INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N00/430/H(3)

PHYSICS
HIGHER LEVEL
PAPER 3

Monday 13 November 2000 (morning)

1 hour 15 minutes

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
	/30	/30	/30
	/30	/30	/30
	TOTAL /60	TOTAL /60	TOTAL /60

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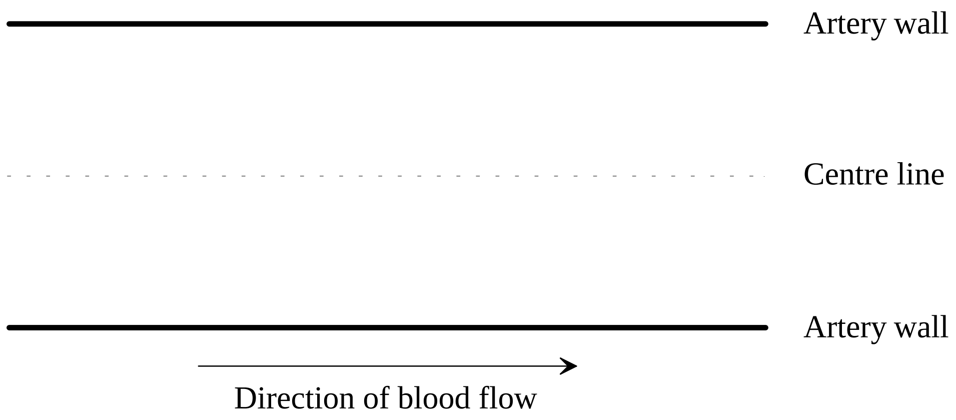
Option D – Biomedical physics

D1. The diagram shows part of an artery.



(a) By sketching arrows of various lengths show how the blood velocity varies across the diameter of the artery. *[2]*

(b) Describe **one** reason why the internal diameter of the artery might decrease over time. *[1]*

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(c) Given that the average blood velocity is proportional to $(\text{radius})^2$, explain why the volume flow rate is proportional to $(\text{radius})^4$. *[3]*

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(d) By what factor does the flow rate change if the effective radius of the artery is decreased by 5 %, keeping the pressure difference across the artery constant? *[2]*

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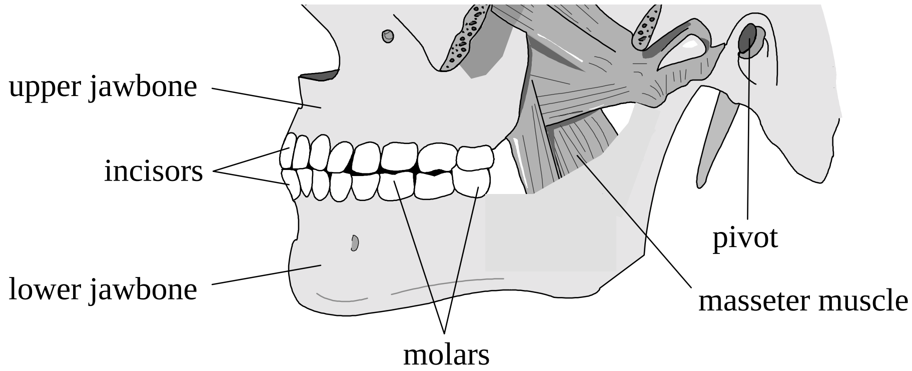
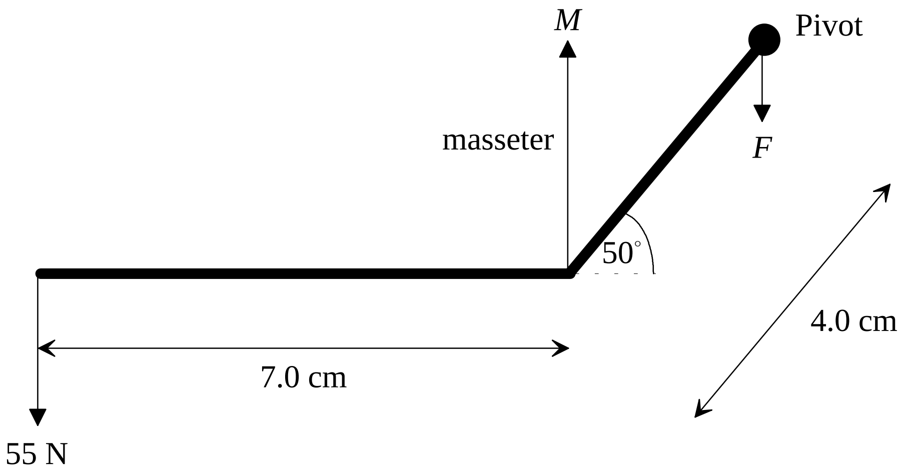
D2. The diagram below shows the position of a person's jawbones. The lower jawbone pivots at one end. The muscle that makes it move is called the masseter muscle.



