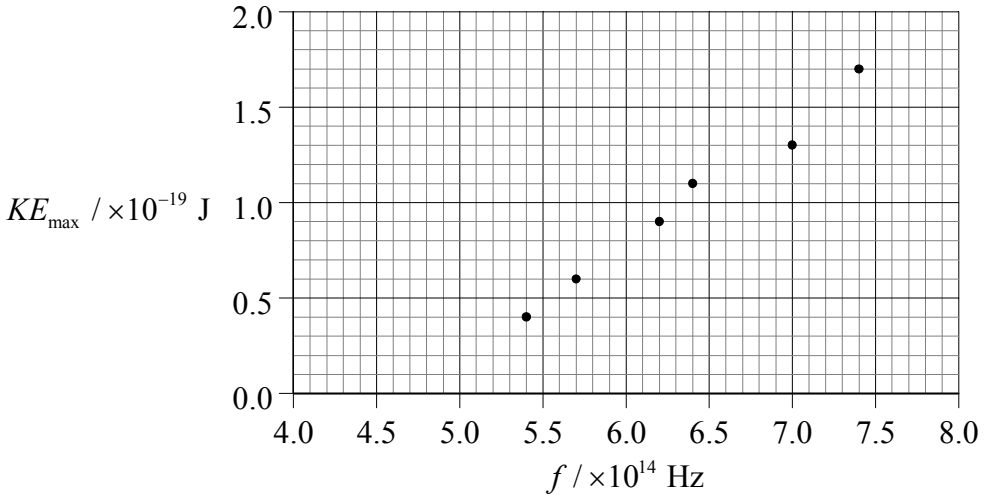
Option B – Quantam physics and nuclear physics

B1. This question is about the photoelectric effect.

Light is incident on a clean metal surface in a vacuum. The maximum kinetic energy KE_{max} of the electrons ejected from the surface is measured for different values of the frequency f of the incident light.

The measurements are shown plotted below.



(a) Draw a line of best fit for the plotted data points. *[1]*

(b) Use the graph to determine

(i) the Planck constant. *[2]*

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(ii) the minimum energy required to eject an electron from the surface of the metal (the *work function*). *[3]*

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(This question continues on the following page)

(Question B1 continued)

(c) Explain briefly how Einstein's photoelectric theory accounts for the fact that no electrons are emitted from the surface of this metal if the frequency of the incident light is less than a certain value. *[3]*

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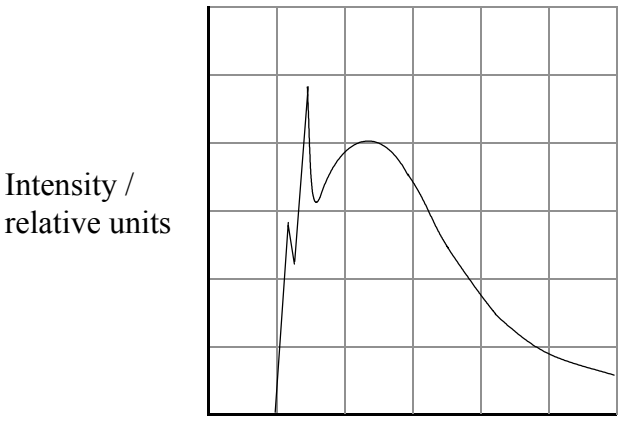
B2. This question is about X-rays.

Electrons are accelerated through a potential difference of 25 kV and strike a target made from molybdenum.

The diagram below shows a partly labelled sketch graph of the resulting X-ray spectrum.



(a) On the diagram label

(i) the horizontal axis. *[1]*

(ii) a point P corresponding to the "braking radiation". *[1]*

(iii) the characteristic spectrum of the target. *[1]*

(b) Calculate the maximum frequency of the radiation produced. *[2]*

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B3. This question is about radioactive decay and fundamental forces.

(a) The nucleus of manganese-54 ($^{54}_{25}$Mn) undergoes **positive** beta decay to form a nucleus of chromium (Cr). Complete the following equation for this decay process. *[3]*

$$^{54}_{25}\text{Mn} \rightarrow \quad \text{Cr} \quad + \quad \beta^{+} \quad +$$

(b) Positive beta decay of a nucleus involves the weak nuclear interaction (force). State the name of the **exchange** particle involved in the weak nuclear interaction. *[1]*

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(c) State the name of

(i) the **interaction** involved when a nucleus undergoes **alpha** particle decay. *[1]*

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(ii) an **exchange** particle involved with **alpha** particle decay. *[1]*

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Option C – Energy extension

C1. This question is about the production of nuclear energy and its transfer to electrical energy.

