INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

MARKSCHEME

November 2000

PHYSICS

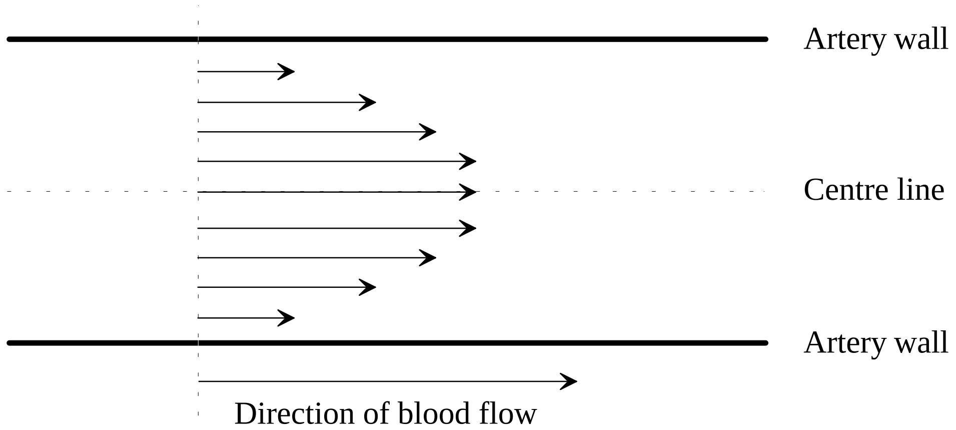
Higher Level

Paper 3

28 pages

D1. (a) Maximum velocity at centre, *[1]*
Symmetrically decreasing towards zero velocity at the walls. *[1]*

(Accept answers that do not emphasise that the velocity is zero at the walls so long as the velocity shown nearest the wall is less than ***half*** *the velocity in the centre.)*



(b) Any plausible reason, *e.g.* fatty deposits/hypertension. (*Reject answers in terms of exercise* ***unless*** *the assumption that the artery is connected to the digestive system is clearly stated*.) *[1]*

(c) If radius increases, area is increased, therefore more space for fluid to flow / area is proportional to $(\text{radius})^2$. *[1]*

Volume flow rate = area × average blood velocity. *[1]*
Both effects lead to increased flow rate and both are proportional to $(\text{radius})^2$ so overall, volume flow rate is proportional to $(\text{radius})^4$. *[1]*

(d) Attempted use of flow rate $\propto$ $(\text{radius})^4$. *[1]*
New flow rate $= (0.95)^4 \times$ old flow rate
$= 0.81$ / 81 % of old flow rate / 19 % decrease. *[1]*

(Accept any method of stating the above answer.
Accept statement that if r goes down by 5 % then r^4 *goes down by 20 %.)*

D2. (a) (i) Correct application of the principle of moments *[1]*
i.e. $M \times 4\cos 50 = 55 \times (7 + 4\cos 50)$

*(Award this mark if candidate attempts a **correct** application of the principle of moments, but is unable to calculate the perpendicular distance from M to the pivot.)*

Rearrangement gives $M = 204.7\ \text{N} \approx 205\ \text{N} \approx 200\ \text{N}$ *[1]*

(Accept up to three significant figures.)

(ii) Resultant force overall is zero, *i.e.* $F + 55 = M$ *[1]*
Therefore $F = 149.7 \approx 150\ \text{N}$ *[1]*

(Accept, of course, answers where the candidate has correctly applied the principle of moments taken about another axis.)

(b) Realisation that the molars are nearer to the pivot. *[1]*
For a given moment, the closer one gets to the pivot, the larger force / owtte. *[1]*

(Award no marks for answers in terms of pressure and/or the area of the top of the tooth.)

D3. (a) $\text{Area} = \pi r^2 = \pi(0.001)^2 = 3.14 \times 10^{-6}\ \text{m}^2 \approx 3 \times 10^{-6}\ \text{m}^2$ *[1]*
$\text{Stress} = 0.8\ \text{N} \div \text{area} = 2.55 \times 10^{5}\ \text{N m}^{-2} \approx 3 \times 10^{5}\ \text{N m}^{-2}$ *[1]*

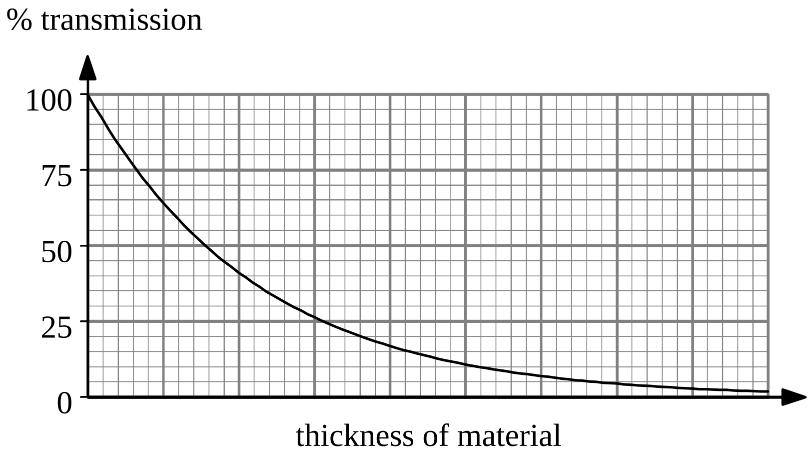
(b) Force increases by 8 **and** area increases by 4. *[1]*
Therefore stress increases by two *i.e.* new stress $\approx 6 \times 10^{5}\ \text{N m}^{-2}$ *[1]*

(c) Realisation that both stalk and apple cannot scale together as new stress is now greater than given breaking stress. *[1]*
Stalk must be more than double in diameter. *[1]*

(Accept plausible alternative e.g. as stalk grows the material is altered/becomes stronger so that the breaking stress is increased.)

D4. (a) (i) Any curve starting at 100 % and approaching zero. ***[1]***
Approximately exponential. ***[1]***

(Need to be quite generous with the second mark – check to see if the thickness to get to 25 % ≈ 2 × thickness to get to 50 % etc.)



