INTERNATIONAL BACCALAUREATE
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N00/430/S(3)M

MARKSCHEME

November 2000

PHYSICS

Standard Level

Paper 3

27 pages

A1. (a) 24 hours / a day / owtte. ***[1]***

(b) Communication aerial(s) always point in the same direction / owtte.
Satellite never goes below horizon / owtte.
(Any sensible comment that shows understanding.) ***[1]***

(c) Gravitational force provides CPF (seen or implied) ***[1]***

Attempted use of $F = \frac{GMm}{r^2}$ or $g = \frac{GM}{r^2}$ ***[1]***

Attempted use of $\text{CPF} = \frac{mv^2}{r}$ or equivalent. ***[1]***

Correct substitution of values in both equations. ***[1]***

$$r = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$$

to give $r = 4.2 \times 10^7$ m or 6.6 × (radius of the Earth). ***[1]***

(d) Direction: From the satellite towards the centre of the Earth. ***[1]***
Attempt at use of inverse square law with numbers. ***[1]***

i.e. field is $\left(\frac{1}{6.6^2}\right) \times 9.8\ \text{N kg}^{-1}$

i.e. $g \approx 0.22\ \text{N kg}^{-1}$ ***[1]***

(Accept any answer in the range 0.12 to 0.32 for full marks. Deduct sig. fig. mark if answer has more than three decimal places.)

A2. (a) Motion such that acceleration / force is proportional to – (displacement). ***[2]***

*(Award **[1]** out of **[2]** for:*
- *Any sensible definition that does not state or imply the opposite directions of acceleration and displacement – a negative sign in an equation is sufficient;*
- *An example (mathematical or otherwise) of SHM as opposed to the above e.g. "motion where the displacement varies sinusoidally";*
- *Quoting a formula from the data booklet **with** definitions of symbols but without further explanation.)*

*(Award **[0]** out of **[2]** for:*
- *Quoting a formula **without** definitions of symbols or further explanation;*
- *An attempt without any detail such as "an oscillating motion".)*