During biting, the lower jawbone can be represented by the simplified model shown below. It has a horizontal part 7.0 cm in length and a part at a 50° angle from the horizontal, which is 4.0 cm long. The force from the masseter muscle is vertical at the junction of the two parts. The weight of the lower jawbone is negligible.



During biting, there is a 55 N force on the incisors at the front of the lower jawbone.

(This question continues on the following page)

(Question D2 continued)

(a) Calculate the magnitude of

(i) *M*, the force applied by the masseter muscle; *[2]*

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(ii) *F*, the force at the pivot. *[2]*

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(b) Explain why more force can be provided at the molars, during chewing, than at the incisors. *[2]*

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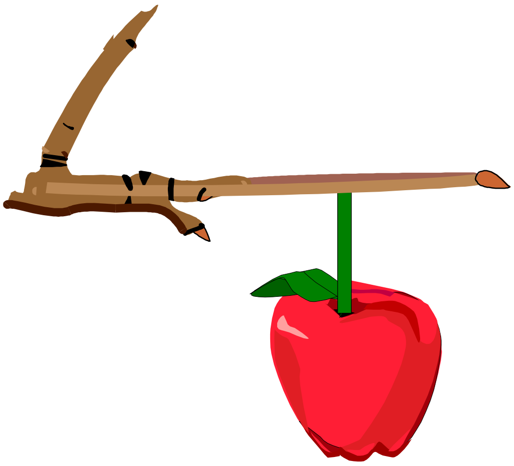
D3. This question is about scaling.

An apple, A, hangs vertically from a branch and is supported by its stalk as shown below.



The stalk will not part from the branch provided the *stress* in the stalk remains less than $4.5\times10^{5}\ \text{N m}^{-2}$. The *stress* is defined as:

$$\text{Stress} = \frac{\text{Tension force}}{\text{Cross sectional area}}$$

If the mass of A is 0.08 kg and the diameter of the stalk is 2.0 mm,

(a) calculate the stress in the stalk; *[2]*

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(b) calculate the new stress if all the linear dimensions of the apple and stalk were scaled up by a factor of 2. *[2]*

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(c) In real life, an apple double the size of A can remain on its tree. Explain how this can happen. *[2]*

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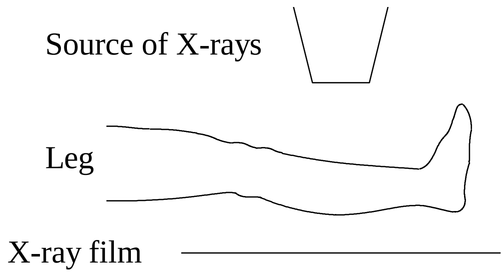
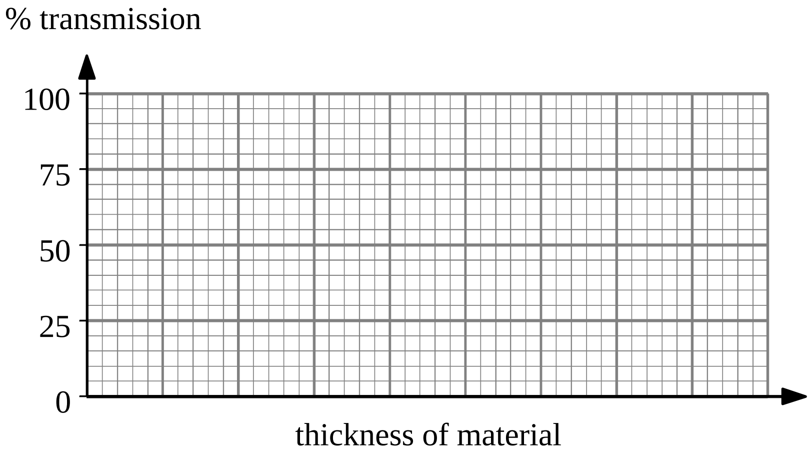
D4. An X-ray photograph is taken of a leg as shown below. In order to obtain a clear image the correct exposure needs to be chosen. The amount of attenuation can be investigated.



The transmission of X-rays by matter depends on several factors. One of these is the thickness of the material in the path of the X-rays.