(a) When a neutron "collides" with a nucleus of uranium-235 ($^{235}_{92}U$) the following reaction can occur.

$$^{235}_{92}U \quad + \quad ^{1}_{0}n \quad \rightarrow \quad ^{144}_{56}Ba \quad + \quad ^{90}_{36}Kr \quad + \quad 2\,^{1}_{0}n$$

(i) State the name given to this type of nuclear reaction. *[1]*

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(ii) Energy is liberated in this reaction. In what form does this energy appear? *[1]*

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(b) Describe how the neutrons produced in this reaction may initiate a chain reaction. *[1]*

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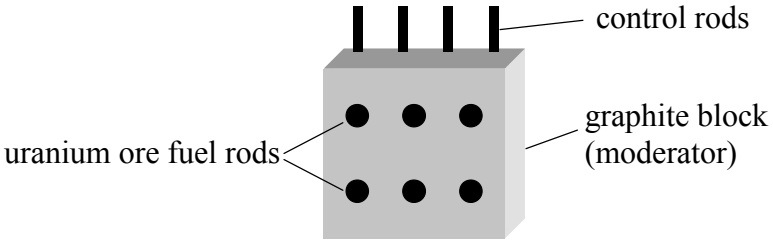
The purpose of a nuclear power station is to produce electrical energy from nuclear energy. The diagram below is a schematic representation of the principle components of a nuclear reactor "pile" used in a certain type of nuclear power station.



The function of the moderator is to slow down neutrons produced in a reaction such as that described in part (a) above.

(c) (i) Explain why it is necessary to slow down the neutrons. *[3]*

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(Question C1 continued)

(ii) Explain the function of the control rods. *[2]*

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(d) Describe briefly how the energy produced by the nuclear reactions is extracted from the reactor pile and then transferred to electrical energy. *[4]*

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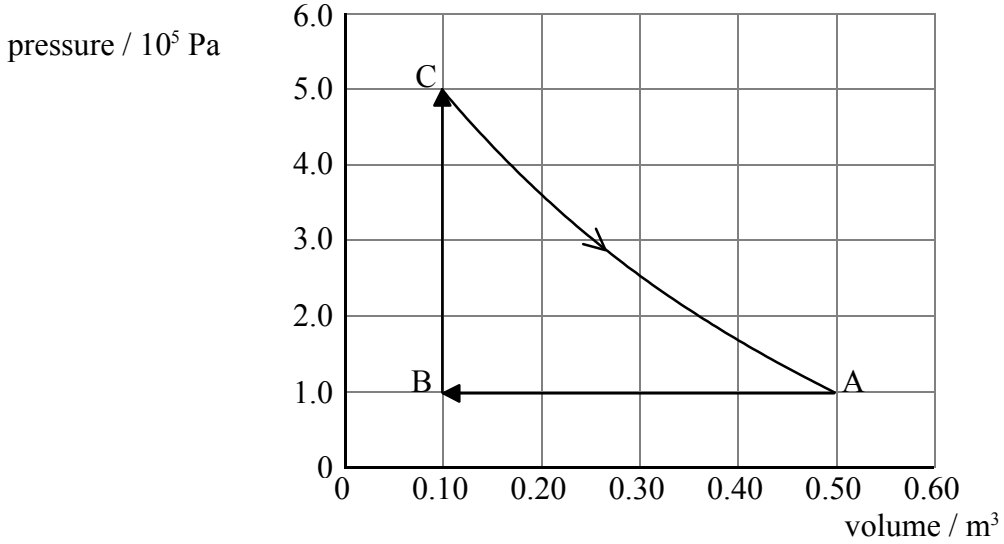
C2. This question is about a heat engine.

A certain heat engine uses a fixed mass of an ideal gas as a working substance. The graph below shows the changes in pressure and volume of the gas during one cycle ABCA of operation of the engine.