(b) (i) Use of $T = 2\pi\sqrt{\frac{m}{k}}$ ***[1]***

To get $k = 49.3 \approx 50\ \mathrm{N\,m^{-1}}$ ***[1]***

(ii) max force $= k \times \text{amplitude}$

$= 4.93\ \mathrm{N} \approx 5\ \mathrm{N}$ ***[1]***

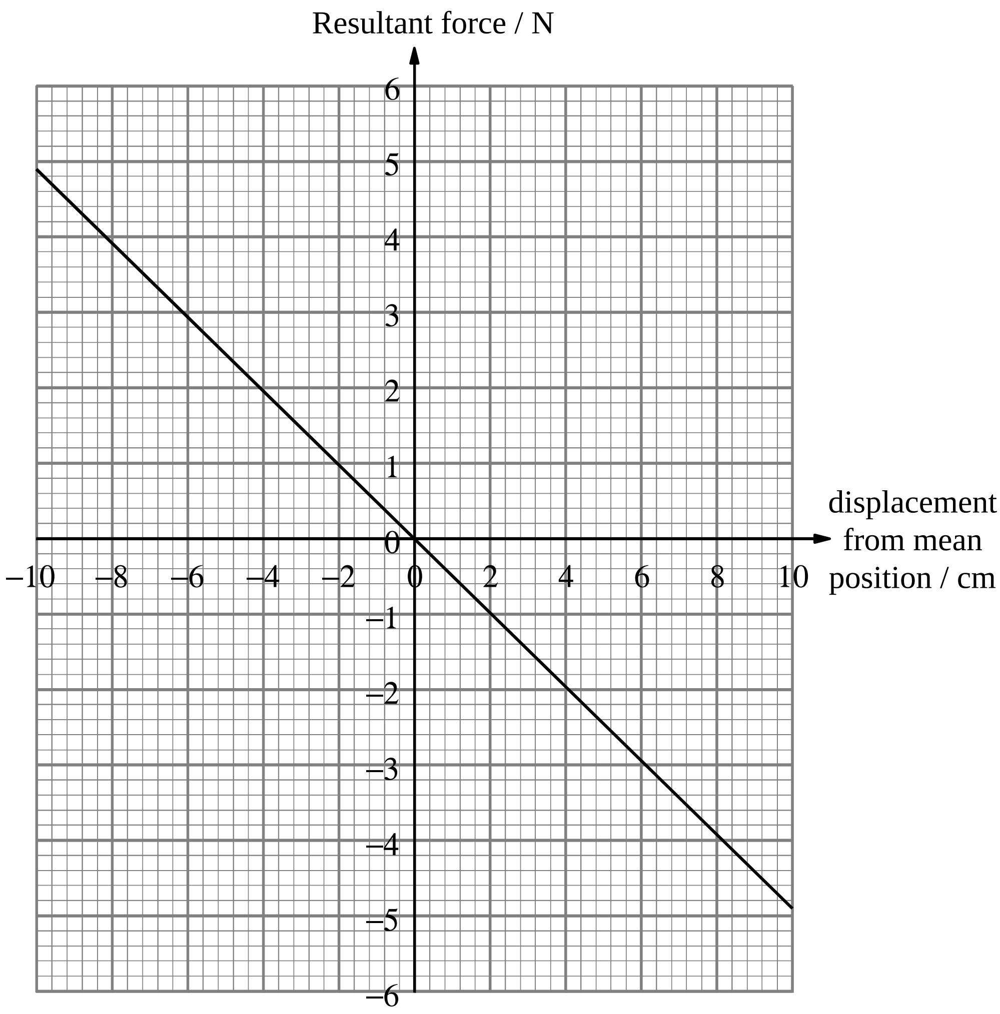
so max acceleration $= \frac{4.93}{5}$

$= 0.987 \approx 1\ \mathrm{m\,s^{-2}}$ ***[1]***

continued…

Question A2 continued

(c) Straight line with gradient $= -k$, going through origin. **[2]**



*(Award **[1]** for:*
- *any straight line of negative gradient;*
- *a straight line of gradient $= +k$.)*

(d) Idea that area under graph = elastic potential energy stored **[1]**

$$= 0.5 \times 0.1 \times 4.9 \text{ J}$$

$$\approx 2.5 \times 10^{-1} \text{ J}$$ **[1]**

*(Award **[1]** for candidates that get the correct answer without using their graph e.g. using $E_{elas} = \frac{1}{2}ks^2$.)*

B1. (a) $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\alpha$

Atomic numbers **and** mass numbers consistent with candidate's numbers for the α, *i.e.* both adding up correctly. ***[1]***

Correct numbers everywhere. ***[1]***

(b) (i) Initial KE $= 5.3\ \text{MeV}$

$= 5.3\times10^{6}\times1.6\times10^{-19}\ \text{J}.$ ***[1]***

$= 8.48\times10^{-13}\ \text{J}$ ***[1]***

(ii) mass difference $= 0.006118\ \text{U}$ ***[1]***

$= 0.006118\times931.5\ \text{MeV}$

$= 9.12\times10^{-13}\ \text{J}$ ***[1]***

(iii) Total KE after = KE before + energy liberated

$= 1.76\times10^{-12}\ \text{J}$ ***[1]***

(iv) Use of $\frac{1}{2}mv^2 = \text{KE}$

with KE from answer (iii) above **and** mass of neutron. ***[1]***

$v = 4.58\times10^{7}\ \text{m}\,\text{s}^{-1}$ ***[1]***

(c) Carbon nucleus not formed at rest / momentum must be conserved / owtte. ***[1]***

*(Award **[0]** for "energy lost into heat" or "reaction not 100 % efficient" owtte. Also award **[0]** for a candidate that just states that the assumption given in (iv) must be wrong without any extra detail.)*

B2. (a) (i) The emission of electrons (from the surface) of a metal when electromagnetic waves (of high enough) frequency fall on the surface / owtte. ***[2]***

*(Award **[1]** for poor answers that do, however, demonstrate an understanding that it either:*

- *results in the emission of electrons; or*
- *depends on electromagnetic waves / light falling on a surface.)*

*(Award **[0]** for a description, correct or otherwise, of a different effect, e.g. of thermionic emission.)*

(ii) The energy needed to remove an electron… ***[1]***
…from the **surface** (of a metal) / owtte. ***[1]***

(Award full marks for e.g. "the MINIMUM energy needed to remove an electron" / owtte.)

