INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N00/430/S(3)

PHYSICS
STANDARD LEVEL
PAPER 3

Monday 13 November 2000 (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

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Option A – Mechanics extension

A1. Communication satellites are put into *geostationary* orbits. This means that the satellite orbits so that it stays above the same point on the Earth.

(a) What is the period of a communication satellite? *[1]*

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(b) Explain why it is useful for a communication satellite to stay above the same point on the Earth. *[1]*

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(c) Show that the radius of a geostationary orbit is about 6.6 times the radius of the Earth. The following data is available:

Mass of the Earth, m_E :	6.0×10^{24} kg;
Radius of the Earth, r_E :	6.4×10^{6} m;
Gravitational constant, G:	6.7×10^{-11} N m^2 kg^{-2} ;
Gravitational field at the surface of the Earth, g_0 :	9.8 N kg^{-1}.

[5]

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(d) Determine the magnitude and the direction of the Earth's gravitational field at this distance. *[3]*

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A2. A 5 kg mass on the end of a spring undergoes *Simple Harmonic Motion* with an amplitude of 10 cm and a time period of 2 s.

(a) Define what is meant by the term ‘*Simple Harmonic Motion*’. *[2]*

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(b) Calculate the

(i) spring constant for the spring; *[2]*

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(ii) maximum acceleration of the mass. *[2]*

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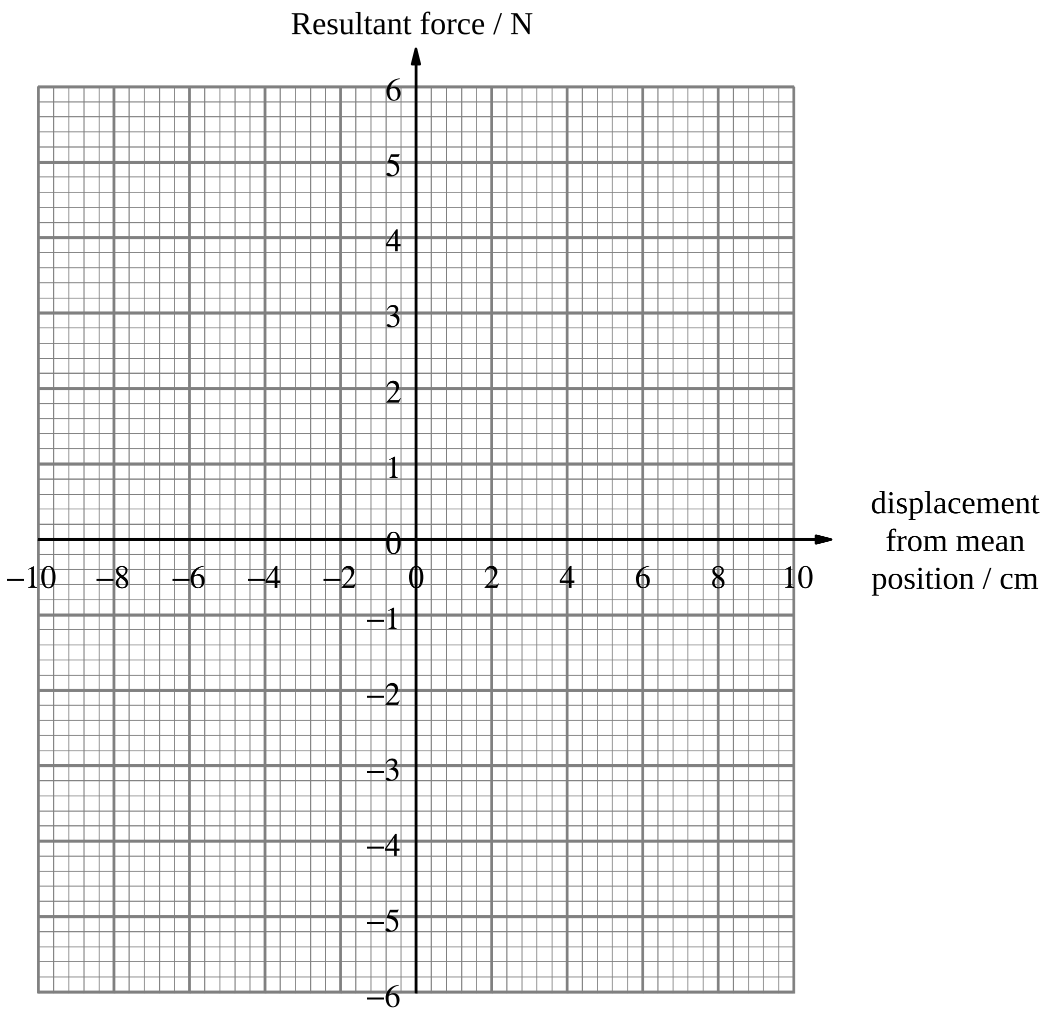
(This question continues on the following page)