(a) (i) On the axes below, sketch how you would expect the percentage (%) transmission to depend on the thickness of the material. *[2]*



(ii) Use your graph to explain the term 'half-value thickness'. *[2]*

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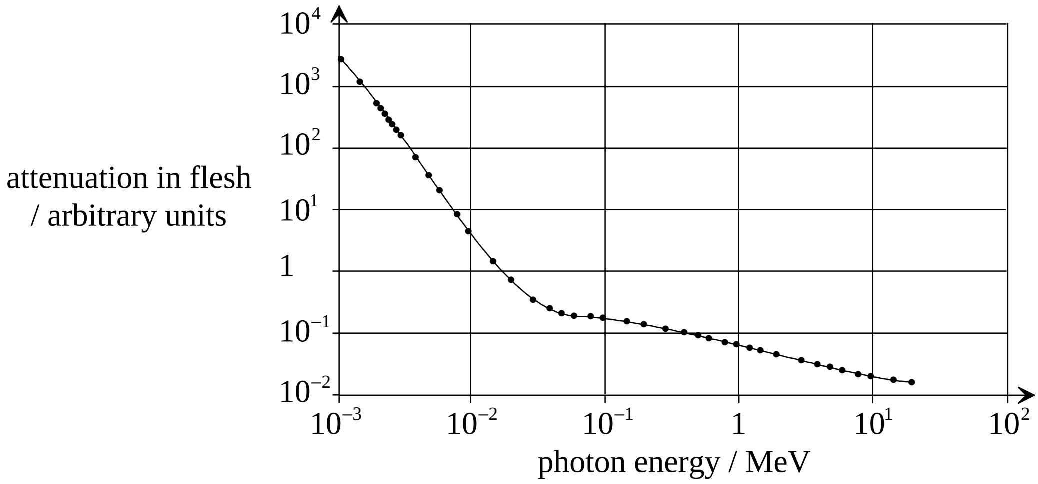
(Question D4 continued)

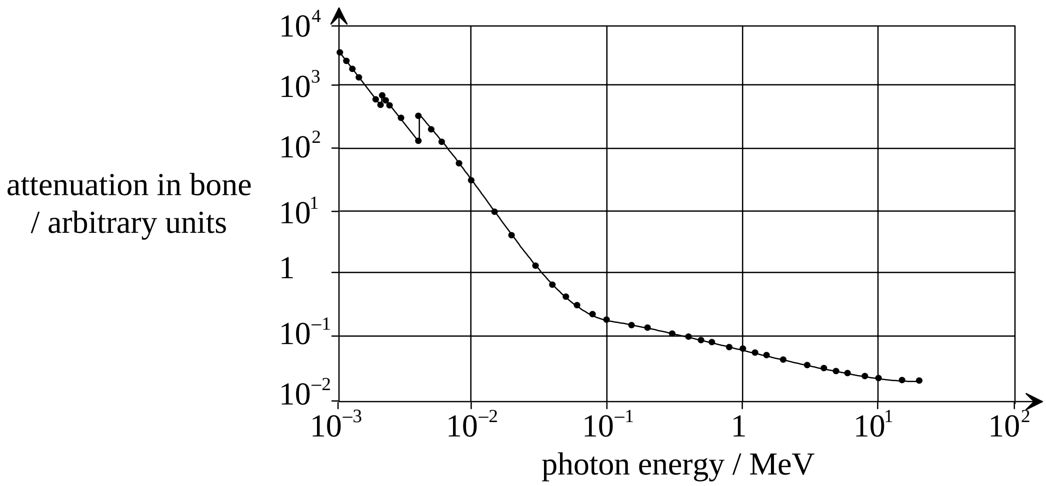
The attenuation of X-rays by matter depends on the type of material, **and also on the energy of the X-ray photons**.

The following graphs show how the X-ray attenuation (in arbitrary units) for flesh and bone depends on the photon energy.

X-ray attenuation in flesh



X-ray attenuation in bone



(b) Overall, the general shape of the graphs is a decreasing curve. What does this tell you about the **transmission** of X-rays at different energies? *[2]*

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(Question D4 continued)

(c) Explain why X-rays of energy around 10^{-2} MeV would be good to distinguish clearly between flesh and bone and why other energies would not. *[2]*

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(d) State **two** precautions, for either the patient or the operator, that minimise the medical risk when using X-rays. *[2]*

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Option E – Historical physics

E1. This question is about the quantum concept.

A biography of Schrödinger contains the following sentence: "Shortly after de Broglie introduced the concept of *matter waves* in 1924, Schrödinger began to develop a new atomic theory."

(a) Explain the term '*matter waves*'. State what quantity determines the wavelength of such waves. *[2]*

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(b) Electron diffraction provides evidence to support the existence of matter waves. What is electron diffraction? *[2]*

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(c) Calculate the de Broglie wavelength of electrons with a kinetic energy 30 eV. *[3]*

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(Question E1 continued)

(d) How does the concept of *matter waves* apply to the electrons within an atom? *[2]*

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E2. The figures below represent two different models of the universe.