(b) (i) Some do not come from the surface / owtte. ***[1]***
For example, "Electrons undergo collisions while being ejected."

(ii) Use of $hf = \phi + \text{KE}$ ***[1]***
One correct conversion of…
either wavelength $\rightarrow$ frequency **or** joules $\rightarrow$ eV. ***[1]***

$$\phi = \frac{6.63\times10^{-34}\times\left(\dfrac{3\times10^{8}}{150\times10^{-9}}\right)}{1.6\times10^{-19}} - 3.53\,\text{eV}$$

to give $\phi = 4.76$ eV. ***[1]***

(iii) 375 nm $\Rightarrow$ photon energy of 3.31 eV.
Therefore no ejected electrons. ***[1]***
Since photons do not have enough energy / owtte. ***[1]***

C1. (a) A source that can continue to supply energy (effectively) indefinitely / A source that can supply energy without the source being (effectively) "used up" / owtte. ***[1]***

(Reject answers that are simply different examples of renewable sources.)

(b) (i) **Photovoltaic device:**
Solar / EM / light energy $\rightarrow$ electrical energy / owtte ***[1]***

Active solar heater:
Solar / EM / light energy $\rightarrow$ Thermal / heat energy / owtte ***[1]***

(N.B. It is the ***conversions*** *that are important.*
Award ***[0]*** *for a (correct) list of the energies involved without clear indication of the conversions involved.)*

(ii) **Photovoltaic device:**
Any appropriate situation where an electric device could rely on solar power, *e.g.* solar powered calculator. ***[1]***

(Award ***[0]*** *for:*
- *answers that are ambiguous or lack clarity e.g. "a calculator";*
- *answers where power requirement would be unfeasible.)*

Active solar heater:
Any appropriate situation where a supply of thermal energy could rely on solar power, *e.g.* warming water for a home. ***[1]***

(Award ***[0]*** *for:*
- *answers that are ambiguous or lack clarity e.g. "heating";*
- *answers where power requirement would be unfeasible.)*

(c) (i) Plausible assumption about hours of daylight ***[1]***
e.g. Assuming 12 hours of sunlight, in one day.
Appropriate calculation of energy received per day ***[1]***
e.g. Energy received by 1 $\text{m}^2 = 12 \times 1400\ \text{W hr} = 16.8\ \text{kW hr}$.
Appropriate use of efficiency information ***[1]***
e.g. Electric energy available per $\text{m}^2 = 0.85 \times 16.8$
$= 14.28\ \text{kW hr}$.
Appropriate final calculation ***[1]***
e.g. Area required $= 120 \div 14.28 = 8.4\ \text{m}^2$.

(N.B. Candidates can, of course, gain full marks by considering the powers, rather than the energies involved – see general comments. Conversions into joules can be ignored unless errors are made and they cause the final answer to be wrong. Award ***[3]*** *out of* ***[4]****.)*

(ii) Each appropriate reason gains ***[1]*** up to a maximum of ***[2]***. ***[2]***
For example, At times, power consumption will be more than the typical / Could be cloudy day / Sun's rays not at 90° to panel / owtte.

C2. (a) ΔQ – thermal energy / heat supplied **to** the system / owtte. ***[1]***
ΔU – increase in internal energy **of** the system / owtte. ***[1]***
ΔW – work done **by** the system / owtte. ***[1]***

(For each symbol, award no marks if candidate does not make it clear whether, for example, the thermal energy is supplied ***to*** *the system or* ***by*** *the system* ***unless*** *candidate misses this information for all three. In this case award* ***[1]*** *in total if otherwise correct.)*

(b) (i) ΔQ – zero + appropriate reason. ***[1]***
For example, "No heat provided from surroundings, *i.e.* zero change" / owtte.
ΔU – positive + reason. ***[1]***
For example, "Temperature has increased, therefore internal energy has increased" / owtte.
ΔW – negative + reason. ***[1]***
For example, "Gas has been compressed, therefore work has been done **on** the gas therefore work done **by** the gas is negative" / owtte.