(a) For the part A → B of the cycle, explain whether

(i) work is done **by** the gas or work is done **on** the gas. *[1]*

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(ii) thermal energy (heat) is absorbed **by** the gas or is ejected **from** the gas to the surrounding. *[1]*

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(b) Calculate the work done during the change A → B. *[2]*

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(c) Use the graph to estimate the total work done during one cycle. *[2]*

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(This question continues on the following page)

(Question C2 continued)

(d) The total thermal energy supplied to the gas during one cycle is 120 kJ. Estimate the efficiency of this heat engine. *[2]*

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Option D – Biomedical physics

D1. This question is about scaling and looks at why it is dangerous for insects to fall into water.

(a) A sphere of radius r and mass M is completely immersed in water and then removed. A thin film of water of constant thickness sticks to the sphere. Assuming that the mass m of the film is proportional to the surface area of the sphere, deduce that $\frac{m}{M}$ is proportional to $\frac{1}{r}$. *[3]*

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For a sphere of radius 0.80 m, the above ratio $\frac{m}{M}$ is equal to 2 %.

A flying insect lands on the surface of water in a glass. It becomes immersed in the water but eventually manages to crawl on to the rim of the glass.

(b) (i) Assuming that the body of the insect can be approximated to a sphere of radius 4.0 mm, estimate the ratio of the mass of water carried out by the insect to its mass. *[3]*

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

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(iii) Comment on your answer to part b(i) above. *[1]*

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D2. This question is about ultrasound scanning.

(a) State a typical value for the frequency of ultrasound used in medical scanning. *[1]*

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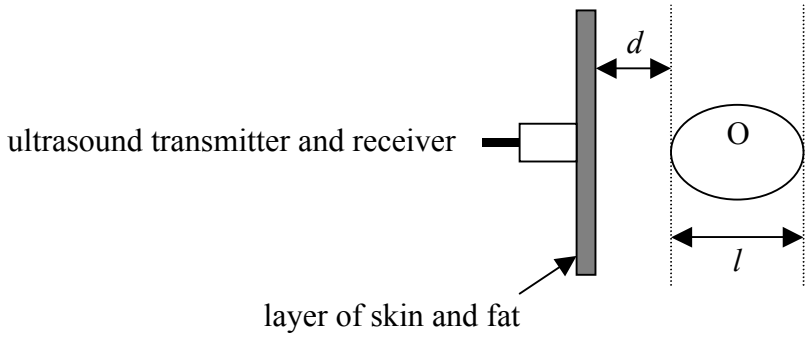
The diagram below shows an ultrasound transmitter and receiver placed in contact with the skin.



The purpose of this particular scan is to find the depth *d* of the organ labelled O below the skin and also to find its length, *l*.

(b) (i) Suggest why a layer of gel is applied between the ultrasound transmitter/receiver and the skin. *[2]*

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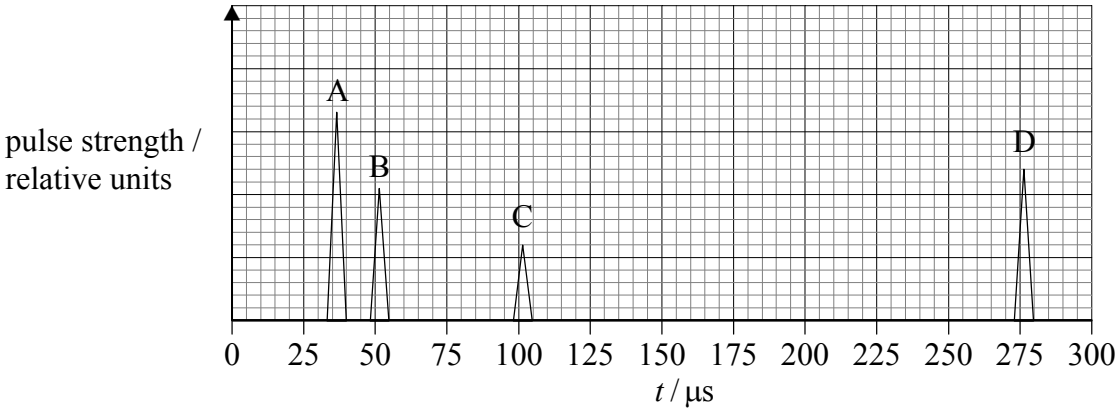
On the graph below the pulse strength of the reflected pulses is plotted against time *t* where *t* is the time lapsed between the pulse being transmitted and the time that the pulse is received.