(ii) Appropriate additions to the graph that show half-thickness. ***[1]***
A description to explain half-thickness. ***[1]***

For example, the (constant) thickness of material that allows 50 % transmission / appropriate labels / owtte.

*(Award **[2]** for very good explanation of half-thickness even if candidate does not use the graph.)*

(b) As the photon energy increases, the attenuation decreases / owtte. ***[1]***
Thus with increasing energy, the transmission of X-ray increases / the absorption of X-rays decreases / more X-rays get through / owtte. ***[1]***

(c) Idea that, at 0.01 MeV, the two graphs show a large difference in attenuation thus they will be able to distinguish / owtte. ***[1]***
Whereas at all other energies, the two graphs are essentially the same and thus unable to distinguish. ***[1]***

*(Essentially **[1]** goes for talking about the 0.01 MeV energy attenuation values and the other mark is awarded for discussing/mentioning the other energies.)*

(d) Any two sensible precautions that protect either the operator or the patient should be awarded ***[1]*** each. ***[2]***

Allow:
- Max number of X-ray sessions allowed in a year for patient;
- Other parts of patient’s body shielded (with lead);
- The operator is in another room / a large distance away;
- The operator is shielded (with lead);
- *etc.*

E1. (a) Any general idea showing relevant understanding. ***[1]***
For example, accept:
- A probability wave associated with particles of matter;
- A wave function that determines the position of a moving particle;
- *etc.*

The wavelength is determined by the *momentum* (of the particle). ***[1]***

*(Award **[1]** for a statement of the de Broglie equation **so long as** the symbols are all defined.*
*Award **[0]** for Speed / mass / energy etc.)*

(b) Outline of an appropriate experiment. ***[1]***
For example, accept electrons 'fired' at an atomic array / a slit/slits
Outline of observations of experiment or explanation. ***[1]***
For example:
- Electrons are observed in maxima and minima;
- Diffraction maxima depend on the accelerating potential and hence the momentum of each electron (as predicted by de Broglie) / owtte;
- *etc.*

(c) Correct principles behind calculation of the momentum. ***[1]***
(Award the mark even if the mathematics contains numerical errors.)
For example, $KE = 30\text{ eV} = 30\times1.6\times10^{-19}\text{ J} = 4.8\times10^{-18}\text{ J}$

$$\text{Velocity} = \sqrt{\frac{2KE}{m}} = 3.25\times10^{6}\text{ m s}^{-1}$$

$$\text{Momentum} = \text{mass}\times\text{velocity}$$
$$= 9.11\times10^{-31}\times3.25\times10^{6} = 2.96\times10^{-24}\text{ kg m s}^{-1}$$

Use of $\lambda = \dfrac{h}{p}$ ***[1]***

$$= \frac{6.63\times10^{-34}}{2.96\times10^{-24}}$$

$$= 2.24\times10^{-10}\text{ m}$$

$$\approx 2\times10^{-10}\text{ m}$$ ***[1]***

(d) The only possible (bound) states for the electron matter waves are *standing waves* / owtte. ***[1]***

(Concept is hard so be generous particularly with diagrams attempting to show electron standing waves. Accept diagrams supposedly showing standing waves around an electron orbit.)

Different standing waves correspond to discrete energy states / electron clouds / owtte. ***[1]***

E2. (a) Figure A – Aristotle.
Figure B – Copernicus. ***[1]***

(Award the mark for either (or both) of the above.)

(b) When compared to the observed motion of the stars… ***[1]***
…the planets sometimes appear to change the direction of their movement / owtte (could be the standard diagram as below). ***[1]***

(For the full two marks, candidates must show an understanding that the planet's retrograde motion is with respect to the 'fixed' background of stars.)

(c) (i) Idea that in this model the stars and the planets rotate around the Earth in different shells. ***[1]***
Any one piece of extra detail that correctly links the model to the observed general motion. ***[1]***

For example, accept:

- Different shells rotate at **slightly** different speeds;
- All the stars are in the same shell;
- *etc.*

(ii) Model is modified by the use of 'epicycles'. ***[1]***
Clear diagram and/or explanation of 'epicycles'. ***[1]***
For example, the planets orbit in additional circles within their shells / owtte.

continued…

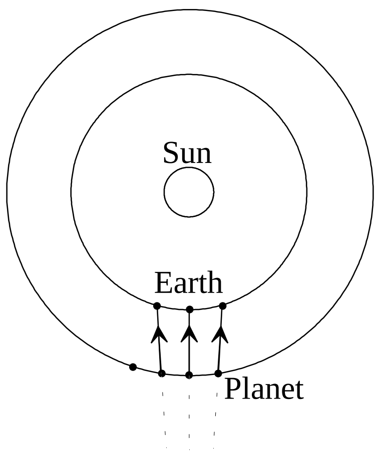
Question E2 continued

(d) (i) Idea that in this model the Earth and the other planets rotate around the Sun. ***[1]***
Any one piece of extra detail that correctly links the model to the observed general motion. ***[1]***

For example, accept:
- The stars are all located at an extremely large distance from the Sun;
- The observed rotation of the stars is due to the rotation of the Earth;
- *etc.*

(ii) Realisation that different planets take different lengths of time to complete one orbit. ***[1]***
The retrograde motion of a particular planet is due to the changing relative position as the Earth and the planet move in their orbits / owtte. ***[1]***

*(Award **[1]** for a diagram (without further explanation) which shows a changing relative position, for example as below.)*



E3. (a) Initially a larger number of faster moving / 'hotter' molecules will go through the hole from A to B compared to the number of slower / 'colder' molecules moving from B to A / owtte. ***[1]***
Collisions between the molecules equate the temperature and eventually the number distribution between A and B / owtte. ***[1]***

*(Award **[1]** for simple argument in terms of just the collisions between molecules.)*

(b) Entropy of system has *increased* / gone up. ***[1]***
Any valid justification. ***[1]***

(Accept (even though second one is not strictly correct):
- *"Must have gone up since overall entropy always increases" / 2nd law of thermodynamics / owtte;*
- *Entropy of A has gone down, but entropy of B has increased by more;*
- *etc.)*

(c) (i) Control the opening… ***[1]***
So as to only let the faster moving molecules go through the opening into A and the slower moving molecule into B / owtte. ***[1]***

