N10/4/PHYSI/SP3/ENG/TZ0/XX/M

International Baccalaureate®
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MARKSCHEME

November 2010

PHYSICS

Standard Level

Paper 3

17 pages

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded**.

3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking. It should be remembered that the script may be returned to the candidate.

4. Unexplained symbols or personal codes/notations are unacceptable.

5. Record marks in the right-hand margin against each mark allocation shown in square brackets *e.g.* ***[2]***. The total mark for a question must equal the number of ticks for the question.

6. Do **not** circle sub-totals. **Circle the total mark** for the question in the right-hand margin **at the end of the question**.

7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin next to the square bracket.

8. Where work is submitted on additional sheets the marks awarded should be shown as ticks and a note made to show that these marks have been transferred to the appropriate square bracket in the body of the script.

9. For each Option: Add the totals for each question in the Option and write it in the Examiner column on the cover sheet.
Total: Add the marks awarded and enter this in the box marked TOTAL in the Examiner column on the cover sheet.

10. After entering the marks on the cover sheet check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **All scripts are checked and a note of all clerical errors will be given in feedback to examiners**.

11. If an answer extends over more than one page and no marks have been awarded on a section draw a diagonal line through that section to indicate that it has been marked.

12. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers and use the marks of those answers that have the highest mark, **even if the candidate has indicated the question(s) to be marked on the cover sheet**.

13. A mark should not be awarded where there is contradiction within an answer. Make a comment to this effect in the left hand margin.

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. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. 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. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Omission of units should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover sheet.

11. 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*

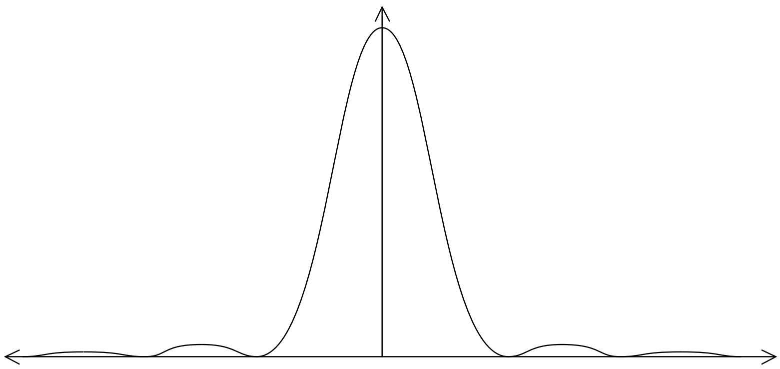
Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover sheet.

Option A — Sight and wave phenomena

A1. (a) the near point is the closest position of an object from the eye that can be clearly focussed / objects placed closer than the near point cannot be focussed by the eye / *OWTTE*;
the far point is the furthest position of an object from the eye that can be clearly focussed / *OWTTE*;
accommodation is the ability of the eye to focus on objects placed anywhere between the near point and the far point / *OWTTE*; ***[3]***
*Award **[1 max]** if near and far points are defined in terms of distance.*

(b) the (ciliary) muscles (of the eye) alter the shape of the eye lens;
thereby altering its focal length; ***[2]***

A2. (a) (i)



general correct shape touching axis and symmetric about $\theta = 0$ (at least one secondary maxima on each side); *(judge by eye)*
central maximum wider than secondary maxima;
secondary maxima at most one third intensity of central maximum; ***[3]***

(ii) $\frac{d}{2} = \frac{D\lambda}{b}$;

$d = \frac{2.0 \times 1.2 \times 5.2 \times 10^{-7}}{4.0 \times 10^{-5}} = 3.12 \times 10^{-2}\ \text{m}$;

$\approx 3\,\text{cm}$ ***[2]***

(b) *Award **[2 max]** for a sensible argument.*
e.g. light from each point forms a diffraction pattern after being focussed by the eyepiece of the telescope;
if the diffraction patterns are not sufficiently well separated then the points will not be resolved as separate sources;

*Award **[1 max]** for the conclusion.*
e.g. if the points cannot be resolved as separate sources the planet cannot be seen as a disc; ***[3]***

A3. (a) no energy propagated in a standing wave;
the amplitude of a standing wave is not constant;
points along a standing wave are either in phase or out of phase with each other / *OWTTE*; ***[1 max]***

(b) (i) antinode at open end node at closed end; ***[1]***

(ii) antinode at open end and node at closed end and one more node along pipe; ***[1]***
(judge by eye)