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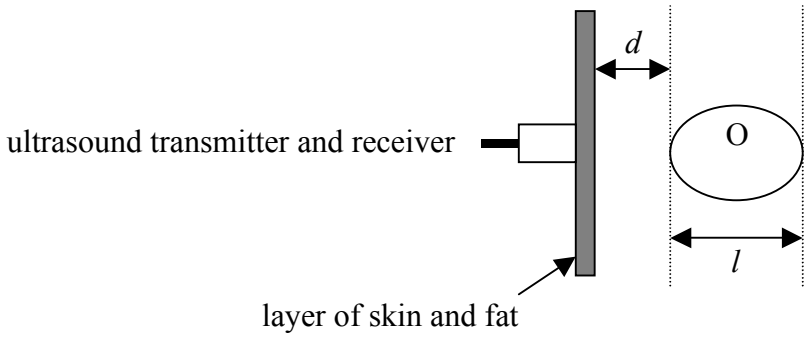
(Question D2(b) continued)

(ii) Indicate on the diagram below the origin of the reflected pulses A, B and C and D. *[2]*



(iii) The mean speed in tissue and muscle of the ultrasound used in this scan is 1.5×10^3 m s^{-1}. Using data from the above graph, estimate the depth *d* of the organ beneath the skin and the length *l* of the organ O. *[4]*

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(c) The above scan is known as an A-scan. State **one** way in which a B-scan differs from an A-scan. *[1]*

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(d) State **one** advantage and **one** disadvantage of using ultrasound as opposed to using X-rays in medical diagnosis. *[2]*

Advantage: . . . . . .

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Disadvantage: . . . . . .

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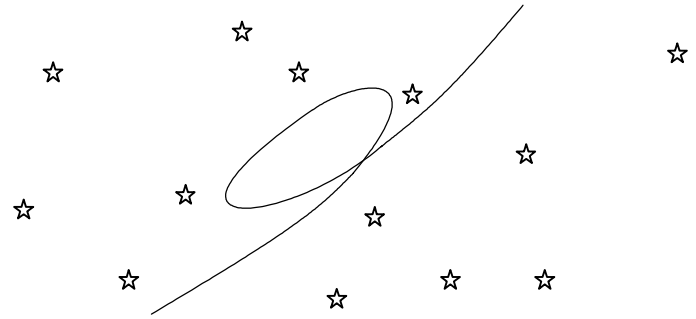
Option E – The history and development of physics

E1. This question is about the motion of Mars as observed from Earth.

The diagram below shows a sketch of the path of Mars as observed from Earth against the background of the fixed stars over a period of six months.



(a) State the name given to this type of observed motion. *[1]*

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(b) Outline how this observed motion of Mars was explained by

(i) Ptolemy. *[2]*

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(ii) Copernicus. *[2]*

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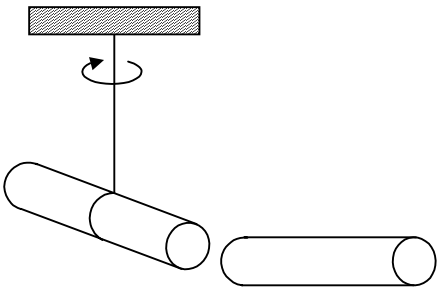
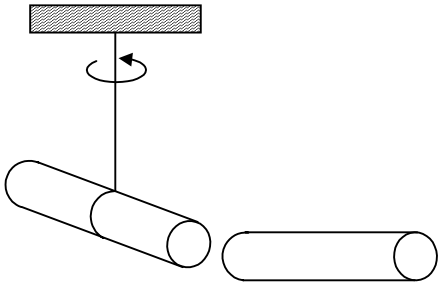
E2. This question is about electrification by contact.

In the Eighteenth Century, Benjamin Franklin demonstrated that there are two types of electricity produced by friction. He did this by using ebonite rods rubbed with fur and glass rods rubbed with silk. The diagram below shows two situations in which one of the rods is suspended vertically by a thread and another rod is brought up close to one end of the suspended rod. This causes the suspended rods to rotate. The direction of rotation of the suspended rod in each situation is shown.