(ii) The overall entropy must have decreased / gone down; ***[1]***
Any valid justification. ***[1]***

(Accept:
- *"Heat has been made to flow from cold to hot";*
- *Discussion in terms of the demon sorting molecules so increasing the order/decreasing the disorder in the system;*
- *etc.)*

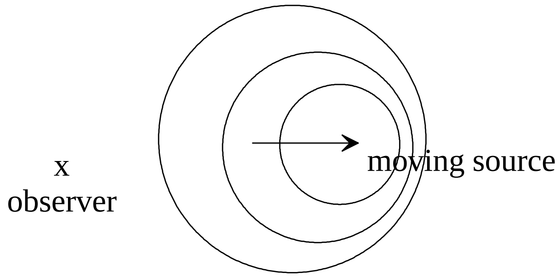
(iii) Energy needed from outside the system / owtte. ***[1]***
Any other additional relevant comment. ***[1]***

(Accept:
- *Entropy of gas might decrease, but overall the total entropy would increase;*
- *Appeal to 2nd law of thermodynamics;*
- *etc.)*

F1. (a) (i) Increase of wavelength / decrease in frequency of light from an object / owtte. ***[1]***

(ii) Idea that for a redshift to occur, object must be receding from observer (either stated or implied in candidate's diagram). ***[1]***
Appropriate explanation in terms of the Doppler effect. ***[1]***

(Accept standard labelled diagram as below ***or*** *a description of the 'stretching' of space and hence an increase in wavelength.)*



(b) Redshift shows that more distant galaxies recede faster / owtte / statement of Hubble's law. ***[1]***
This is consistent with an expanding universe as described in the Big Bang model / owtte. ***[1]***

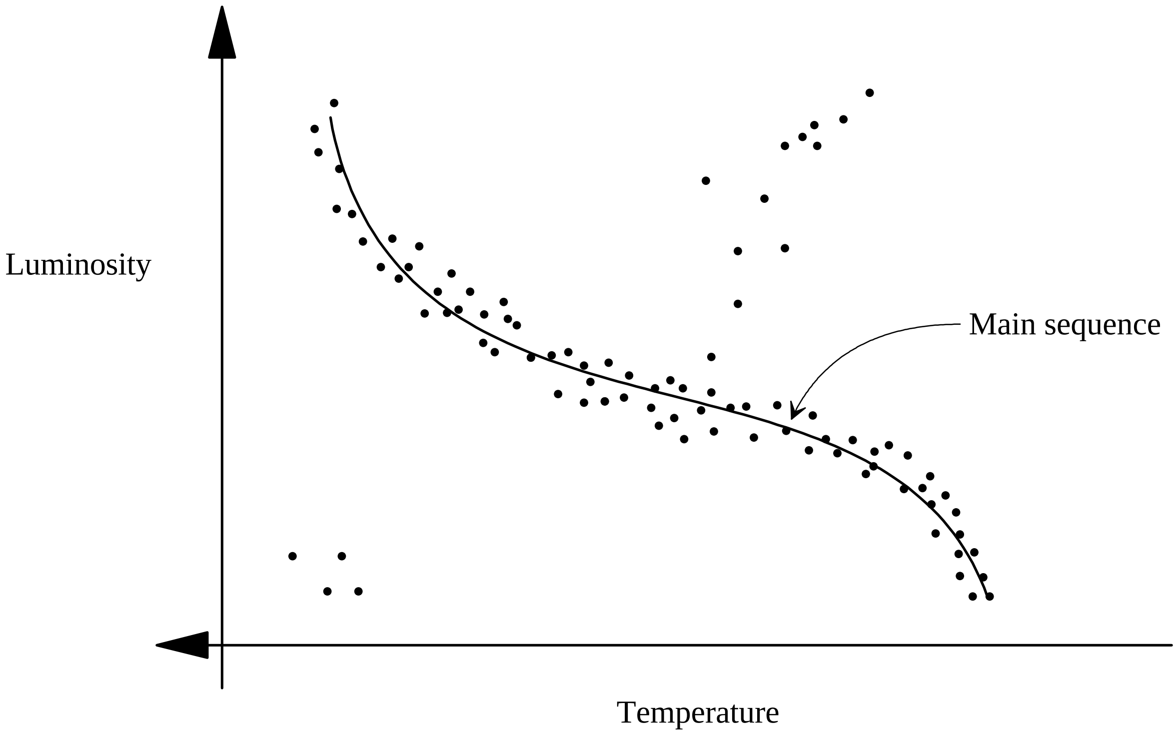
(Award ***[1]*** *for the simple idea that redshift means that the Universe is expanding. For* ***[2]*** *further detail is required.)*

(c) The Sun is stationary with respect to us / owtte. ***[1]***

(d) One limb is coming towards us whereas one is going away; ***[1]***
i.e. the Sun is rotating. ***[1]***

(Award ***[1]*** *for the statement "Sun is rotating" without further explanation.)*

F2. (a) (i) When different stars are plotted on a "Hertzsprung-Russell diagram" / "H-R diagram"… ***[1]***
…The main sequence is the diagonal line going from the top left to the bottom right / owtte. ***[1]***
Identification of both axes. ***[1]***



(For y-axis, accept: (relative) Luminosity ***or Absolute*** *magnitude.*
For x-axis, accept: Spectral class (OBAFGKM) ***or decreasing*** *temperature.)*

(Award full marks for an appropriately labelled sketch.)

