International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2011

PHYSICS

Standard Level

Paper 3

General Marking Instructions

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 20 marks]**.
Maximum total = **[40 marks]**

1. A markscheme often has more marking points than the total allows. This is intentional. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized.

9. Only consider units at the end of a calculation.

10. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

Option A — Sight and wave phenomena

A1. (a) energy is propagated by travelling waves / energy is not propagated by standing waves;
amplitude constant for travelling waves / amplitude varies with position for standing waves;
phase varies with position for travelling waves / phase constant for standing waves;
travelling waves do not have nodes and antinodes / standing waves do have nodes and antinodes;
travelling waves can have any wavelength/frequency / standing waves can only have certain wavelengths/frequencies (to fit boundary conditions); ***[2 max]***

(b) (i) wave from tuning fork travels down tube and is reflected;
incident and reflected waves interfere/superpose/combine/add together to give a standing wave (that fits the boundary conditions); ***[2]***

(ii) the surface of the water (in/at the bottom of the tube); ***[1]***

(iii) the length of the air column has changed;
boundary conditions can no longer be met / the length is no longer equal to one quarter of a wavelength;
hence a standing wave cannot form / resonance no longer occurs / natural frequency of air column no longer equal to frequency of sound; ***[3]***

(c) $\frac{\lambda}{2} = 0.368 \Rightarrow \lambda = 0.736\,\text{m}$;
$v = f\lambda = 440 \times 0.736 = 320\,\text{m s}^{-1}$; ***[2]***

A2. (a) circular wavefronts around source, equally spaced;
moving observer intercepts more wavefronts per unit time / the time between intercepting successive wavefronts is less;
hence observes a higher frequency / $f' > f$;

or

circular wavefronts around source, equally spaced;
the velocity of the sound waves with respect to the observer is greater;
since $f' = \frac{v'}{\lambda}$, observed frequency is also greater; ***[3]***

(b) $f' = f\left(\frac{v+u_o}{v}\right) = 300\left(\frac{330+15}{330}\right)$;
$= 314\,\text{Hz}$; ***[2]***
*Award **[0]** for use of moving source formula.*
*Award **[1]** for use of v-u_o to give 286 Hz.*

A3. (a) $\theta = 1.22\dfrac{\lambda}{b}$ (Rayleigh criterion) and $\theta = \dfrac{d}{D} = \dfrac{0.40}{D}$ (with small angle approximation);

equate two expressions to get $\theta = 1.22\dfrac{550\times10^{-9}}{2.5\times10^{-3}} = \dfrac{0.40}{D}$;

$D = 1500\,\mathrm{m}$; ***[3]***

(b) (ciliary) muscles change the shape of the lens;
for near objects, the lens is thicker/more curved/has shorter focal length / for far objects, the lens is thinner/less curved/has longer focal length; ***[2]***

Option B — Quantum physics and nuclear physics

B1. light consists of photons/quanta/packets of energy;
each photon has energy $E = hf$ / photon energy depends on frequency;
a certain amount of energy is required to eject an electron from the metal;
if photon energy is less than this energy, no electrons are emitted; ***[4]***

B2. (a) $E = \frac{hc}{\lambda}$;

$= \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{658 \times 10^{-9}} = 3.02 \times 10^{-19}$;

$= \frac{3.02 \times 10^{-19}}{1.60 \times 10^{-19}}$;

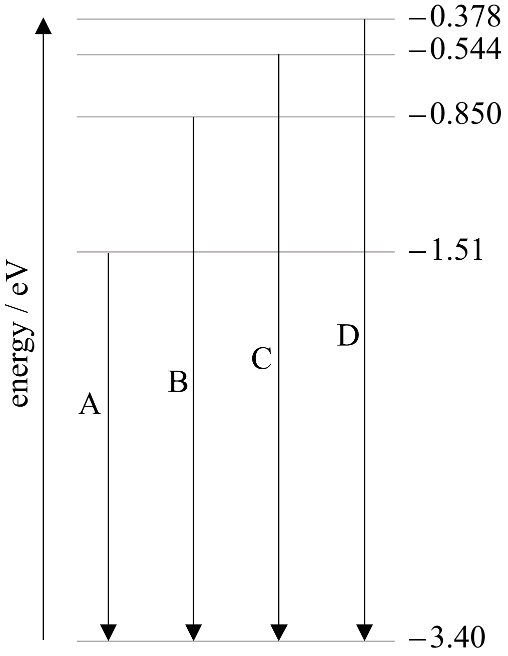
$= 1.89\,\text{eV}$

or

the photon of wavelength 658nm is the longest (in the emission graph);
therefore it has the shortest frequency and lowest energy (from $E = hf$);
therefore it arises from the transition between the –1.51eV and the –3.40eV energy levels which have a difference of 1.89eV; ***[3]***