Situation 1



Situation 2



(a) For each situation, identify possible types of rod (ebonite **or** glass) by labelling them using the letter E for the ebonite rods and the letter G for the glass rods. *[2]*

(b) Franklin called the two types of electricity *positive* and *negative*. Suggest why he gave them these names. *[2]*

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(This question continues on the following page)

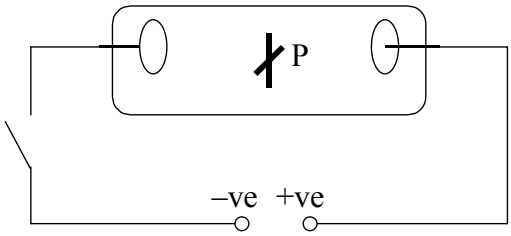
(Question E2 continued)

(c) Complete the table below to show how Franklin's theory about the nature of electricity and how modern atomic theory can be used to explain the phenomenon demonstrated by the diagram in part (a). *[6]*

	Hypothesis / theory	**Explanation**
Franklin	. . . . .	. . . . .
Modern atomic theory	. . . . .	. . . . .

E3. This question is about cathode rays.

The diagram below shows a discharge tube that contains air at low pressure. A cross-shaped object P is placed between the electrodes.



high-voltage supply

When the supply is switched on a greenish glow is seen coming from the tube. The object P also casts a distinct shadow.

(a) Mark on the diagram the region where this shadow appears. *[1]*

(b) In 1876, Eugen Goldstein proposed that such shadows are caused by *cathode rays*.

(i) Explain why Goldstein used this term. *[1]*

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(ii) In 1895, Jean Baptiste Perrin showed that the sign of the electric charge carried by these rays is negative. Describe, using the diagram above, how he managed to do this. *[2]*

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(iii) State the actual nature of cathode rays. *[1]*

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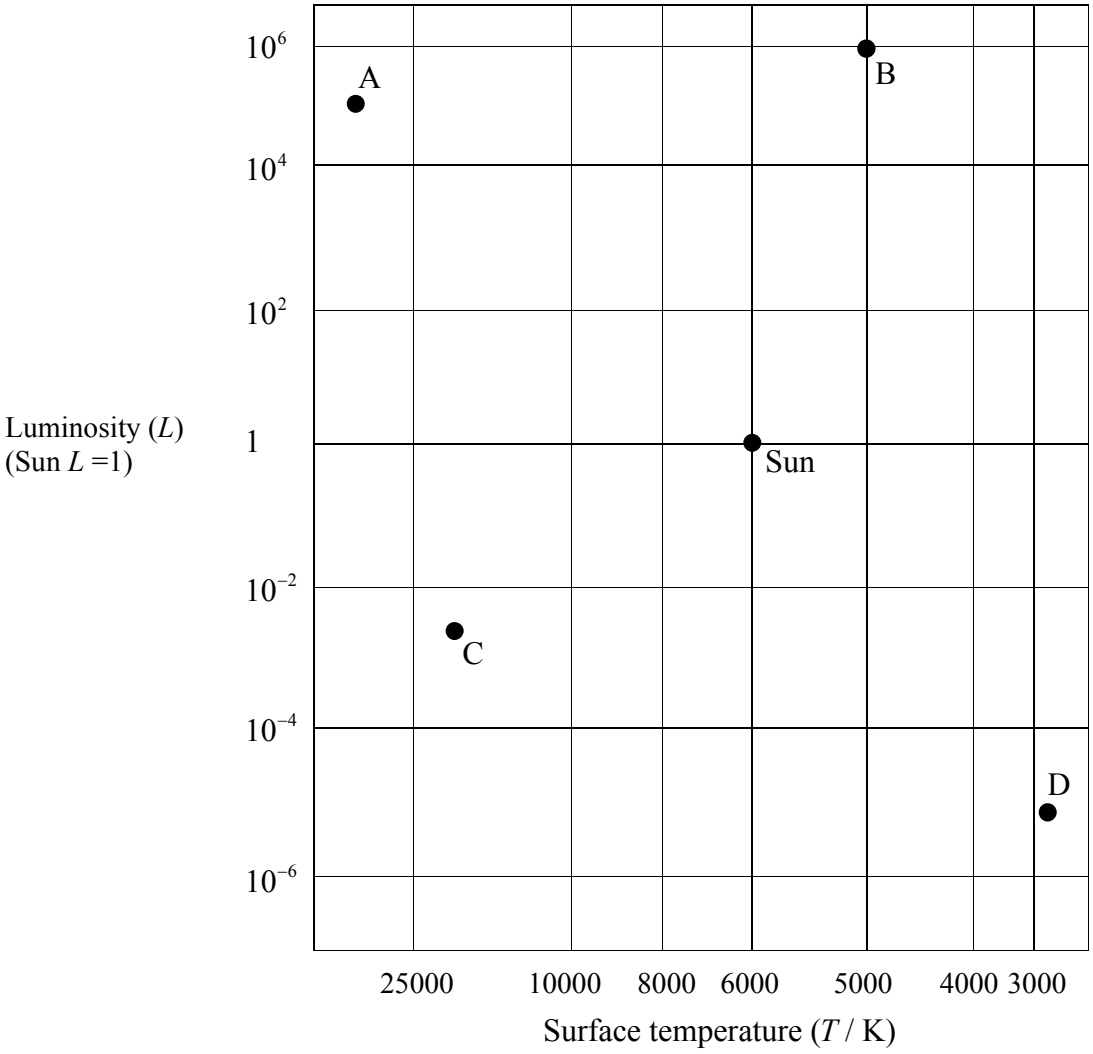
Option F – Astrophysics