(ii) Two (or more) stars orbiting each other / owtte. ***[1]***

(iii) Binary stars identified by a period dip in their combined brightness / luminosity / owtte. ***[1]***

(Award ***[0]*** *for correct but inappropriate description of other types of binary stars.)*

(Answers to (iv) should be read in conjunction with (v) below. Candidates should be attempting to distinguish between a neutron star and a black hole, so award ***[0]*** *for a simple description that could also apply to a black hole.)*

continued…

Question F2 (a) continued

(iv) Any very simple description, *e.g.* "Very dense remnant of a star."
Plus one additional piece of information. ***[1]***

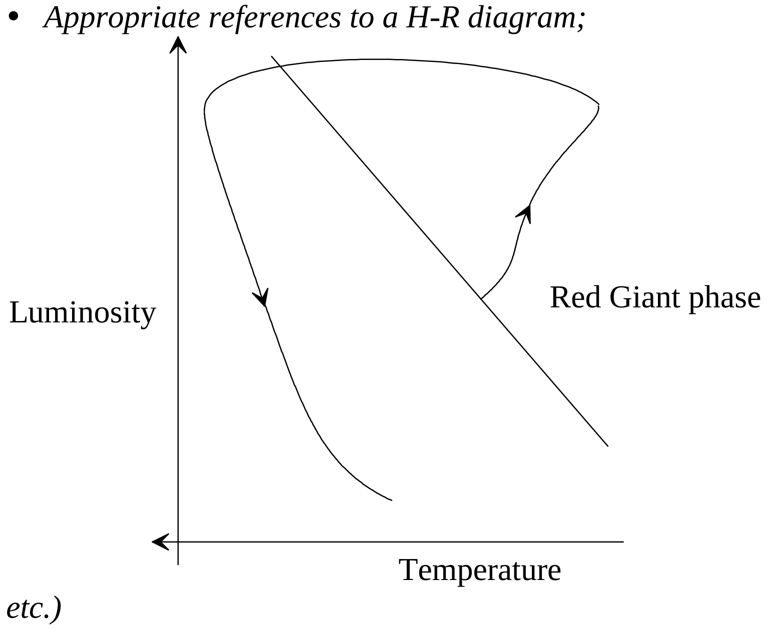
(Accept:
- *Which is cooling / which does not undergo fission any more / which will eventually stop shining / owtte;*
- *Statement of the mass of parent star needed to form it;*
- *Any further detail of its make-up, e.g. "As dense as a huge nucleus."*
- *etc.)*

(v) Any very simple description, *e.g.* "Very dense remnant of a star."
Plus one additional piece of information. ***[1]***

- Which has an escape velocity greater than the speed of light / owtte;
- Statement of the mass of parent star needed to form it;
- *etc.*

(b) *(Each valid and appropriate description of a physical process gains* ***[1]*** *up to the maximum.)* ***[4]***

(Accept the following points (all, of course, are owtte):
- *In the main sequence stars,* ***fusion*** *reactions are converting Hydrogen into Helium;*
- *When the* ***hydrogen runs out****, star enters Red Giant phase…*
- *…here fusion can produce higher elements – up to iron.*
- *At this point no further fission is possible and the mass of the star determines its ultimate fate.*
- *Neutron stars are the remnants of high mass stars after a supernova;*
- *Appropriate references to a H-R diagram;*



etc.)

continued…

Question F2 continued

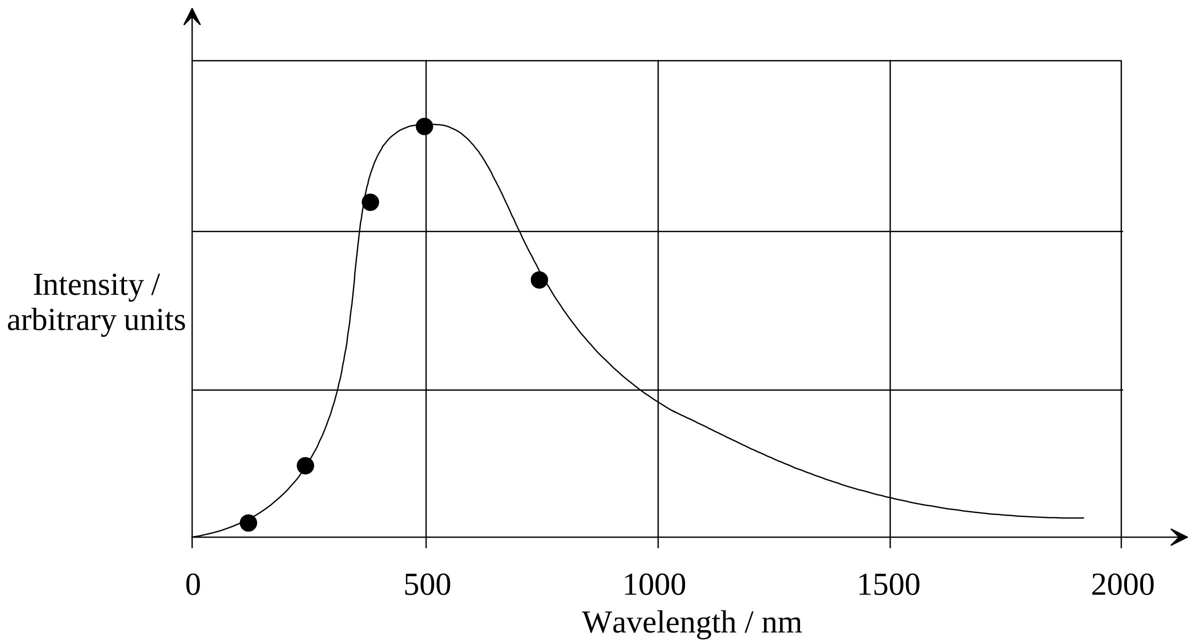
(c) *(Each valid and appropriate comment or piece of detail gets* ***[1]*** *up to the maximum.)* ***[2]***

(Accept the following points (all, of course, are owtte):

- ***Pulsars*** *are rotating neutron stars;*
- *Any detail about pulsars – e.g. "flashing radio stars";*
- *Pulsar at the centre of the crab nebula, which is the visible remains of a supernova;*
- *etc.)*

(d) It is determined by the mass of the star / the remnant. ***[1]***
High mass stars form neutron stars, Very high mass stars form black holes / owtte. ***[1]***

F3. (a) Correct shape through all points. ***[1]***
Appropriate extrapolation. ***[1]***



*(Award **[0]** for candidates who join the dots with straight lines.)*

(b) Identification of maximum wavelength as 500 nm ***[1]***
(Accept 400 to 600 nm.)