(b) (i) see diagram below; ***[1]***

(ii) see diagram below;
All three must be correct for the mark. ***[1]***



(c) at higher energy levels, energy levels become closer together;
the energy differences between higher energy levels and the lower level ($n=2$) become more equal;
hence the difference in wavelength of emitted photons decreases / *OWTTE*; ***[3]***

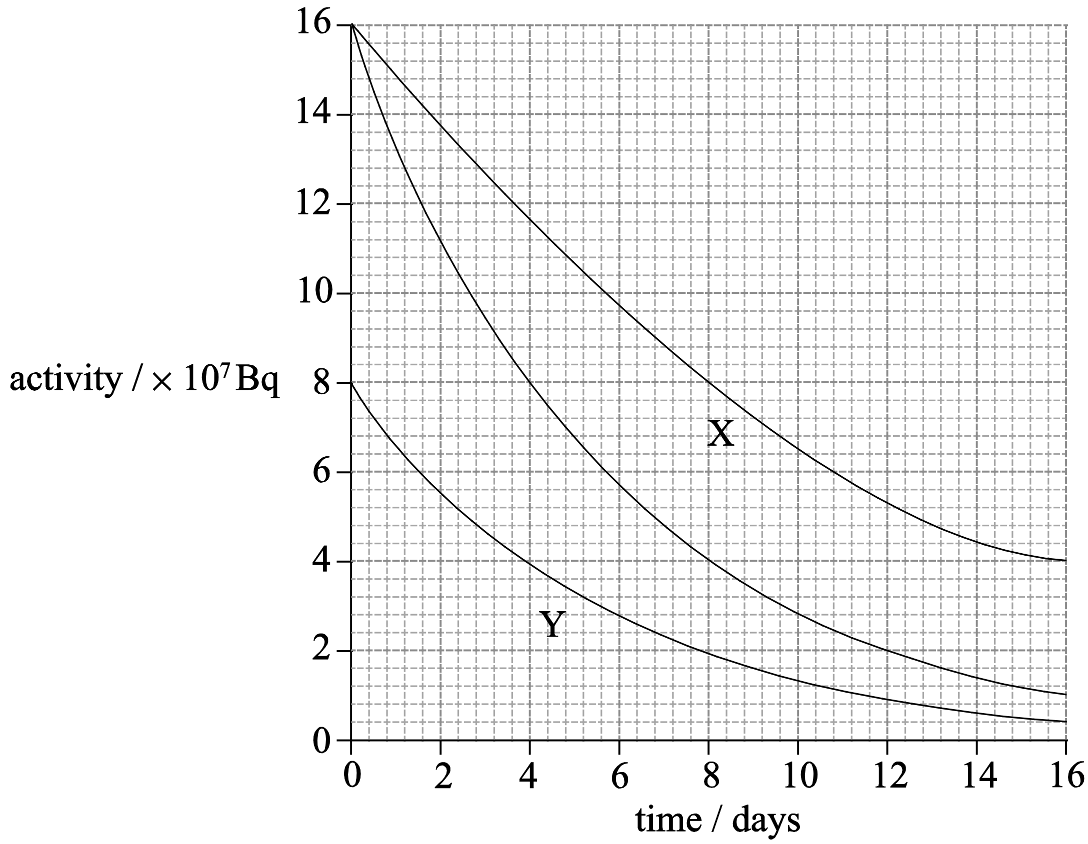
B3. (a) $^{124}_{53}\text{I} \rightarrow {}^{124}_{52}\text{Te} + {}^{0}_{1}\beta^{+}$;
$^{0}_{0}\nu$ / ν; ***[2]***
Do not allow an antineutrino.
*Award **[1 max]** for* $^{124}_{53}\text{I} \rightarrow {}^{124}_{54}\text{Te} + {}^{0}_{-1}\beta^{-} + \overline{\nu}$.

(b) (i) 4 days; ***[1]***

(ii) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{4} = \left(0.173 \text{ day}^{-1}\right)$;
$A = A_0 e^{-\lambda t} = 16 \times 10^7 \times e^{-0.173 \times 21}(\text{Bq})$;
$A = 4.2 \times 10^6\,\text{Bq}$; ***[3]***
*Award **[2 max]** for bald answer in range* $4.2 - 4.5 \times 10^6\,\text{Bq}$, *or linear interpolation between half lives giving* $4.4 \times 10^6\,\text{Bq}$.