(Question A2 continued)

(c) Use the axes below to plot a graph of resultant force against displacement from mean position for the mass. *[2]*



(d) Use your graph to calculate the maximum amount of elastic potential energy stored in the spring as a result of its motion. *[2]*

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Option B – Atomic and nuclear physics extension

B1. This question is about Chadwick's work published in 1932. He bombarded beryllium with alpha particles from the radioactive decay of polonium.

(a) Complete the nuclear equation for the radioactive decay of polonium. *[2]*

$$^{210}_{84}\text{Po} \rightarrow \quad \text{Pb} \quad + \quad \alpha$$

These alpha particles then struck beryllium nuclei that were at rest. The following reaction then took place:

$$^{4}_{2}\alpha + ^{9}_{4}\text{Be} \rightarrow ^{12}_{6}\text{C} + ^{1}_{0}\text{n}$$

Data for the reaction

Mass of Be nucleus:	9.012 180 u
Mass of α particle:	4.002 603 u
Mass of C nucleus:	12.000 00 u
Mass of n:	1.008 665 u
Kinetic energy of each α particle:	5.30 MeV

(b) Use the data above to calculate

(i) the kinetic energy of the α particle in joules; *[2]*

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(ii) the energy liberated by **each** reaction in joules; *[2]*

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(iii) the total kinetic energy of the particles after the reaction; *[1]*

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(This question continues on the following page)

(Question B1 (b) continued)

(iv) the speed of the neutrons. You can assume that the neutrons receive much more energy than the more massive carbon nucleus. *[2]*

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(c) Explain why you would expect the neutrons to have a slightly lower speed than given by your calculation above. *[1]*

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B2. The *photoelectric effect* can be used to find the *work function* of various materials.

(a) Explain what is meant by the terms

(i) ‘*photoelectric effect*’; *[2]*

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(ii) ‘*work function*’. *[2]*

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(This question continues on the following page)

(Question B2 continued)

(b) When UV light of wavelength 150 nm is incident on a gold surface, the maximum kinetic energy of the ejected electrons is 3.53 eV.

(i) Why do all the ejected electrons not have the same kinetic energy? *[1]*

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(ii) Calculate the work function for gold in eV. *[3]*

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(iii) If light of wavelength 375 nm were used, what difference would this make? Explain. *[2]*

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Option C – Energy extension

C1. (a) Explain what is meant by a *renewable* source of energy. *[1]*

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(b) Both *photovoltaic* devices and *active solar heaters* use the Sun as a source of energy.
For **each** device,

(i) outline the energy conversions that take place; *[2]*

Photovoltaic device:

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Active solar heater:

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(ii) describe a situation in which the device could be used. *[2]*

Photovoltaic device:

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Active solar heater:

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(This question continues on the following page)

(Question C1 continued)

(c) The average daily energy consumption of a home is to be supplied by solar panels placed on the roof. The following information is available:

Typical energy consumption of home in one day (in winter)	120 kW hr
Typical solar power falling on 1 m^2 of the Earth (during the day)	1400 W
Efficiency of active solar panels	85 %

(i) Use the above data to estimate the minimum area of solar panels required. *[4]*

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(ii) Give **two** reasons why your answer is a minimum. *[2]*

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C2. The first law of thermodynamics can be expressed symbolically as follows:

$$\Delta Q = \Delta U + \Delta W$$

(a) Explain what quantity is represented by each of the symbols. *[3]*

ΔQ:

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ΔU:

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ΔW:

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(b) When gas in a bicycle pump is rapidly compressed by pushing in the piston, its temperature **increases**.