Use of Wien law / $\lambda_{\text{max}} = \dfrac{2.90\times10^{-3}}{T}$ ***[1]***

To get $T = 5800\ \text{K}$ ***[1]***

(Watch for error carried forward from candidate's value of λ_{max} *.*
Range above for λ_{max} *gives range for temperature as 7250 K to 4830 K.)*

(c) Use of $L = \sigma A T^4$ ***[1]***

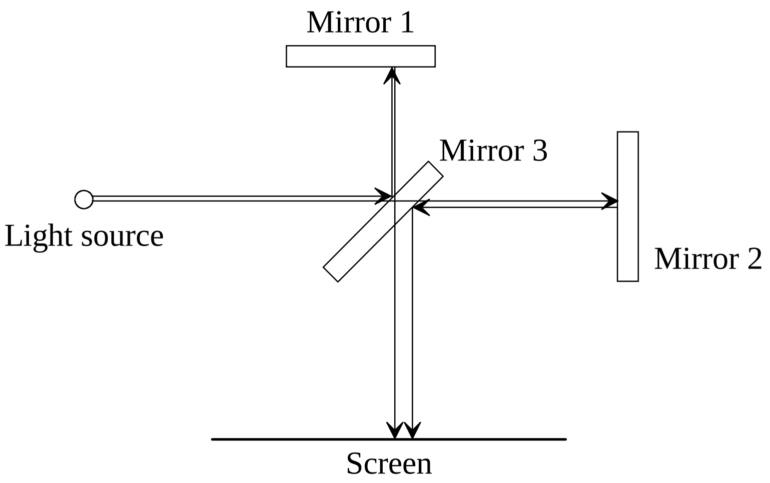
To get $\dfrac{L}{A} = 5.67\times10^{-8}\times5800^4 = 6.4\times10^7\ \text{W m}^{-2}$ ***[1]***

(Watch for error carried forward from candidate's value of temperature.
Range above for T gives range of answers as:
$1.6\times10^8\ W\ m^{-2}$ *to* $3.1\times10^7\ W\ m^{-2}$ *.)*

G1. (a) Mirror 3. ***[1]***

(b) Ray 1: Source → reflection M3 → reflection M1 → through M3 → screen.
Ray 2: Source → through M3 → reflection M2 → reflection M3 → screen. ***[2]***

*(Each correct ray gets **[1]**. N.B. do not allow error carried forward from (a).)*



(c) Purpose was to measure the speed of the Earth / owtte. ***[1]***
Relative to the speed of light / as it travelled through the 'Aether'. ***[1]***

(If candidates answer in terms of how the experiment was conducted, they can gain marks. Award marks as follows:

Rotate the apparatus ***[1]***
Look for change in interference pattern ***[1]****)*

(d) No observed change in pattern upon rotation of apparatus / null result / owtte. ***[1]***
Speed of light is constant / independent of motion of the Earth / owtte / Lorentz-FitzGerald contraction. ***[1]***

G2. (a) Calculation of γ-factor / correct use of relativistic equations. ***[1]***
(This mark can be awarded in ***any*** *of the sections in this question, if candidates fail to gain the mark here.)*

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-0.95^2}} = \frac{1}{0.3122} = 3.2$$

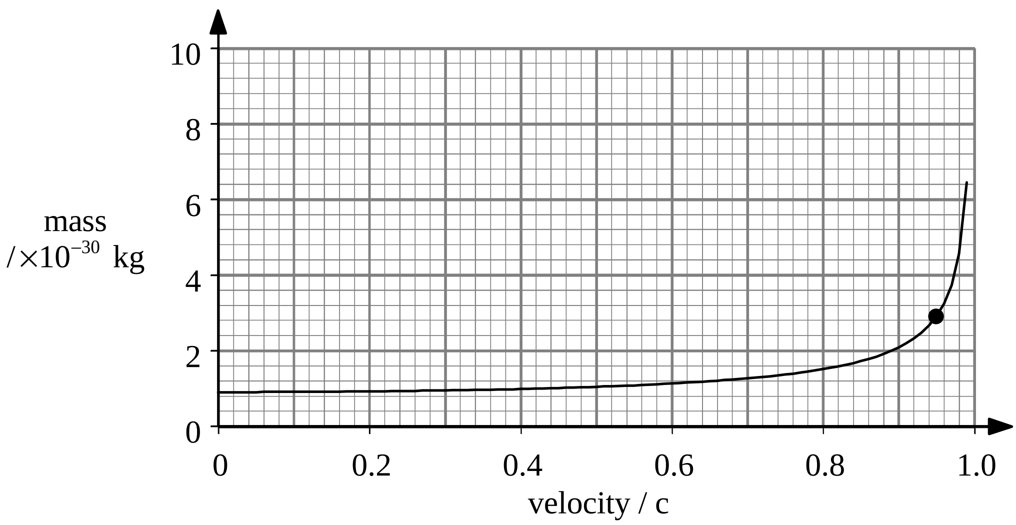
(b) $L = L_0 \div \gamma = 100 \div 3.2$
$= 31.22\text{ m} \approx 31\text{ m}$ ***[1]***

(c) Time in laboratory frame $= 100 \div (3\times10^8 \times 0.95) = 3.51\times10^{-7}$ s ***[1]***
Time in electron's frame, $\Delta t_0 = \Delta t \div \gamma$
$= 3.5\times10^{-7} \div 3.2$
$= 1.09\times10^{-7}$ s
$\approx 1.1\times10^{-7}$ s ***[1]***

(Watch for incorrect substitution.)