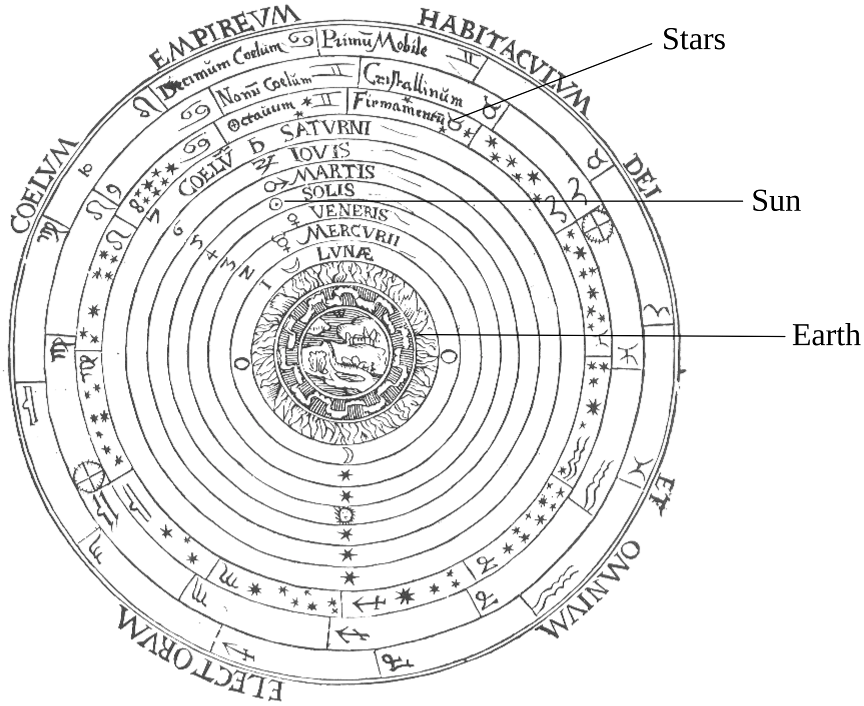

Figure A

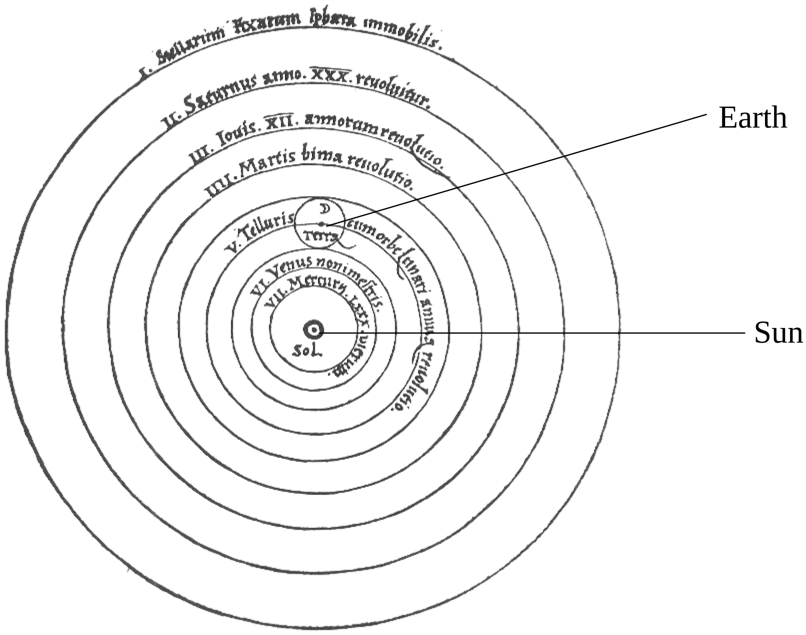

Figure B

(This question continues on the following page)

(Question E2 continued)

(a) Which figure represents Copernicus's model of the universe and which Aristotle's model of the universe? *[1]*

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On any one particular night, the stars' and planets' observed **general** motion appears to be a rotation about the Earth. If observed on more than one night, the planets also show retrograde motions.

Both models can explain this observed **general** motion of the stars and the planets. Only the model in figure B can explain the *observed retrograde motions of the planets* without further modifications.

(b) Explain what is meant by the '*observed retrograde motions of the planets*'. *[2]*

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(This question continues on the following page)

(Question E2 continued)

(c) The following questions are about the model in **Figure A**.

(i) How does it account for the observed *general* motion of the stars **and** the planets? *[2]*

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(ii) Explain what modifications are required for this basic model to be able to explain retrograde motion. *[2]*

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(d) The following questions are about the model in **Figure B**.

(i) How does it account for the observed *general* motion of the stars **and** the planets? *[2]*

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(ii) Explain how this model is able to explain retrograde motion. *[2]*

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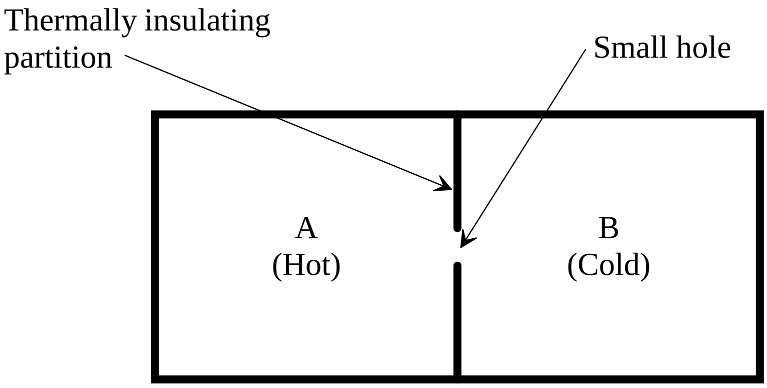
E3. Two gases, A and B, are thermally isolated from their surroundings and separated by a thermally insulating partition with a small hole in it as shown below. The temperature of A is initially higher than that of B. The system is allowed to reach thermal equilibrium.