(i) Explain whether each quantity below is positive, negative or zero for the gas as a result of this process. *[3]*

ΔQ:

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ΔU:

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ΔW:

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(This question continues on the following page)

(Question C2 (b) continued)

(ii) Explain, in terms of the motion of the gas molecules, why the temperature of the gas increases during this process. *[3]*

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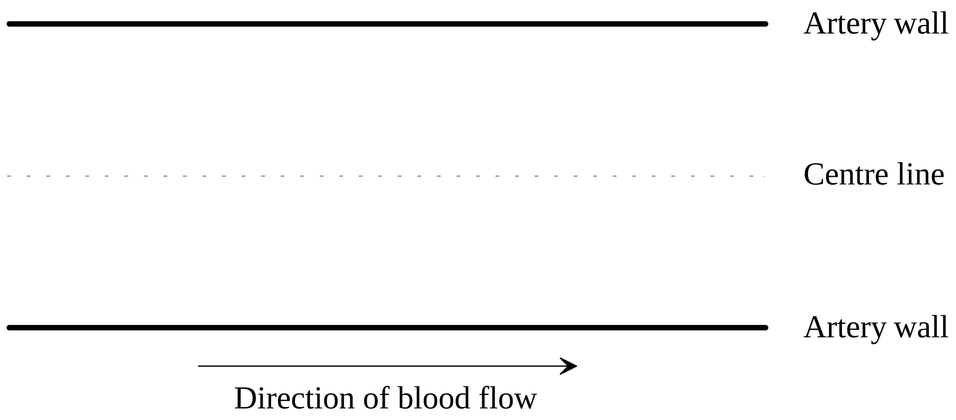
Option D – Biomedical physics

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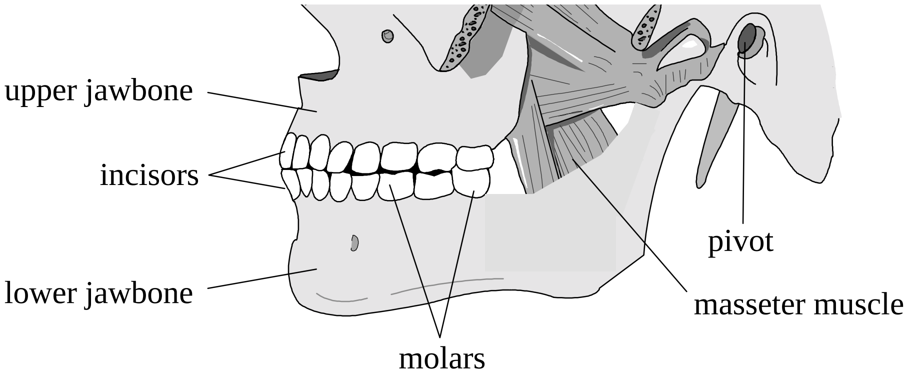
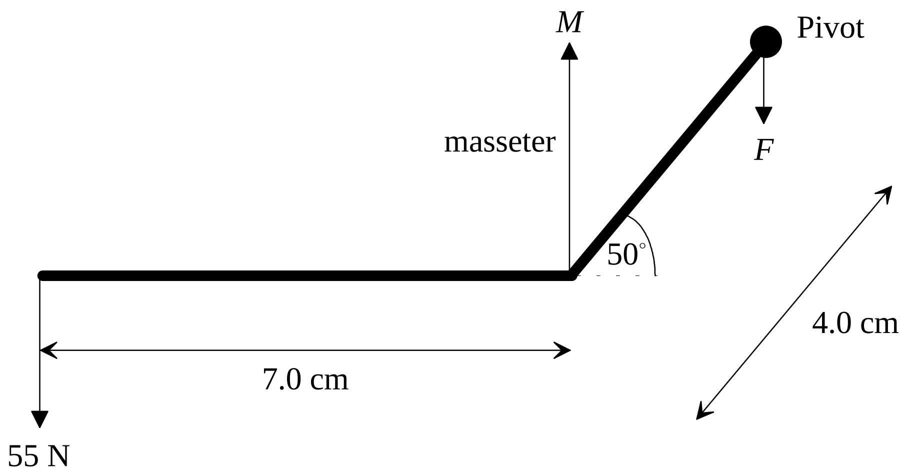
D2. The diagram below shows the position of a person's jawbones. The lower jawbone pivots at one end. The muscle that makes it move is called the masseter muscle.