(d) Mass in laboratory frame $= \gamma m_0$ ***[1]***
$= 3.2\times9.11\times10^{-31}$
$= 2.91\times10^{-30}$ kg $\approx 2.9\times10^{-30}$ kg ***[1]***

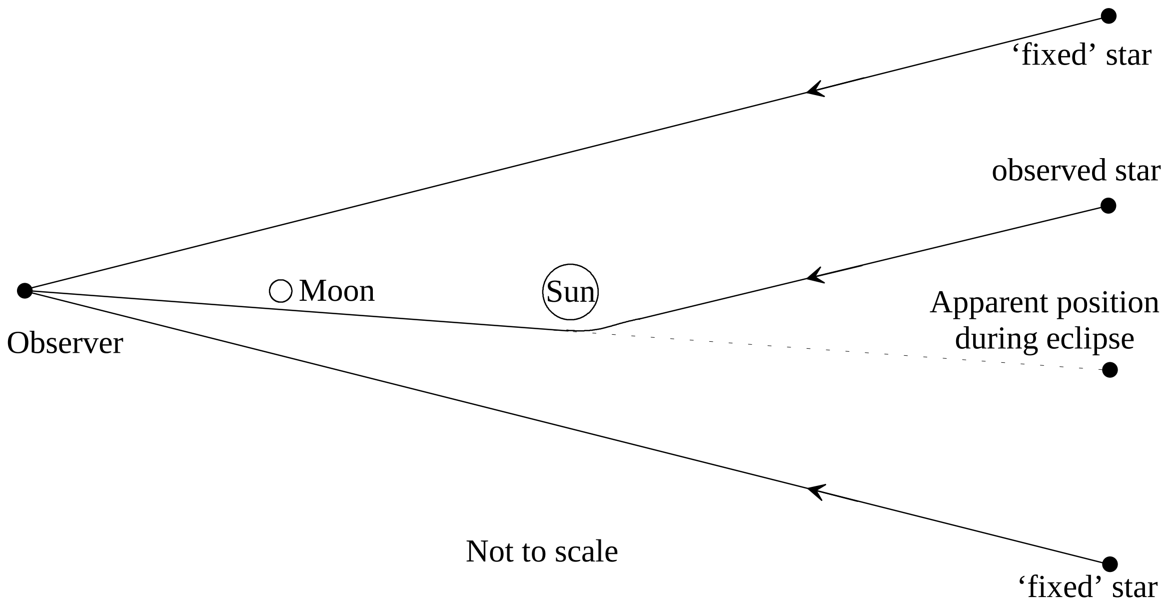
(e) Answer shown below:



Marking points include the following ideas:
At low velocities the mass is just the rest mass of the electron, *i.e.* Line starts at approximately 0.9×10^{-30} kg at zero velocity **and** has no significant increase up to 0.1 c. ***[1]***
Line goes through point $(0.95\text{ c}, 2.9\times10^{-30}\text{ kg})$ ***[1]***
(N.B. watch for error carried forward with candidate's value.)
Line is asymptotic to c. ***[1]***

G3. During eclipse, observed position of star (relative to other stars) that appeared close to the surface of Sun / owtte. ***[1]***
This was compared to positions without Sun / at night / owtte. ***[1]***
Idea that the altering of apparent position is because Sun bends light from star / owtte. ***[1]***
Which is a prediction of general theory of relativity. ***[1]***

(A diagram showing the bending of light around the Sun and hence its apparent change in position as compared to the stars can get ***[3]*** *out of* ***[4]****. Some link to the general theory of relativity is needed for the final mark.)*



G4. (a) (i) Calculation of γ ***[1]***

90 GeV means that $\gamma = \dfrac{90\,000}{0.511} = 1.76 \times 10^{5}$

Therefore velocity $= 0.9999\ldots\ \mathrm{c} \approx \mathrm{c}$, the speed of light. ***[1]***

(Ignore significant figures here – accept any number of figures.)

(ii) Use of $E^2 = p^2\mathrm{c}^2 + m_0^2\mathrm{c}^4$ or otherwise ***[1]***

to give $p = 90\dfrac{\mathrm{GeV}}{\mathrm{c}} = 4.8 \times 10^{-17}\ \mathrm{kg\,m\,s^{-1}}$ ***[1]***

(Accept answer in any units, so long as it is correct.
Award full marks to candidates who just write down the momentum as $90\dfrac{GeV}{\mathrm{c}}$ from the total energy of 90 GeV without further explanation.)

(b) Velocity of each particle is essentially c. ***[1]***
Therefore relative velocity of approach = c. ***[1]***

(Award full marks if candidate uses relativistic equations to get to same result.
*Award **[1]** if candidate clearly understands that the relative velocity of approach will be less than* c*, but fails to realise that it is essentially* c*.*
*Award **[1]** if candidate starts off with correct relativistic equations correctly, but makes a mistake.)*

(c) Total momentum = zero. ***[1]***

(d) (i) Attempt to add the energies **and** convert this into mass.

OR Total energy $= 180\ \mathrm{GeV}$ ***[1]***

Therefore total rest mass available $= \dfrac{180\ \mathrm{GeV}}{\mathrm{c}^2}$

$= 3.2 \times 10^{-25}\ \mathrm{kg}$ ***[1]***

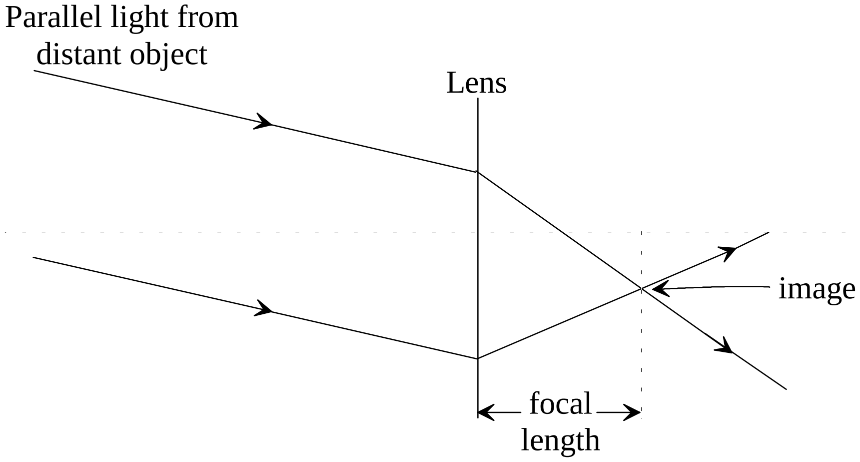
(The correct answer does not have to be in kg; any appropriate unit is acceptable.)