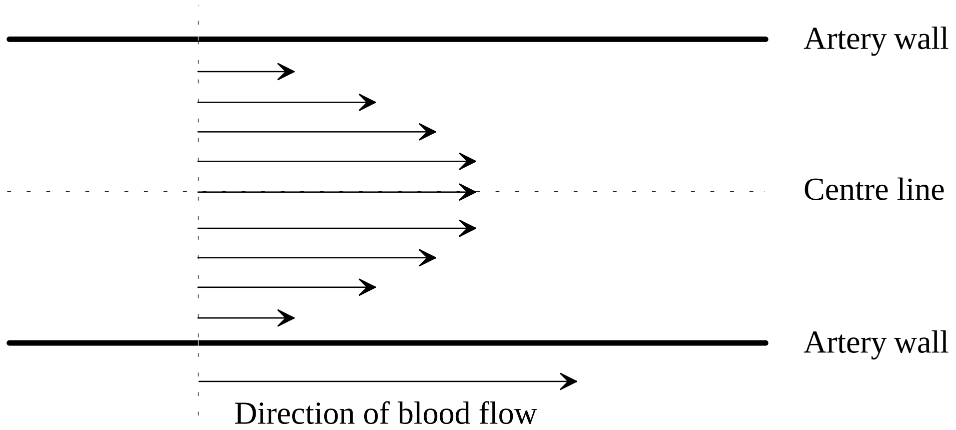
(ii) Realisation that the temperature increase means that the gas molecules are moving faster. (*This mark can be awarded even if the reason for their increase in speed is not understood.*) ***[1]***

Moving piston speeds up / accelerates the molecules / owtte… ***[1]***
… upon collision between piston and molecule. ***[1]***

(Explanation for increase in speed is essentially ***[2]*** *or* ***[0]****. Award* ***[0]*** *for answers in terms of:*
- *friction;*
- *collisions causing heat.)*

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.)

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, $KE = 30\text{ eV} = 30 \times 1.6 \times 10^{-19}\text{ J} = 4.8 \times 10^{-18}\text{ J}$

$$\text{Velocity} = \sqrt{\frac{2KE}{m}} = 3.25 \times 10^{6}\text{ m s}^{-1}$$

$$\text{Momentum} = \text{mass} \times \text{velocity}$$
$$= 9.11 \times 10^{-31} \times 3.25 \times 10^{6} = 2.96 \times 10^{-24}\text{ kg m s}^{-1}$$

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

$$= \frac{6.63 \times 10^{-34}}{2.96 \times 10^{-24}}$$

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

$$\approx 2 \times 10^{-10}\text{ m}$$ ***[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…

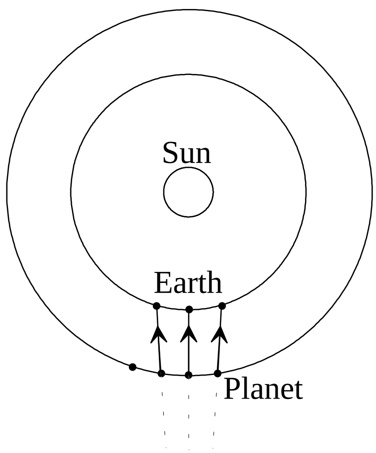
Question E2 continued

(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]***

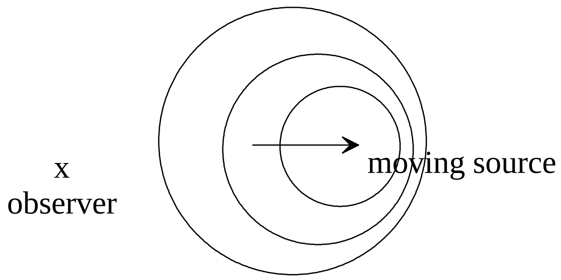
(Award ***[1]*** *for a diagram (without further explanation) which shows a changing relative position, for example as below.)*