F1. This question is about the nature of certain stars on the Hertzsprung-Russell diagram and determining stellar distance.

The diagram below shows the grid of a Hertzsprung-Russell (H-R) diagram on which the positions of the Sun and four other stars A, B, C and D are shown.



(a) State an alternative labelling of the axes.

(i) *x*-axis . . . . . *[1]*

(ii) *y*-axis . . . . . *[1]*

(This question continues on the following page)

(Question F1 continued)

(b) Complete the table below. *[4]*

Star	Type of star
A	
B	
C	
D	

(c) Explain, using information from the H-R diagram, and without making any calculations, how astronomers can deduce that star **B** is larger than star **A**. *[3]*

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(d) Using the following data and information from the H-R diagram, show that star **B** is at a distance of about 700 pc from Earth. *[4]*

Apparent visual brightness of the Sun $= 1.4\times10^{3}$ W m^{-2}
Apparent visual brightness of star B $= 7.0\times10^{-8}$ W m^{-2}
Mean distance of the Sun from Earth $= 1.0$ AU
1 parsec $= 2.1\times10^{5}$ AU

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(e) Explain why the distance of star **B** from Earth cannot be determined by the method of stellar parallax. *[1]*

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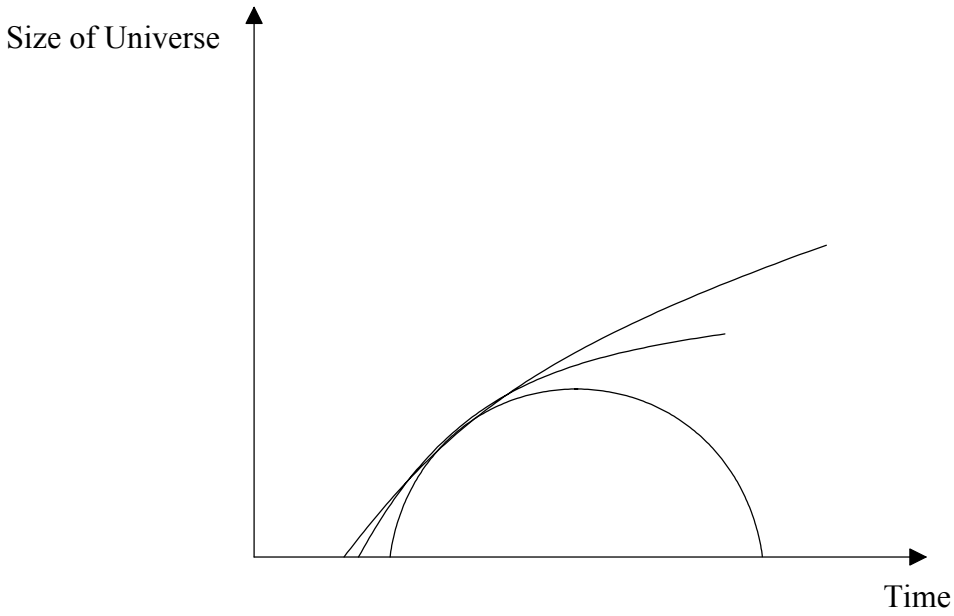
F2. This question is about the possible evolution of the Universe.