(ii) Moving particles (as opposed to stationary particles) might be created. ***[1]***

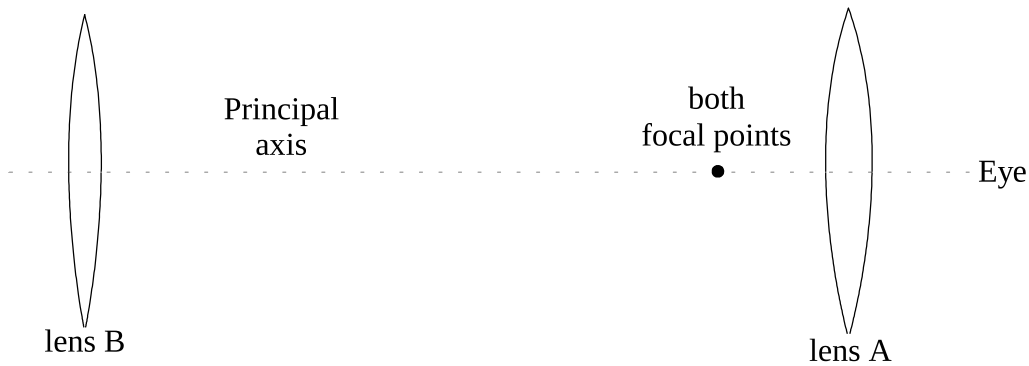
*(Do **not** accept:*
- *"heat lost";*
- *"not 100 % efficient";*
- *etc.)*

H1. (a) Arrange lens to form image of **distant** object (on a screen). ***[1]***
Lens to image distance is the focal length. ***[1]***

(Award full marks for any method that finds the focal length however complex – i.e. do not subtract marks if method is not 'simple'. Full marks can also be gained from a simple diagram, for example as below.)



(b)



Two lenses aligned on a common principal axis. ***[1]***
Eye looking through lens A. ***[1]***
Focal points for each lens shown in one concurrent position on the principal axis between the lenses. ***[1]***
Concurrent position closer to lens A. ***[1]***

*(Award **[2]** if candidate's diagram is ambiguous, i.e. do not award any marks that rely on knowing which lens is which. (Allow the drawing of a fatter lens to imply lens A given BOD).)*

(c) Image shown at the concurrent focal points. ***[1]***

(Accept, within reason, any image shown by the candidate e.g. arrow etc. so long as it is in the correct position.
If candidate has made mistakes in part (c) e.g. failed to put the focal points concurrent or mixed up the lenses, award this mark if image is unambiguously shown on the focal point of any lens that has the eye on its other side.)

continued…

Question H1 continued

(d) Upside-down / inverted / owtte. ***[1]***

(e) Approximate total length of telescope $= f_a + f_b = 60$ cm ***[1]***

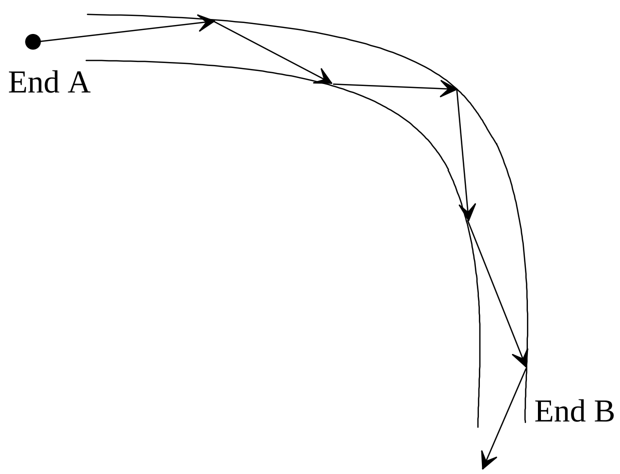
*(Award full marks if candidate increases this value **and** includes any discussion/estimations of extra small lengths to be added on to allow for mounting etc.)*

H2. (a) A diagram showing:

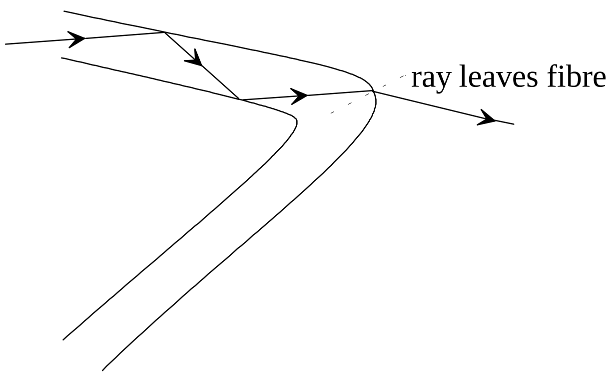
- Light entering one end;
- Multiple reflections of any sort;
- Light exiting from other end. ***[1]***

Explanation involving multiple **total internal** reflections **or** reflections shown with reasonable accuracy. ***[1]***

(In order to award this second mark, the angle of incidence should be seen to be the same as the angle of reflection throughout the rays.)



(b) If curve is too extreme, at some point, the angle of incidence will be less than the **critical angle**. ***[1]***
Some light energy will leave the fibre / be absorbed by coating / owtte. ***[1]***
Appropriate diagram. ***[1]***



*(In order to get full marks candidate must make some mention of critical angle. Award **[0]** for answers in terms of the fibre optic being unable to bend or breaking if the curve is too extreme.)*

Question H2 continued

(c) Naming or the basics concept behind any sensible practical use. ***[1]***

(Accept:
- *Endoscopes;*
- *Data transfer and telecommunications – telephones/computers etc.;*
- *Decorative lamps;*
- *etc.)*

(Do not award the mark if the named use is ambiguous and there is no further detail, e.g. bald 'medicine' is insufficient.)