(iii) graph passing through or near (0,16), (8,8) and (16,4) – see below; ***[1]***

(iv) graph passing through or near (0,8), (4,4) and (8,2) – see below; ***[1]***
Do not penalize if graph does not pass through (12,1) and (16,0.5).



Option C — Digital technology

C1. (a) (cassette) tape / LP / vinyl; ***[1]***

(b) Isobel's/analogue recording expected to fall in quality whereas digital/Claire's recording expected to maintain quality;
analogue process of retrieval affects quality of future retrievals / *OWTTE*; ***[2]***

(c) number of bits $= 30\times 60\times 40\times 10^3\times 2\times 16$;
number of bits $= 2.3\times 10^9$ $(= 288$ Mbytes); ***[2]***

C2. (a) magnification $= \dfrac{6.0\times 10^{-2}}{12\times 10^{3}}$;
$= 5.0\times 10^{-6}$; ***[2]***
*Award **[2]** for bald correct answer.*

(b) distance between pixels $= \dfrac{6\,\text{cm}}{10^4} = 6\times 10^{-6}\,\text{m}$;
resolution $= \dfrac{6\times 10^{-6}\,\text{m}}{5\times 10^{-6}} = 1.2\,\text{m}$; ***[2]***
Also allow 2.4 m for candidates who assume that objects need to be separated by two pixels to be completely resolved.

(c) no effect; ***[1]***

C3. (a) infinite (open loop) gain;
no current drawn on inputs / infinite input resistance/impedance; ***[2]***

(b) switchover happens when non-inverting input ≥ 3 V;
current through $100\,\text{k}\Omega = \dfrac{3-[-13]}{100\times 10^3} = \dfrac{16}{100\times 10^3} = 0.16\,\text{mA}$;
$V_{IN} = 3 + [0.16\,\text{mA}\times 22\,\text{k}\Omega] = 3 + 3.52 = 6.5\,\text{V}$; ***[3]***
*Award **[2 max]** for calculating other threshold value i.e. 0.8V.*

(c) idea that noise and/or dispersion distort digital pulse;
idea of two fixed outputs with different switch over points;
link to cleaning up of signal / removal of noise / no stray pulses produced; ***[3]***

C4. (a) new base station selected and connected; ***[1]***

(b) no change; ***[1]***

Option D — Relativity and particle physics

D1. (a) the length of an object as measured by an observer who is at rest relative to the object; ***[1]***

(b) (i) $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-0.75^2}} = 1.5$; ***[1]***

(ii) $L = \frac{L_0}{\gamma} = \frac{240}{1.5} = 160\,\text{m}$; ***[1]***

(iii) $L_0 = \gamma L = 1.5 \times 200 = 300\,\text{m}$; ***[1]***

(iv) the spaceship is never completely inside the tunnel;
because (according to observer B) the spaceship is longer than the tunnel; ***[2]***
Apply ECF in all parts of question (b).

(c) observer B will not see the two flashes simultaneously;
according to B, light 2 is moving to the left/towards observer B;
since the speed of light is the same for both sources;
the flash from light 2 reaches B before the flash from light 1;

or

according to B, the two flashes arrive at A simultaneously;
according to B, A is moving to the left/away from light 2;
since light from both sources moves with the same speed;
for the flashes to be received by A at the same time, the flash from light 2 must be emitted first; ***[4]***
Accept any equivalent discussion.

D2. (a) a particle that mediates/carries/transmits one of the fundamental forces / a particle that is exchanged between two particles when undergoing one of the fundamental interactions / *OWTTE*; ***[1]***

(b) $R \approx \dfrac{h}{4\pi mc} \Rightarrow m \approx \dfrac{6.63\times10^{-34}}{4\pi\times1.5\times10^{-15}\times3\times10^{8}}$;
$\approx 1.2\times10^{-28}$ kg; ***[2]***

(c) π^{+};
from conservation of charge at either vertex, the pion must have charge of +1; ***[2]***

(d) 0 or 1;

mesons consist of one quark and one anti-quark (which have spin $\pm\dfrac{1}{2}$);

the spins can be parallel (giving 1) or antiparallel (giving 0) / $\dfrac{1}{2}+\dfrac{1}{2}=1$ and $\dfrac{1}{2}-\dfrac{1}{2}=0$ / *OWTTE*; ***[3]***