(c) for $\lambda_1 = 4L$ and for $\lambda_2 = \frac{4L}{3}$;

$f_1 = \frac{c}{4L}$ and $f_2 = \frac{3c}{4L}$;

$\frac{f_1}{f_2} = \frac{1}{3}$; ***[3]***

(d) there must always be a node at the closed end and an antinode at the open end / there must always be an integer number of $\frac{\lambda}{4}$; ***[1]***

Option B — Quantum physics and nuclear physics

B1. (a) (i) light consists of photons/quanta;
a certain minimum amount of energy (the work function) is required to remove an electron from the metal;
if the photon energy is below this energy/work function no electrons will be emitted;
the energy of the photons is proportional to the frequency / $E = hf$ (with terms defined); ***[4]***
*If work function is mentioned it must be defined to award **[4]**.*

(ii) different metals need a different amount of minimum energy for electrons to be removed; ***[1]***
Accept answers in terms of work function if defined either here or in (a)(i).

(b) (i) $KE_{\text{max}} = hf - \phi$;
$= 6.6\times10^{-34}\times1.0\times10^{15} - 3.2\times10^{-19}$;
$= 3.4\times10^{-19}$ J ***[2]***

(ii) use of $E = \dfrac{p^2}{2m}$ and $p = \dfrac{h}{\lambda}$ ***or*** use of $v = \sqrt{\dfrac{2E}{m}}$ and $p = mv = \dfrac{h}{\lambda}$;
to give $\lambda = \dfrac{h}{\sqrt{2mE}}$;
$\lambda = 8.4\times10^{-10}$ m; ***[3]***

B2. (a) light from incandescent/hot/glowing hydrogen/hydrogen discharge tube is passed through a slit;
then through a prism/diffraction grating;
and brought to focus on a screen / observed with a telescope/eye; ***[3]***
*Allow **[3]** for a correctly drawn and labelled diagram.*

(b) $E = \left(\dfrac{hc}{\lambda} = \right) 3.03\times10^{-19}$ J;
$= 1.90$ eV; ***[2***

B3. (a) *X*: positron ***or*** β^+;
A: 189 and *Z*: 78; *(both responses needed)* ***[2]***

(b) (i) $0.0784\,\text{min}^{-1}$; ***[1]***

(ii) recognize to use $A = A_0 e^{-\lambda t}$;
$A = 48.4$ Bq; ***[2]***

Option C — Digital technology

C1. (a) (i) 1011; ***[1]***

(ii) as a series of bumps/pits and flats on the surface;
a flat/bump corresponds to binary zero / transition between flat and bump is one; *(vice versa)* ***[2]***

(iii) light rays from the edge of the bump and the flat interfere;
they will cancel out if the path difference between them is half a wavelength; ***[2]***

(b) (i) ratio of the charge stored in the pixel to the potential difference across the pixel; ***[1]***

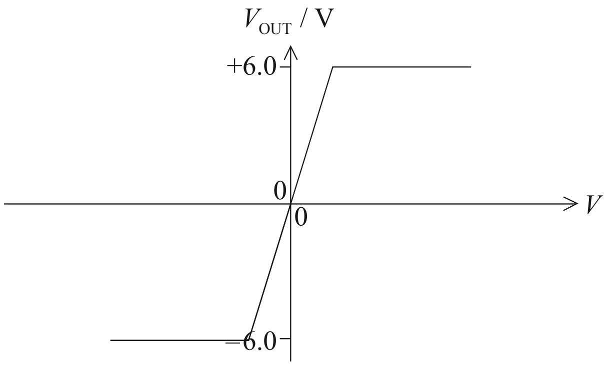
(ii) number on photons per pixel $= \left(4.0\times10^{13}\times2.8\times10^{-10}=\right)1.12\times10^{4}$;

number of electron(-hole pairs) $= \left(1.12\times10^{4}\times0.74=\right)8.29\times10^{3}$;

charge produced $= \left(8.29\times10^{3}\times1.6\times10^{-19}=\right)1.33\times10^{-15}\ (\mathrm{C})$;

potential $= \left(\frac{Q}{C}=\frac{1.33\times10^{-15}}{2.0\times10^{-11}}=\right)0.066\,\mathrm{mV}$ ***or*** $6.6\times10^{-5}\ \mathrm{V}$; ***[4]***

C2. (a) (i) *Award marks for the graph as below with*:
constant value at -6.0 V for large negative voltages and constant value at $+6.0$ V for large positive voltages;
sharp linear rise to connect the two constant values; {*accept instantaneous transition*} ***[2]***