(a) In terms of molecular motion, explain the mechanism by which the system reaches thermal equilibrium. *[2]*

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(b) Explain how and why the entropy of the system changes as a result of this process. *[2]*

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(Question E3 continued)

(c) Suppose there is a small cover to the hole that can be opened or closed by 'Maxwell's demon.' The demon's aim is to get the system back to its initial condition, *i.e.* with the temperature in A higher than that in B.

(i) Explain what 'Maxwell's demon' would have to do to achieve this. *[2]*

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(ii) Explain what effect this change would have on the overall entropy of the system. *[2]*

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(iii) State why 'Maxwell's demon' would be unable to succeed. *[2]*

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Option F – Astrophysics

F1. The spectrum of light from distant galaxies shows a *redshift*.

(a) (i) Explain what is meant by the term ‘*redshift*’. *[1]*

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(ii) Describe, in terms of wavelength and relative motion, why a redshift occurs. *[2]*

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(b) Explain how the redshift of light from different distant galaxies supports the Big Bang model of the origin of the Universe. *[2]*

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(c) One would **not** expect light from the Sun to show a redshift. Explain why. *[1]*

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(d) In fact, the spectrum from one limb (‘edge’) of the Sun shows a small redshift whereas the other limb of the Sun shows a small blueshift. Explain what this tells you about the Sun. *[2]*

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F2. A star viewed from the Earth is not always a single, constant object. Many stars in the *main sequence* are, in fact, *binary stars*. For example, β-Persei is an *eclipsing binary*. Over time, stars are known to change. Some will end up as *neutron stars* or even *black holes*.

(a) What is meant by:

(i) *main sequence*; *[3]*

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(ii) *binary stars*; *[1]*

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(iii) *eclipsing binary*; *[1]*

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(iv) *neutron star*; *[1]*

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(v) *black hole*. *[1]*

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(Question F2 continued)

(b) Identify the physical processes by which a main sequence star develops into a neutron star. *[4]*

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(c) What evidence is there for the existence of the neutron stars? *[2]*

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(d) What property determines whether a star might develop into a neutron star or a black hole? Outline how this property can be used to predict the outcome. *[2]*

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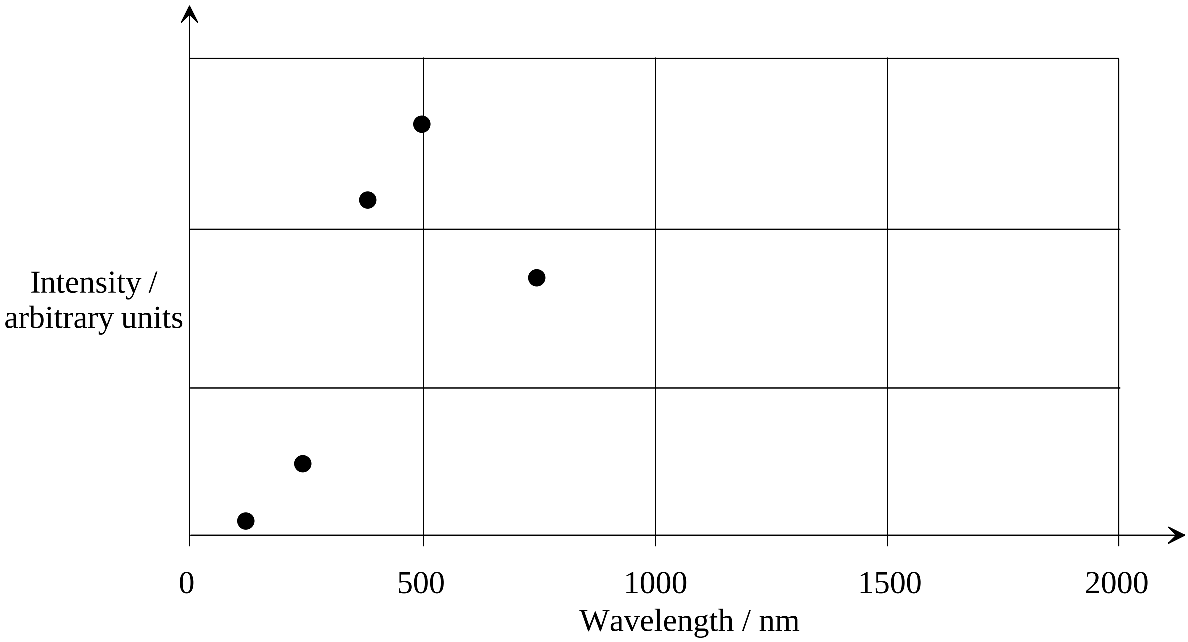
F3. The intensity of the light from a star is measured at different wavelengths and five of the readings are plotted on a graph as shown below.