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.)*

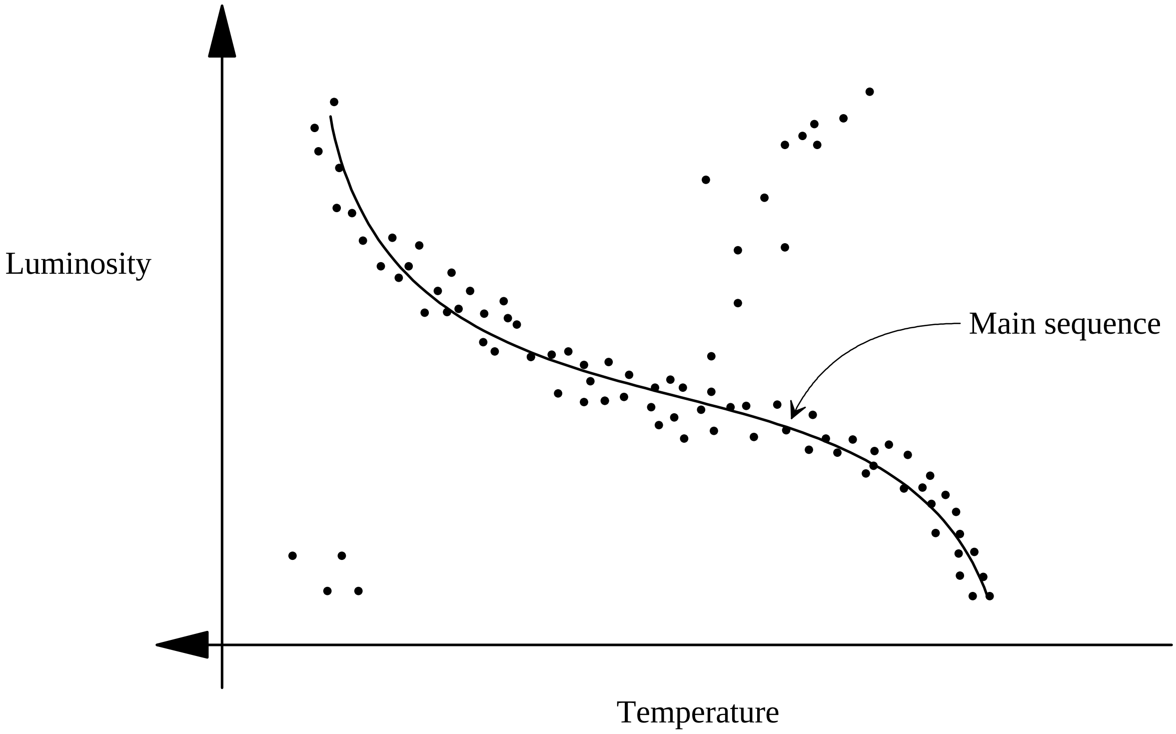
F2. (a) When different stars are plotted on a "Hertzsprung-Russell diagram" / "H-R diagram"… ***[1]***

…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, for example as below.)