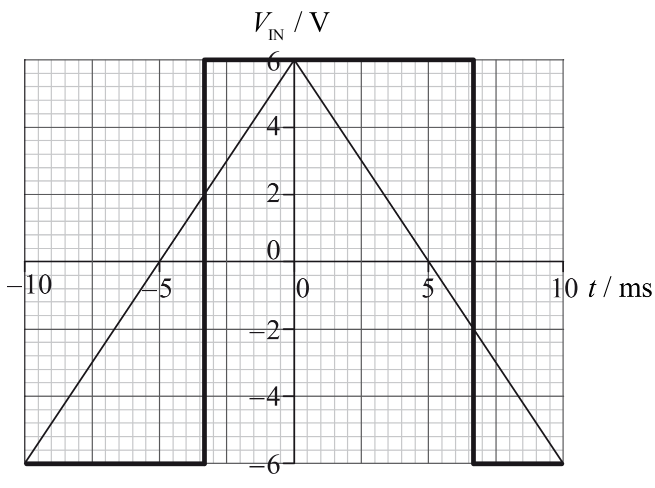
(ii) the output voltage changes abruptly from a low to a high value;
depending on whether the input voltage is smaller/larger than some reference voltage; ***[2]***

(b) (i) (switchover occurs when voltage in between resistors is 0 V with output at -6.0 V and so) current in 15 kΩ resistor is $I = \left(\frac{6}{15\times10^{3}} =\right) 4.0\times10^{-4}\text{ A}$;
$V_{IN} = 5.0\times10^{3}\times4.0\times10^{-4}$;
$= 2.0\text{ V}$ ***[2]***

or

p.d. across $15\text{ k}\Omega = 6\text{ V}$;
p.d. across $5\text{ k}\Omega = \frac{5}{15}\times6 = 2.0\text{ V}$;

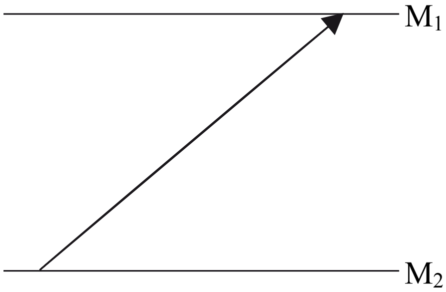
(ii) square wave pulse;
with verticals intercepting at +2.0 V and –2.0 V; ***[2]***



(c) digital signals are <u>distorted</u> (by noise/dispersion) during transmissions;
the Schmitt trigger <u>reshapes</u> the signals; ***[2]***

Option D — Relativity and particle physics

D1. (a) any diagonal line as shown; ***[1]***



(b) (i) $v\Delta t$; ***[1]***

(ii) speed of pulse $\left(c^2+v^2\right)^{\frac{1}{2}}$;

distance $=\left(c^2+v^2\right)^{\frac{1}{2}}\Delta t$; ***[2]***

(c) $c\Delta t$; ***[1]***

(d) $d=c\Delta t'$;

from Pythagoras $d^2=c^2\Delta t'^2=c^2\Delta t^2-v^2\Delta t^2$;

$\Delta t=\dfrac{\Delta t'}{\sqrt{1-\dfrac{v^2}{c^2}}}$; ***[3]***

(e) recognize that $2.3=\dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$;

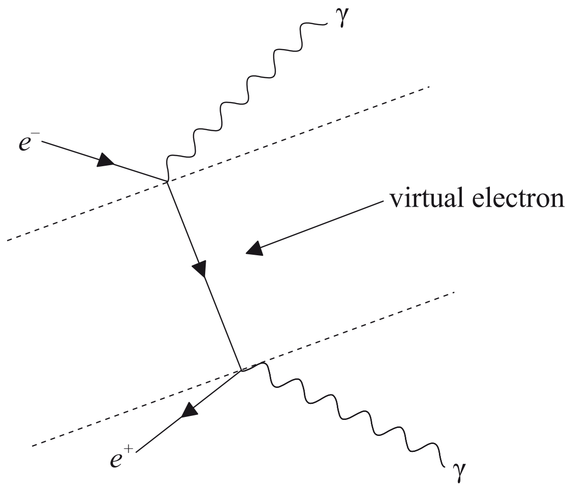
some evidence of rearranging *e.g.* $v=\sqrt{\dfrac{[2.3]^2-1}{[2.3]^2}}$;

$=0.90\text{c}$ ***[2]***

D2. (a) (i) a particle that cannot be made from any smaller constituents/particles; ***[1]***

(ii) has the same rest mass (and spin) as the lepton but opposite charge (and opposite lepton number); ***[1]***

(b)



*Award **[1]** for each correct section of the diagram.*
e^- correct direction and γ;
e^+ correct direction and γ;
virtual electron/positron; ***[3]***
Accept all three time orderings.