The diagram below is a sketch graph that shows three possible ways in which the size of the Universe might change with time.



Depending on which way the size of the Universe changes with time, the Universe is referred to either being *open* or *flat* or *closed*.

(a) On the diagram, identify each type of Universe. *[3]*

(b) Complete the table below to show how the mean density ρ of each type of Universe is related to the critical density ρ_0. *[3]*

Type of Universe	Relation between ρ and ρ_0
Open	
Flat	
Closed	

Option G – Relativity

G1. This question is based upon a thought experiment first proposed by Einstein.

(a) Define the terms *proper time* and *proper length*. *[2]*

Proper time: . . . . . .

. . . . . .

Proper length: . . . . . .

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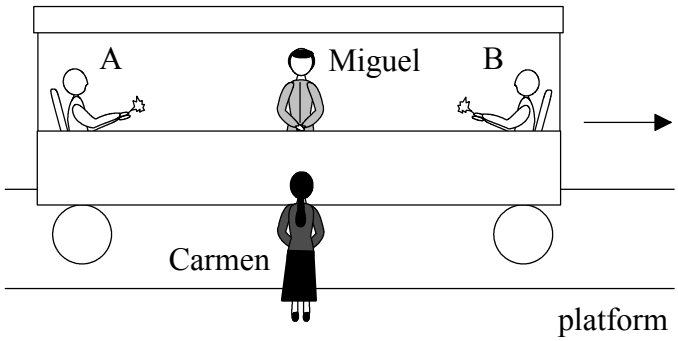
In the diagram below Miguel is in a railway carriage that is travelling in a straight line with uniform speed relative to Carmen who is standing on the platform.

Miguel is midway between two people sitting at opposite ends A and B of the carriage.



At the moment that Miguel and Carmen are directly opposite each other, the person at end A of the carriage strikes a match as does the person at end B of the carriage.

According to Miguel these two events take place simultaneously.

(b) (i) Discuss whether the two events will appear to be simultaneous to Carmen. *[4]*

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(This question continues on the following page)

(Question G1(b) continued)

(ii) Miguel measures the distance between A and B to be 20.0 m. However, Carmen measures this distance to be 10.0 m. Determine the speed of the carriage relative to Carmen. *[2]*

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(iii) Explain which of the **two** observers, if either, measures the correct distance between A and B? *[2]*

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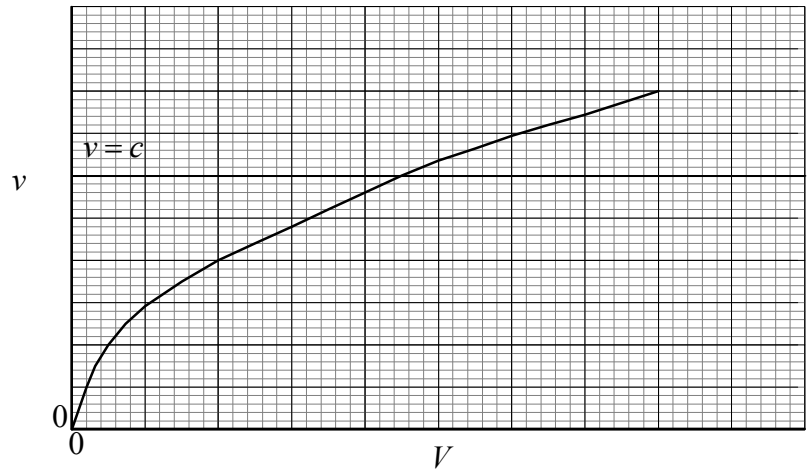
G2. This question is about electrons travelling at relativistic speeds.

A beam of electrons is accelerated in a vacuum through a potential difference V.

The sketch-graph below shows how the speed v of the electrons, as determined by non-relativistic mechanics, varies with the potential V, (relative to the laboratory). The speed of light c is shown for reference.



(a) On the grid above, draw a graph to show how the speed of the electrons varies over the same range of V as determined by relativistic mechanics. *[2]*
(Note this is a sketch-graph; you do not need to add any values)

(b) Explain briefly, the general shape of the graph that you have drawn. *[3]*

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(c) When electrons are accelerated through a potential difference of 1.50×10^6 V, they attain a speed of $0.97c$ relative to the laboratory.