(a) Assuming that the star radiates as a black body, add an appropriate curve to show the probable shape of the complete graph. *[2]*

(b) Use your graph to estimate the surface temperature of the star. *[3]*

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(c) Use your estimate of temperature to estimate the power radiated per unit surface area of the star. *[2]*

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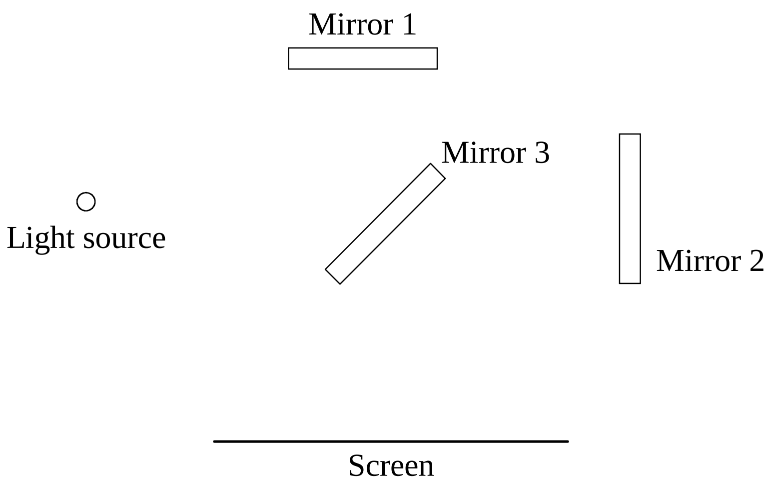
Option G – Special and general relativity

G1. The diagram below shows some of the essential features of the apparatus used in the Michelson–Morley experiment.



(a) Which **one** of the mirrors is **half-silvered**? *[1]*

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(b) On the diagram draw the two paths followed by the light that produce an interference pattern on the screen. *[2]*

(c) What was the purpose of the Michelson–Morley experiment? *[2]*

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(d) What was the result of the experiment and how is the result explained? *[2]*

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G2. An electron is travelling at a constant speed in a vacuum. A laboratory observer measures its speed as 95 % of the speed of light and the length of its journey to be 100 m.

(a) Show that for these electrons, $\gamma = 3.2$. *[1]*

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(b) What is the length of the journey in the **electron's** frame of reference? *[1]*

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(c) What is the time taken for this journey in the **electron's** frame of reference? *[2]*

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(d) What is the mass of the electron according to the **laboratory** observer? *[2]*

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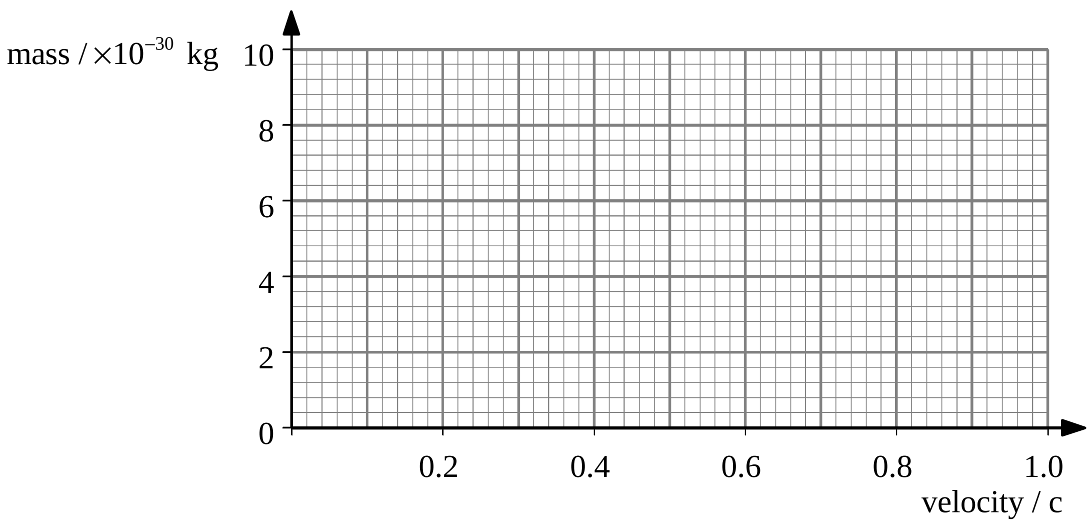
(e) Use the axes below to show how the observed mass of the electron will change with velocity as measured by the laboratory observer. There is no need to do any further calculations. *[3]*