(e) all hadrons are colourless;
not possible for two quarks to cancel out colour / *OWTTE*;

or

particle with two up quarks would have baryon number of 2/3;
not possible as baryon number needs to be –1, 0 or 1 / *OWTTE*;

or

particle with two up quarks would have charge $+\dfrac{4}{3}$;
not possible as charge has to be an integer / a whole number (or zero); ***[2]***

Option E — Astrophysics

E1. (a)

Nearest the Sun	Venus
↓	Mars
	Jupiter
Furthest from the Sun	Neptune

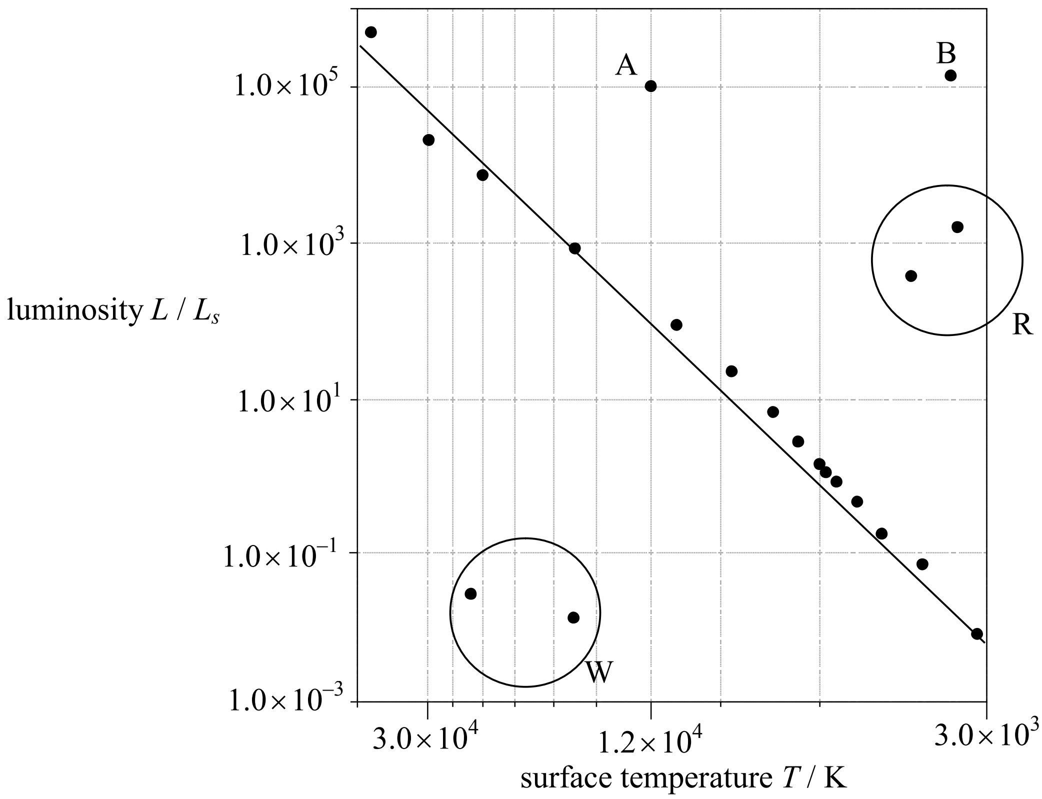
Award ***[2]*** *for all correct and* ***[1]*** *for two correct.* ***[2]***

(b)

Largest diameter	Jupiter
↓	Neptune
	Venus
Smallest diameter	Mars

Award ***[2]*** *for all correct and* ***[1]*** *for two correct.* ***[2]***

E2. (a)



(i) circle labelled R as shown above; ***[1]***
Accept answers that include the star B within the circle.

(ii) circle labelled W as shown above; ***[1]***

(iii) any line (not necessarily straight) going from top left to bottom right, through or near all or most of stars; ***[1]***

(b) star B has lower temperature;
star B has (slightly) larger luminosity / stars have approximately same luminosity;
surface area calculated from $L=\sigma A T^4$, so star B has larger surface area/diameter / to give the same/similar luminosity at lower temperature, star B must have bigger diameter/surface area; ***[3]***

(c) (from HR diagram) $L_A = 10^5 L_S$;

$b = \dfrac{L}{4\pi d^2}$ used;

to give $\dfrac{d_A}{d_S} = \sqrt{\dfrac{L_A}{L_S} \times \dfrac{b_S}{b_A}} = \sqrt{10^5 \times \dfrac{1.4\times10^3}{4.9\times10^{-9}}}$;

hence $d_A = 1.7\times10^8$ AU;

$= 800\,\text{pc}$ ***[4]***

Do not award a mark for the conversion from AU to pc.