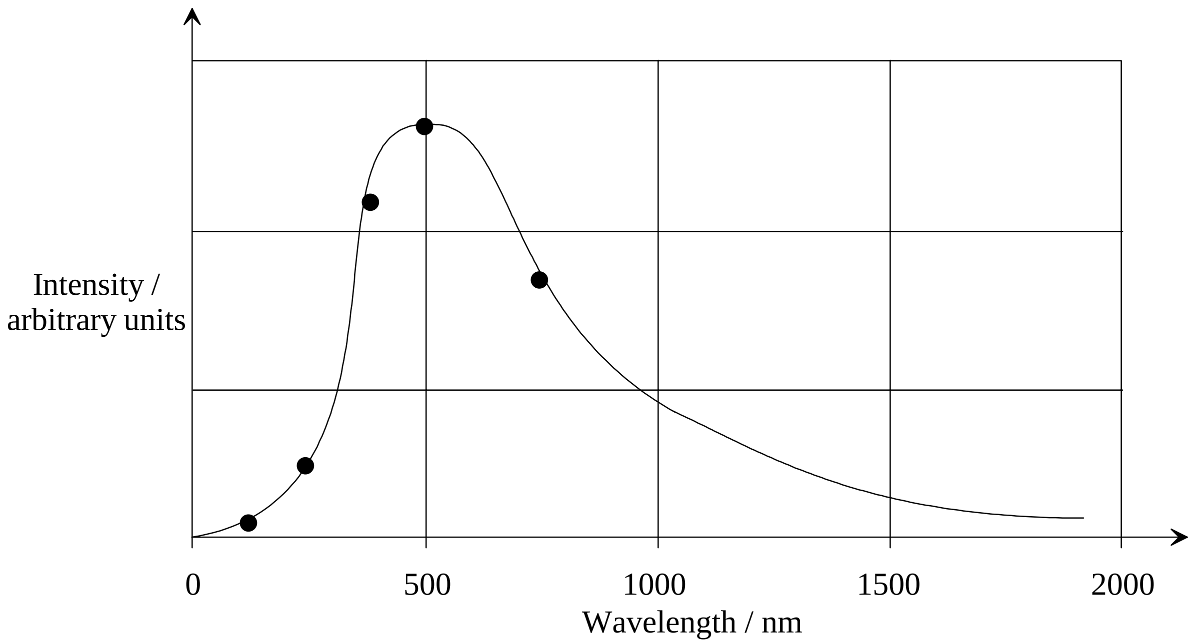


(b) Two (or more) stars orbiting each other / owtte. ***[1]***

(c) 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.)*

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 / $\lambda_{\max} = \dfrac{2.90 \times 10^{-3}}{T}$ ***[1]***

To get $T = 5800$ 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]***

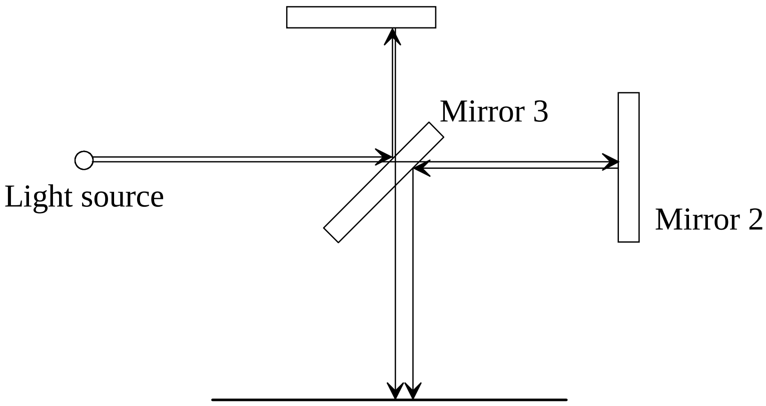
To get $\dfrac{L}{A} = 5.67 \times 10^{-8} \times 5800^4 = 6.4 \times 10^7 \text{ W m}^{-2}$ ***[1]***

(Watch for error carried forward from candidate's value of temperature.
Range above for T gives range of answers as:
1.6×10^8 W m^{-2} to 3.1×10^7 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.)*

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

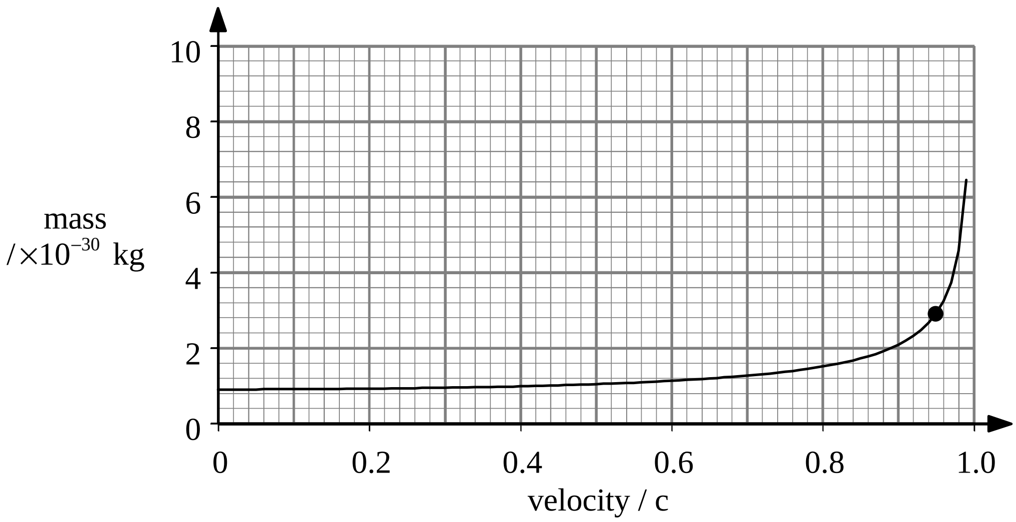
(b) $L = L_0 \div \gamma = 100 \div 3.2$
$= 31.22\text{ m} \approx 31\text{ m}$ *[1]*

(c) Time in laboratory frame $= 100 \div (0.95 \times 3 \times 10^8)$
$= 3.51 \times 10^{-7}\text{ s}$ *[1]*
Time in electron's frame, $\Delta t_0 = \Delta t \div \gamma$
$= 3.51 \times 10^{-7} \div 3.2$
$= 1.09 \times 10^{-7}\text{ s}$
$\approx 1 \times 10^{-7}\text{ s}$ *[1]*

(Watch for incorrect substitution.)