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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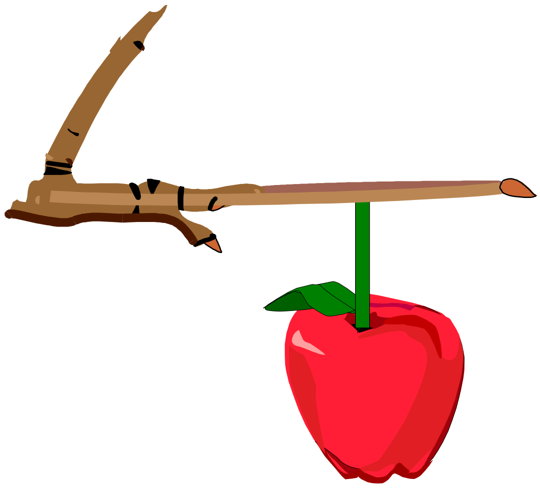
D3. This question is about scaling.

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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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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(This question continues on the following page)

(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.

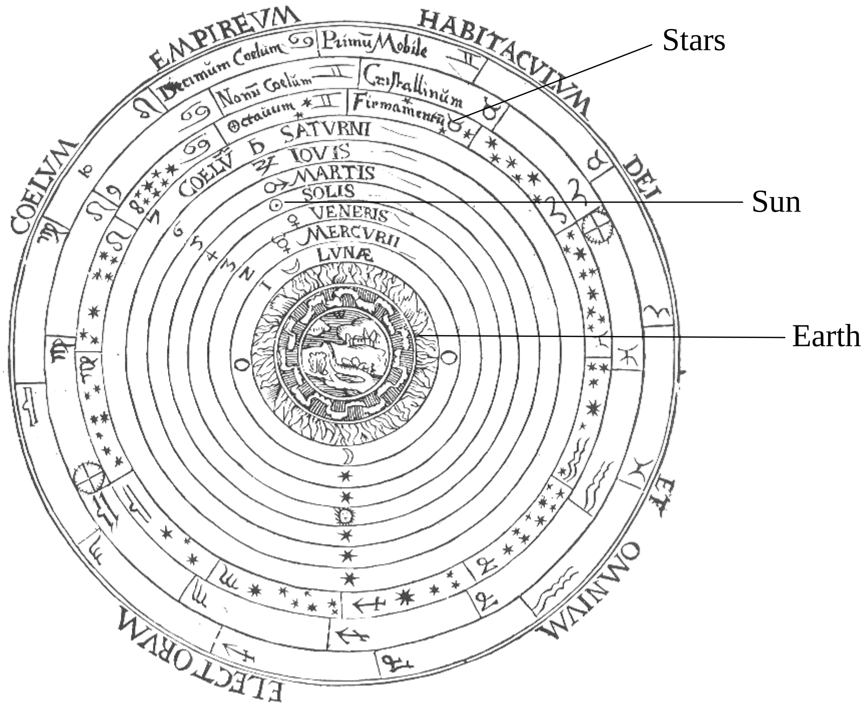

Figure A

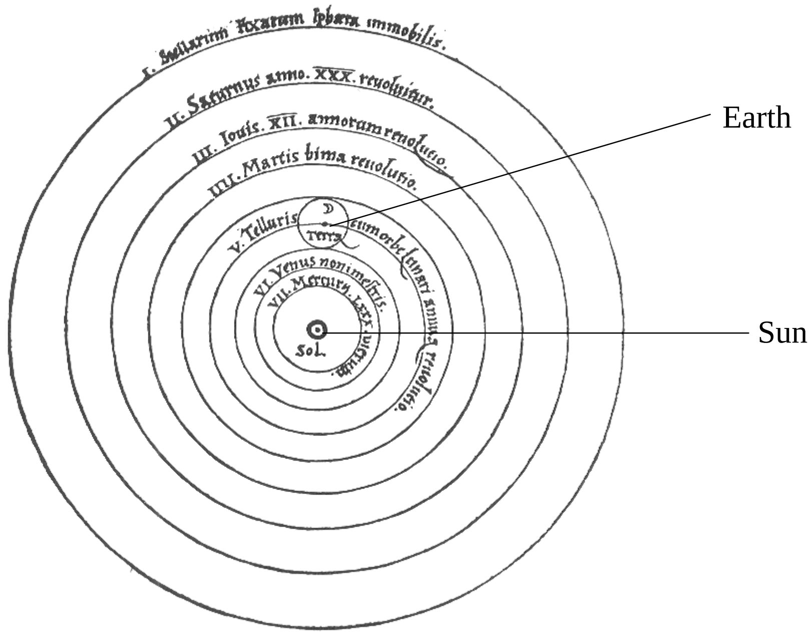

Figure B

(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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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*.