(d) the parallax angle is too small to be measured accurately / the distance is greater than the limit for stellar parallax, which is 100 pc; ***[1]***
Accept any value from 100–800 pc for limit. Do not accept "it's too far away".

E3. (a) the universe is expanding / many galaxies are moving away from us; ***[1]***

(b) the CMBR fills all of space / is uniform / is distributed equally, consistent with an "explosion" (at start of universe);
the temperature of the radiation (2.7 K) is consistent with cooling due to expansion/redshift; ***[2]***

(c) $\lambda_{\text{max}} = \dfrac{2.9\times10^{-3}}{T} \Rightarrow T = \dfrac{2.9\times10^{-3}}{7.0\times10^{-7}}$;
$T = 4100$ K; ***[2]***

Option F — Communications

F1. (a) (i) 100 kHz; *[1]*

(ii) 4 kHz; *[1]*

(iii) 8 kHz; *[1]*

(b) (i) *AM*: *e.g.* signal information encoded in a variation of the carrier signal's amplitude / *OWTTE*;
FM: *e.g.* signal information encoded in a variation of the carrier signal's frequency / *OWTTE*; *[2]*
*Award **[0]** for restating amplitude modulation and frequency modulation.*
The answer needs to explain "modulation". Accept good labelled diagrams as explanation.

(ii) *Advantage*: not as susceptible to noise / quality better / less fading;
Disadvantage: larger bandwidth needed / more complex circuitry / limited range of broadcast; *[2]*

F2. (a) analogue; *[1]*

(b) sample / hold; *[1]*

(c) realisation that S_1 is 8 bit whereas S_2 is 4 bit;
therefore quality of reproduction of S_1 > quality of reproduction of S_2; *[2]*

(d) (i) definition equation $\left(=10\lg\frac{I_1}{I_2}\right)$ and definition of symbols / the loss of power of a signal (with distance travelled) / *OWTTE*; *[1]*

(ii) $\text{attenuation} = 10\lg\left[\frac{1}{100}\right] = -20\,\text{dB}$;

$\text{length} = \frac{-20}{-4} = 5\,\text{km}$; *[2]*

(iii) amplification;
reshaping; *[2]*

F3. (a) microwave; ***[1]***

(b) permanent link not possible;
requires tracking; ***[2]***

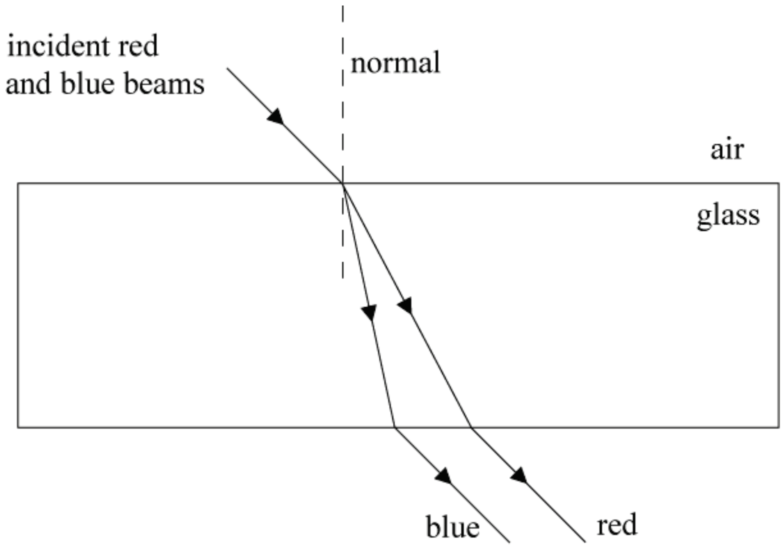
(c) cultural judgement involved in what is and what is not acceptable to broadcast / how does one decide what is and what is not acceptable; ***[1]***
Accept any sensible and appropriate comment.