(d) Mass in laboratory frame $= \gamma m_0$ *[1]*
$= 3.2 \times 9.11 \times 10^{-31}$
$= 2.91 \times 10^{-30}\text{ kg} \approx 2.9 \times 10^{-30}\text{ kg}$ *[1]*

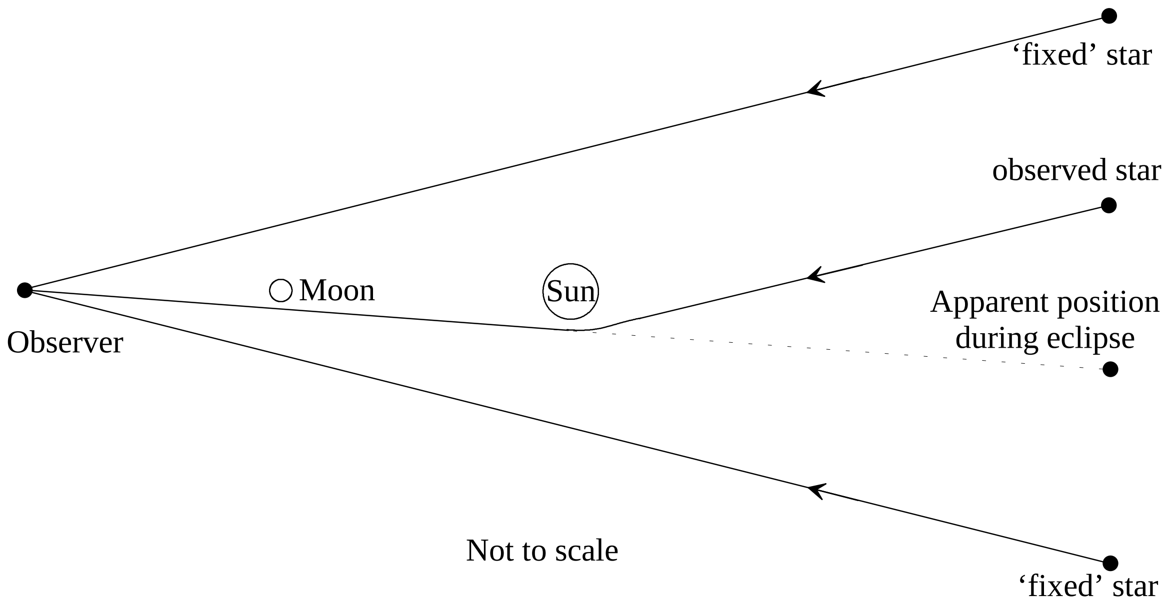
(e) Answer shown below:



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 $(0.95\text{ c}, 2.9 \times 10^{-30}\text{ kg})$ *[1]*
(N.B. watch for error carried forward with candidate's value.)
Line is asymptotic to c. *[1]*

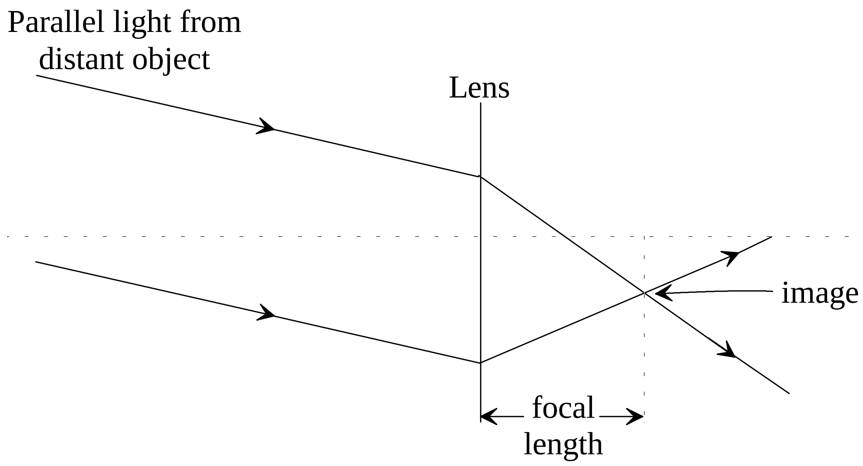
G3. During eclipse, observed position of star (relative to other stars) that appeared close to the surface of Sun / owtte. ***[1]***
This was compared to positions without Sun / at night / owtte. ***[1]***
Idea that the altering of apparent position is because Sun bends light from star / owtte. ***[1]***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