What is meant by:

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

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

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(c) *eclipsing binary*. *[1]*

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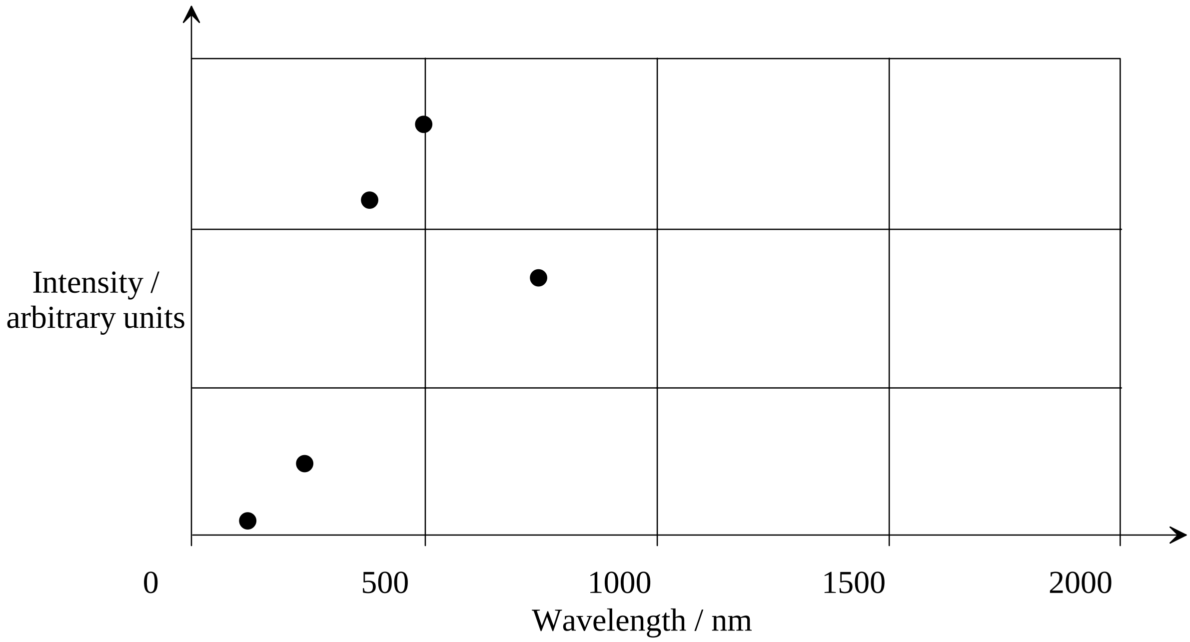
F3. The intensity of the light from a star is measured at different wavelengths and five of the readings are plotted on a graph as shown below.



(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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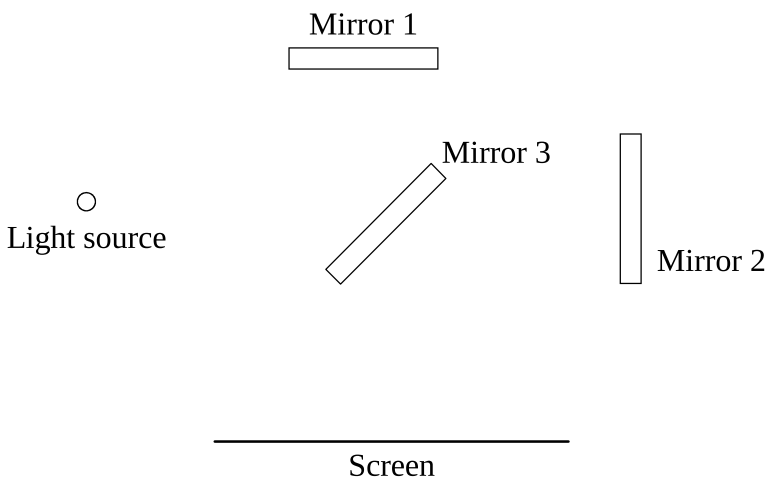
Option G – Special and general relativity