Option G — Electromagnetic waves

G1. (a) any value within the range $320-780\,\text{nm}$; *[1]*

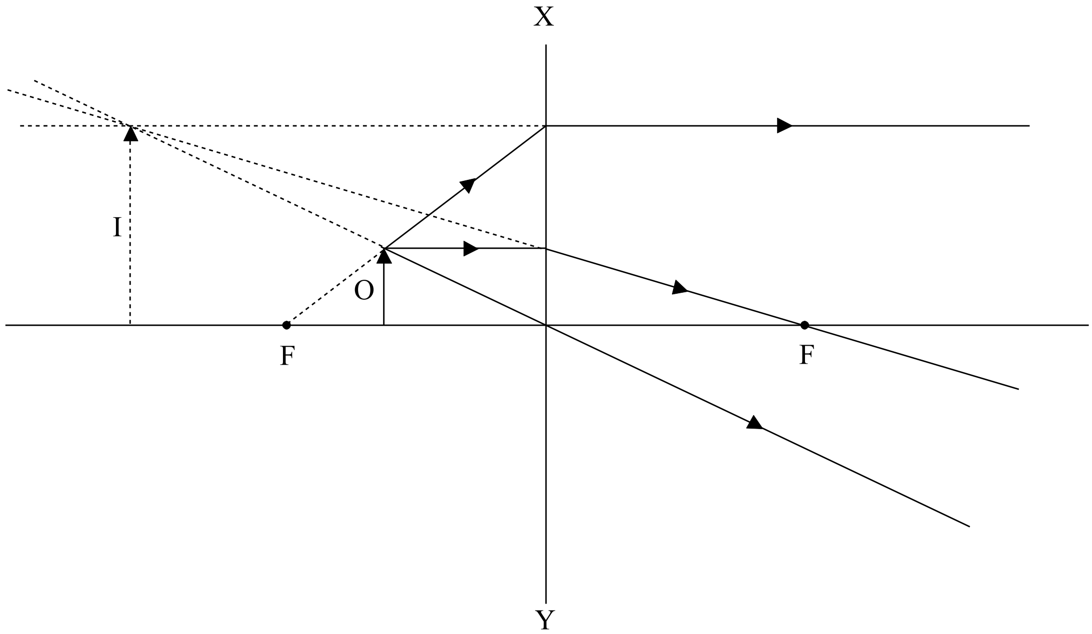
(b) splitting/separation into component colours/wavelengths/frequencies;
because different colours/wavelengths/frequencies have different refractive indices / refract by different amounts; *[2]*

(c) refraction towards normal for both rays at first surface, blue ray refracted more than red ray;
both rays refracted away from normal at second surface, both emergent rays parallel to incident beam; *[2]*
See diagram below. Judge answers by eye.



G2. (a) (i) the point on the principal axis;
through which parallel rays pass after going through the lens / from which rays are parallel after passing through the lens; ***[2]***

(ii)



any two correct rays out of the three shown above;
image correctly located and labelled; ***[3]***

(iii) virtual because no rays pass through the image / image cannot be formed on a screen; ***[1]***
Mark is for explanation, not for statement of virtual.

(b) (i) $\frac{1}{f}=\frac{1}{D}+\frac{1}{u}\Rightarrow\frac{1}{u}=\frac{1}{5.0}-\left[-\frac{1}{25}\right]$;

$\frac{1}{u}=\frac{5+1}{25}=\frac{6}{25}\Rightarrow u=4.2\,\text{cm}$; ***[2]***

(ii) $m=\frac{D}{f}+1=\frac{25}{5.0}+1=6$ ***or*** $m=-\frac{D}{u}=-\left[\frac{-25}{4.167}\right]=6$;

$m=\frac{h_i}{h_o}\Rightarrow h_i=mh_o=6.0\times0.80=4.8\,\text{cm}$; ***[2]***

*Award **[4]** for (b)(i) and (b)(ii) on a scale diagram with the points shown below.*

suitable scale identified;
correct placement of principal axis, lens and object;
correct rays to enable location of image;
correct measurements for both answers;
Award final mark for correct answers based on diagram (judge by eye).

G3. (a) $d = \frac{1}{8.00 \times 10^5} = 1.25 \times 10^{-6}\,\text{m}$;

$d \sin\theta = n\lambda \Rightarrow \theta = \sin^{-1}\left[\frac{n\lambda}{d}\right]$;

$\sin^{-1}\left[\frac{2 \times 589 \times 10^{-9}}{1.25 \times 10^{-6}}\right] = 70.5^\circ$, $\sin^{-1}\left[\frac{2 \times 590 \times 10^{-9}}{1.25 \times 10^{-6}}\right] = 70.7^\circ$;

$70.7^\circ - 70.5^\circ = 0.2^\circ$; ***[4]***

(b) the lines are closer together / not clearly separate in the first order spectrum; ***[1]***