H3. (a) Use of $m\lambda = a\sin\theta$ ***[1]***

to get $\sin\theta = 400 \div 1600; 800 \div 1600$

$= 0.25; 0.5;$

Therefore $\theta = 14\frac{1}{2}^\circ; 30^\circ;$ ***[1]***

*(Award **[1]** for candidates that only calculate the first angle.)*

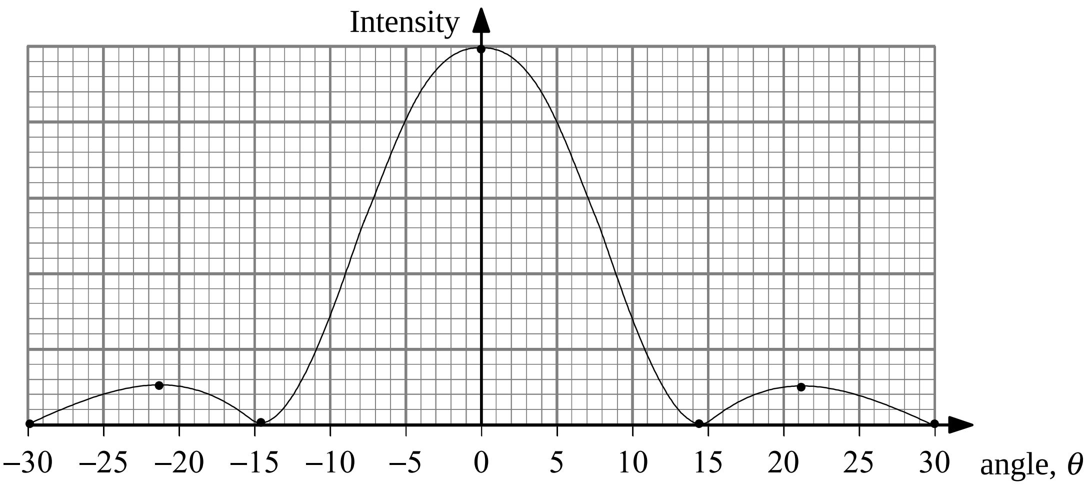
(b) Any varying pattern of intensity that has:

A maximum in the centre **and** is symmetrical about the centre. ***[1]***

The minima at the correct angles $(14\frac{1}{2}^\circ; 30^\circ)$ ***[1]***

A decreasing intensity of maxima with increasing angle. ***[1]***

(Watch for error carried forward with candidate's values of minima.)



(c) Correct use of $n\lambda = d\sin\theta$ ***[1]***

to get $\sin\theta = 400 \div 3200; 800 \div 3200; 1200 \div 3200; 1600 \div 3200$

$= 0.125; 0.25; 0.375; 0.5;$

Therefore $\theta = 7^\circ; 14\frac{1}{2}^\circ; 22^\circ; 30^\circ;$ ***[1]***

*(Award **[1]** for candidates that only calculate the first angle.*
Award full marks for candidates that calculate three or more angles.)

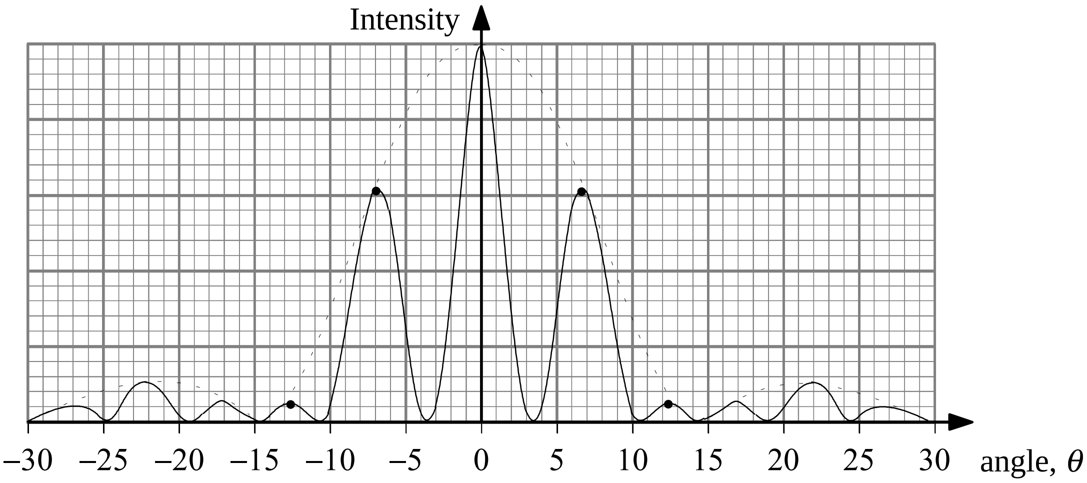
continued…

Question H3 continued

(d) Any varying pattern of intensity that has:

A maxima (the highest one) in the centre **and** is symmetrical about the centre. ***[1]***
The correct maxima for the double slit pattern. ***[1]***
Correctly modulated by the single slit pattern. ***[1]***

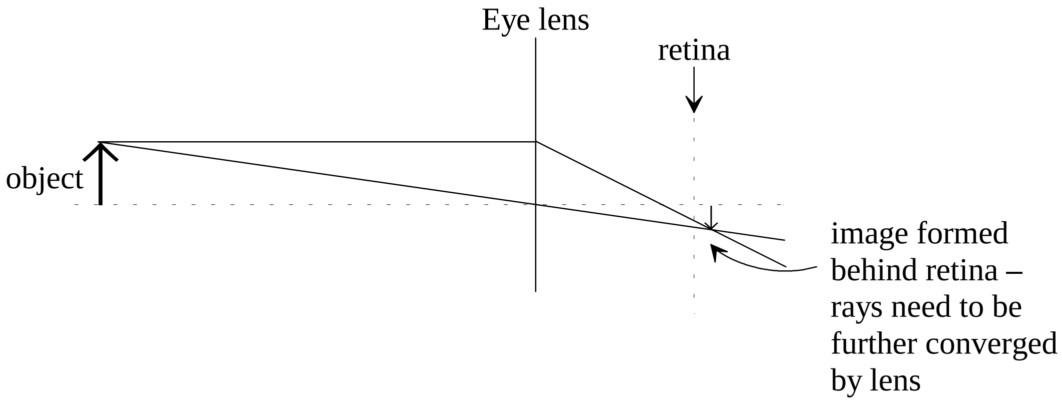
(Watch for error carried forward with candidate's values of maxima and minima.)



H4. (a) Converging. ***[1]***

(b) Long sighted (Hypermetropia). ***[1]***
The lenses of long sighted people form the image **behind the retina** thus the rays need to be converged. ***[1]***

(Error carried forward possible if answer to (a) is clear and not contracted by a diagram or further explanations.
A labelled diagram could be sufficient explanation.)



(c) Attempted use of lens makers' equation: ***[1[***

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

With $R_1 = 7.5$ cm and $R_2 = -12.5$ cm (note negative sign).
Gives $f = 36.8$ cm. ***[1]***