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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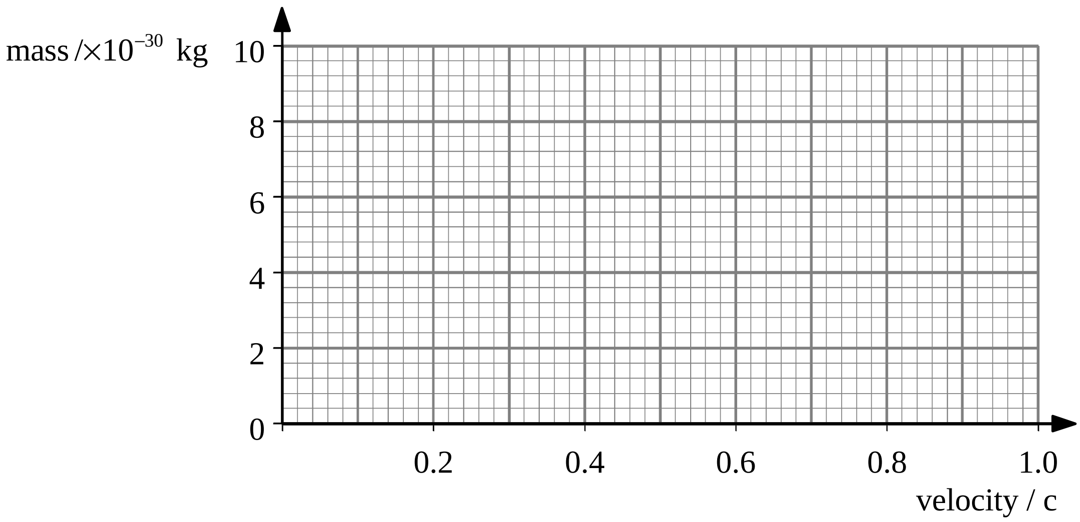
(This question continues on the following page)

(Question G2 continued)

(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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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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(This question continues on the following page)

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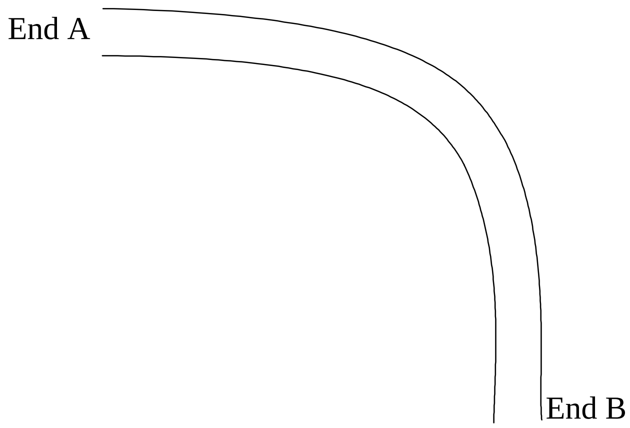
H2. Optical fibres allow light to be transmitted along their length with almost no loss, even if the fibre is bent.

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

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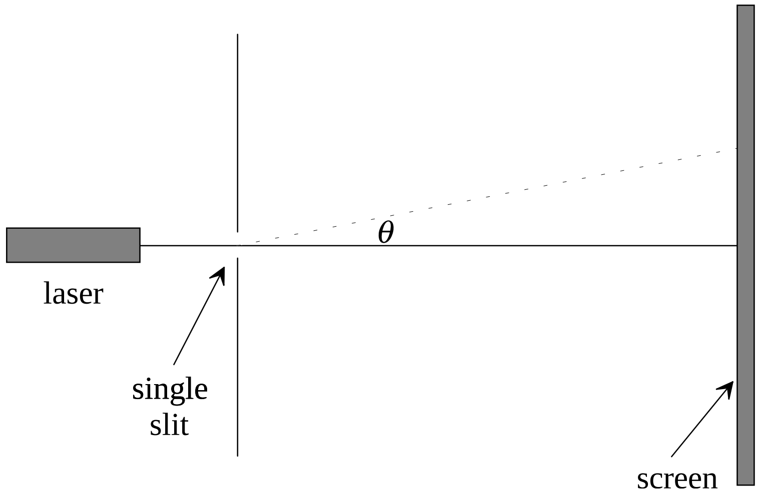
H3. In an experiment, monochromatic light of wavelength 400 nm is incident on a single slit of width 1600 nm. Fringes are viewed on a screen as shown in the diagram below.



(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]*