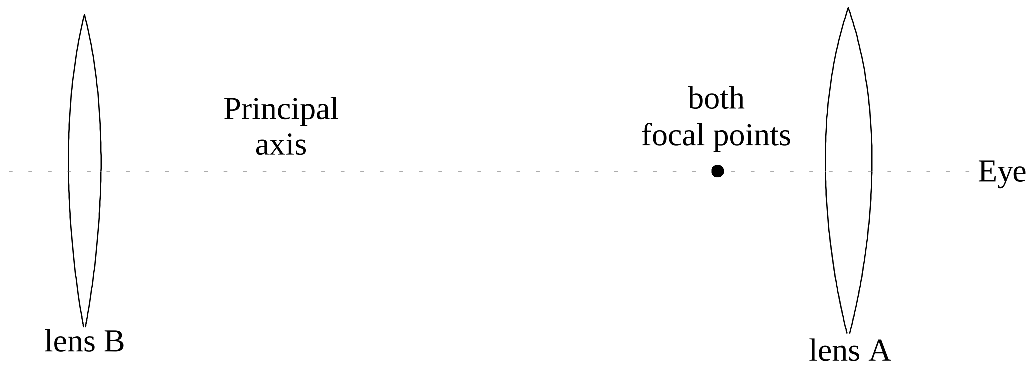


H1. (a) Arrange lens to form image of **distant** object (on a screen). ***[1]***
Lens to image distance is the focal length. ***[1]***

(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 $= f_a + f_b = 60\ \text{cm}$ ***[1]***

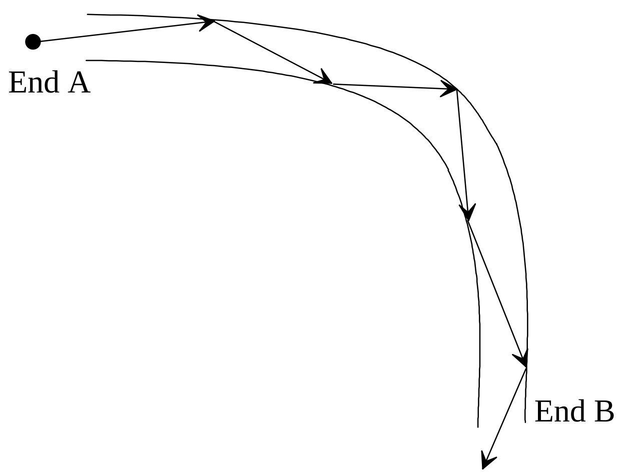
(Award full marks if candidate increases this value ***and*** *includes any discussion/estimations of extra small lengths to be added on to allow for mounting etc.)*

H2. (a) A diagram showing:

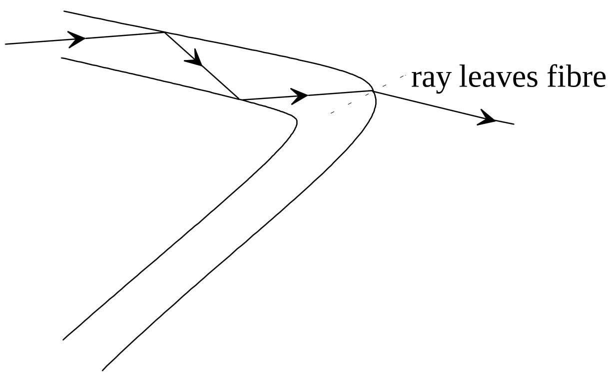
- Light entering one end;
- Multiple reflections of any sort;
- Light exiting from other end. ***[1]***

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.)*

continued…

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.)