(c) (i) $u\bar{d}$ / up and anti-down; ***[1]***

(ii) baryon number is not conserved / quarks are not conserved; ***[1]***

(d) two identical particles that have half-integer spin/fermions cannot occupy the same quantum state; ***[1]***

(e) quarks are subject to the Pauli principle;
the introduction of colour ensures that the principle is not violated; ***[2]***

Option E — Astrophysics

E1. (a) *constellation*:
a collection/group of stars that form a recognizable pattern (as viewed from Earth) / a group/pattern of stars not close together (in space);

stellar cluster:
a group of stars (including gas and dust) held together by gravity/forming a globular/open arrangement / a group of stars close to each other (in space); ***[2]***

(b) (i) the apparent magnitude of P_A is (much) smaller than that of P_B;
in the apparent magnitude scale the smaller the magnitude the brighter the star; ***[2]***
Accept argument in terms of P_B being fainter than P_A.

or

apparent brightness of P_A is greater than P_B;
apparent brightness is intensity at surface of Earth;

(ii) the absolute magnitude of P_A is smaller than that of P_B;
the absolute magnitude is the apparent magnitude at a distance of 10 pc (from Earth);
so at the same distances from Earth P_A is much brighter than P_B so must be more luminous; ***[3]***
Accept argument in terms of P_B being fainter than P_A.

or

absolute magnitude of P_A is less than absolute magnitude of P_B;
absolute magnitude is a measure of luminosity;
lower values of absolute magnitude refer to brighter/more luminous star;

or

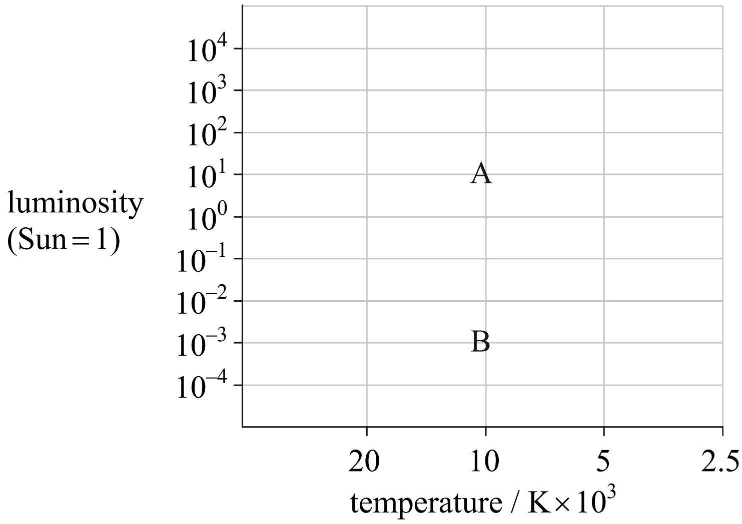
Accept answer based on answer to (c).
distances are the same from (c);
since $L = 4\pi d^2 b$ P_A is brighter than P_B;

(c) $m - M$ for $P_A = -2.28$ and $m - M$ for $P_B = -2.30$;
since $m - M = 5\lg\frac{d}{10}$ then d for each is very nearly same; ***[2]***
Accept answer based on calculation of individual d's (~ 3.5 pc).

(d) same distance from Earth <u>and</u> in the same region of space; ***[1]***

(e) recognize that the ratio of the luminosities is the same as the ratio of apparent brightness;
$\frac{L_A}{L_B} = \left(\frac{2.06\times10^{-8}}{1.46\times10^{-12}} =\right) 1.41\times10^{4}$; ***[2]***

(f)



(i) $P_A \rightarrow$ 10 000 K at 10; *(labelled A)* ***[1]***

(ii) $P_B \rightarrow$ 10 000 K at 10^{-3}; *(labelled B)* ***[1]***

(g) white dwarf; ***[1]***
Allow ECF from diagram.