Determine, for an accelerated electron,

(i) its mass. *[3]*

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(ii) its total energy. *[2]*

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Option H – Optics

H1. This question is about refraction.

(a) With the aid of a suitable diagram define the term *refractive index* as applied to an optical material. *[2]*

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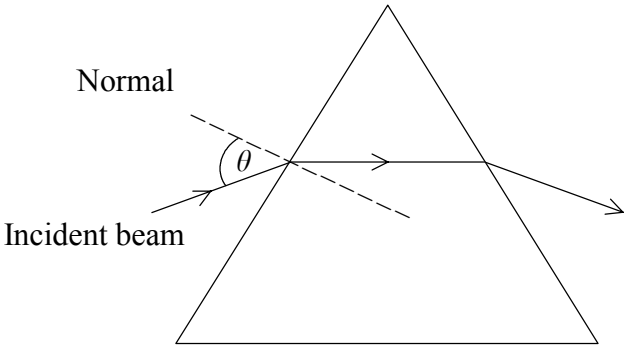
The diagram below shows the path followed by a ray of red light that is incident on one face of a glass prism at an angle θ to the normal.



(b) (i) The red light is now replaced by blue light. On the diagram sketch the corresponding path followed by a ray of blue light incident at the same angle θ. *[3]*

(ii) State and explain whether the refractive index for red light in the glass is greater than, equal to or less than the refractive index for blue light. *[1]*

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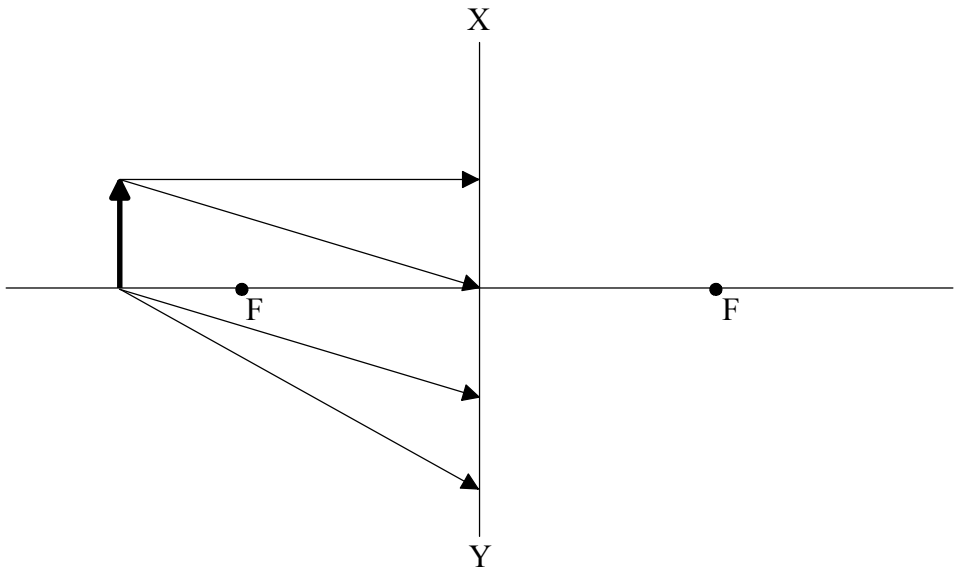
H2. This question is about a concave (diverging) lens.

The diagram below shows four rays of light from an object O that are incident on a thin **concave** (**diverging**) lens. The *focal points* of the lens are shown labelled F. The lens is represented by the straight line XY.



(a) Define the term *focal point*. *[2]*

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(b) On the diagram,

(i) complete the paths of the four rays in order to locate the position of the image formed by the lens. *[4]*

(ii) show where the eye must be placed in order to view the image. *[1]*

(c) State and explain whether the image is real **or** virtual. *[2]*

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(This question continues on the following page)

(Question H2 continued)

(d) The focal length of the lens is 50.0 cm. Determine the linear magnification of an object placed 75.0 cm from the lens. *[3]*

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(e) Half of the lens is now covered such that only rays on one side of the principal axis are incident on the lens. Describe the effects, if any, that this will have on the linear magnification and the appearance of the image. *[2]*

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