G3. In order to help verify the General Theory of Relativity, the astronomer Arthur Eddington made some measurements during a total eclipse of the Sun in 1919. What measurements did he make and how did these provide experimental support for the General Theory of Relativity? *[4]*

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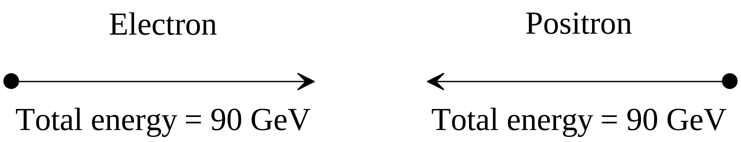
G4. The Large Electron / Positron (LEP) collider at the European Centre for Nuclear Research (CERN) accelerates electrons to total energies of about 90 GeV. These electrons then collide with *positrons* moving in the **opposite direction** as shown below. Positrons are identical in rest mass to electrons but carry a positive charge. The positrons have the **same energy** as the electrons.



(a) Use the equations of special relativity to calculate,

(i) the velocity of an electron (with respect to the laboratory); *[2]*

(ii) the momentum of an electron (with respect to the laboratory). *[2]*

(b) For these two particles, estimate their relative velocity of approach. *[2]*

(c) What is the total momentum of the system (the two particles) before the collision? *[1]*

(This question continues on the following page)

(Question G4 continued)

(d) The collision causes new particles to be created.

(i) Estimate the maximum total rest mass possible for the new particles. *[2]*

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(ii) Give **one** reason why your answer is a *maximum*. *[1]*

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Option H – Optics

H1. A student is given two converging lenses, A and B, and a tube in order to make a telescope.

(a) Describe a simple method by which she can determine the focal length of each lens. *[2]*

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(Question H1 continued)

(b) She finds the focal lengths to be as follows:

Focal length of lens A	10 cm
Focal length of lens B	50 cm

Draw a diagram to show how the lenses should be arranged in the tube in order to make a telescope. Your diagram should include:

(i) labels for each lens;
(ii) the focal points for each lens;
(iii) the position of the eye when the telescope is in use. *[4]*

(c) On your diagram, mark the location of the intermediate image formed in the tube. *[1]*

(d) Is the image seen through the telescope upright or upside-down? *[1]*

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(e) Approximately how long must the telescope tube be? *[1]*

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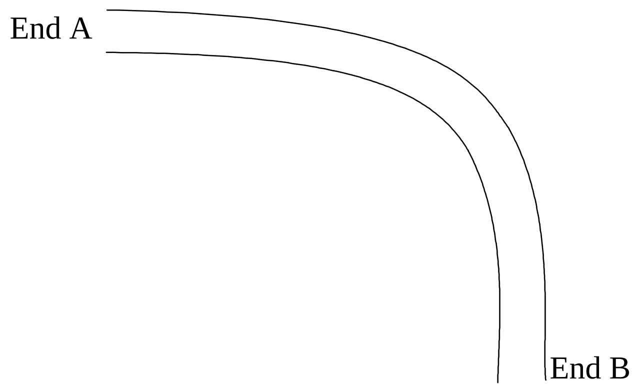
H2. Optical fibres allow light to be transmitted along their length with almost no loss, even if the fibre is bent.

(a) With the aid of the diagram below, explain how light can be transmitted along an optical fibre even when bent. *[2]*



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(b) Explain, with the aid of a diagram, why this method will not work if the curve is too extreme. *[3]*

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(Question H2 continued)

(c) State **one** practical use for optical fibres. *[1]*

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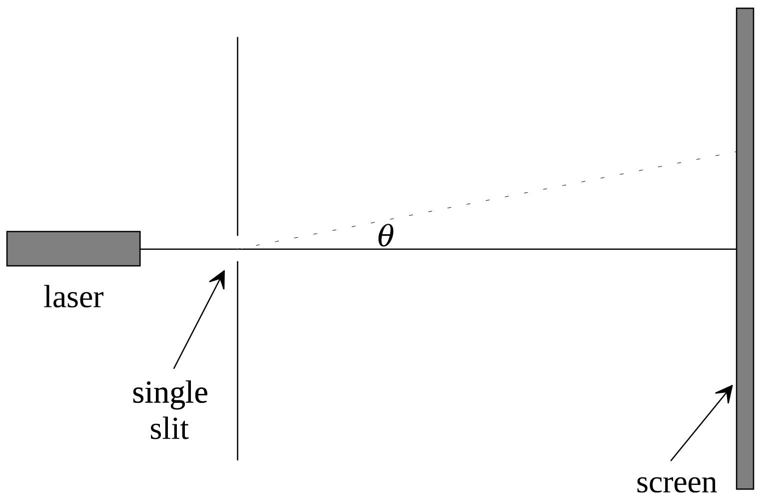
H3. In an experiment, monochromatic light of wavelength 400 nm is incident on a single slit of width 1600 nm. Fringes are viewed on a screen as shown in the diagram below.



(a) Calculate the first two angles at which the light intensity is at a **minimum**. *[2]*

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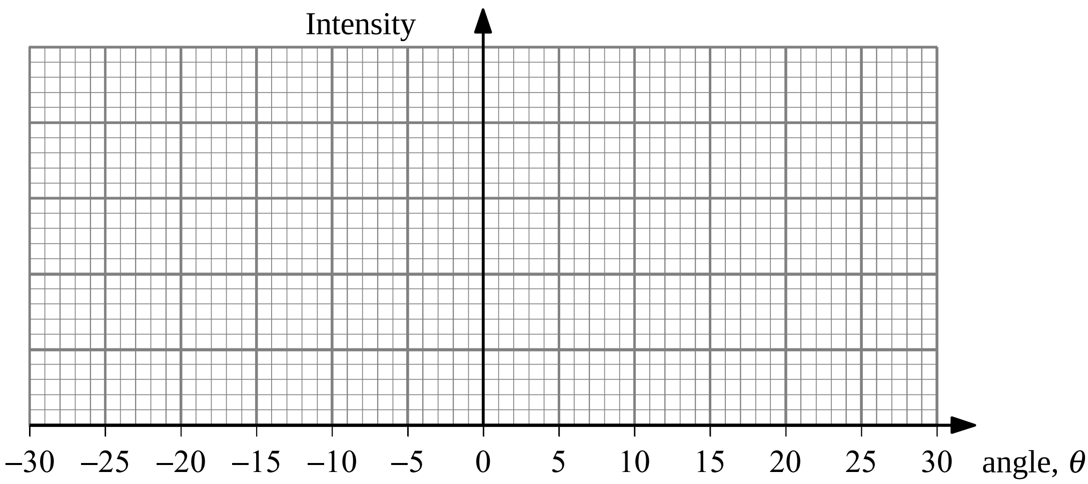
(b) Use the axes below to sketch a graph of how the intensity of the light varies as a function of angle up to $\theta = 30^{\circ}$. *[3]*



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(Question H3 continued)

The slit is now replaced by two slits separated by 3200 nm (centre to centre). Each slit is identical in width to the single slit (1600 nm).

(c) Calculate **all** the angles up to 30° at which interference maxima will occur. *[2]*

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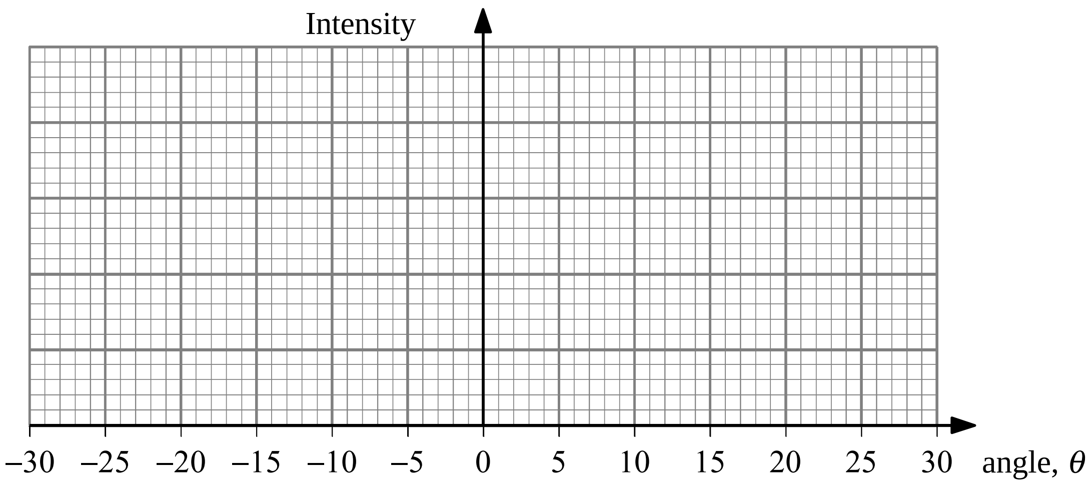
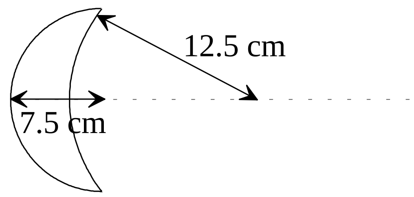
(d) Use your answers to sketch a graph, on the axes below, of how the intensity of the light varies as a function of angle up to $\theta = 30^\circ$. *[3]*



H4. A thin lens for use in spectacles is shown below.



The lens surfaces are ground to have a radii of curvature 7.5 cm and 12.5 cm as marked.

(a) Is this a converging or diverging lens? *[1]*

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(b) Would this type of lens be used by people who suffer from short sightedness or long sightedness? Explain your answer. *[2]*

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(c) Given that the lens is made out of glass with a refractive index of 1.51, calculate its focal length. *[2]*

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