E2. (a) <u>space and time</u> originated from a single point in a large explosion / an expanding universe that originated from a single point / *OWTTE*; ***[1]***

(b) (i) temperature of the universe immediately after the Big Bang was very high;
as it expanded it cooled down;
the wavelength of the CMB corresponds to a temperature consistent with this cooling down / *OWTTE*;
red shift is due to expansion of universe; ***[3 max]***

(ii) indicates that the universe is expanding; ***[1]***

Option F — Communications

F1. (a) the modification/change of a carrier wave by addition/superposition of another signal wave; ***[1]***

(b) (i) 30 kHz; ***[1]***

(ii) 1.5 kHz; ***[1]***

(iii) difference between maximum and minimum displacement divided by two;
$\frac{2.8-1.1}{2}=0.85\,\text{V}$; *(accept answer in the range of 0.80 V to 0.90 V)* ***[2]***

(iv) 3.0 kHz; ***[1]***

(c) less susceptible to noise / better reception quality;
because noise gets added to amplitude in AM but in FM amplitude is constant; ***[2]***

F2. (a) speed of propagation depends on frequency/wavelength;
(and so after some time) different frequencies cover different distances; ***[2]***

(b) pulses will start to overlap (if bit-rate is too high); ***[1]***

(c) (i) pulse with longer duration and shorter height shown; ***[1]***

(ii) dispersion is caused by a range of signal frequencies/wavelengths;
so reduce range of frequencies/wavelengths / use monochromatic signal; ***[2]***

(d) (i) speed is $\frac{3.0\times10^{8}}{1.5}=2.0\times10^{8}\,\text{m}\,\text{s}^{-1}$;
and so time is $\frac{500\times10^{3}}{2.0\times10^{8}}=2.5\,\text{ms}$; ***[2]***

(ii) bit rate is $\left(\frac{1}{0.5\times10^{-9}}=\right)2.0\times10^{9}\,\text{Hz}$;
(since bit rate $=f\times$number of bits,) $f=\frac{2.0\times10^{9}}{32}=62.5\,\text{MHz}$; ***[2]***

(e) an optical fibre might be preferable because the data are transmitted along a protected line;
in a satellite transmission the data can be intercepted by anyone; ***[2]***

or

a satellite is preferable provided that it has an encryption system/encoded signal;
wider coverage than cable / any other sensible suggestion;

Option G — Electromagnetic waves

G1. (a) (i) (the waves) all have the same frequency/wavelength; ***[1]***
Do not accept "one colour".

(ii) (the waves) are all in phase with each other / the phase difference between the waves is constant; ***[1]***

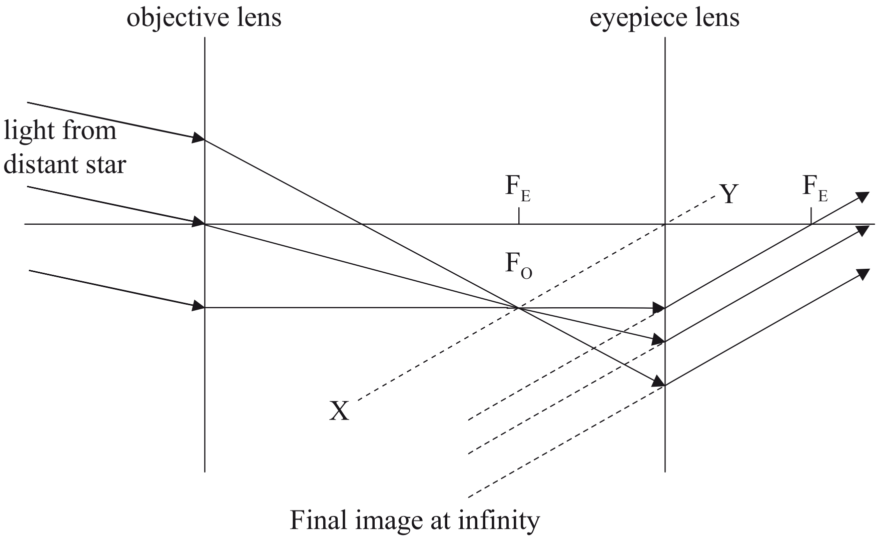
(b) (i) there are more electrons in the metastable state than in the ground state; ***[1]***

(ii) from excited state to metastable state; ***[1]***

(iii) from metastable state to ground state; ***[1]***

(iv) $\lambda = \left(\frac{hc}{eV} =\right)\frac{6.6\times10^{-34}\times3.0\times10^{8}}{1.8\times1.6\times10^{-19}} = 6.9\times10^{-7}\text{ m}$;
$=690\text{ nm}$ ***[1]***

G2. (a)



(i) same distance to left of eyepiece as F_E is to the right; *(judge by eye)* ***[1]***

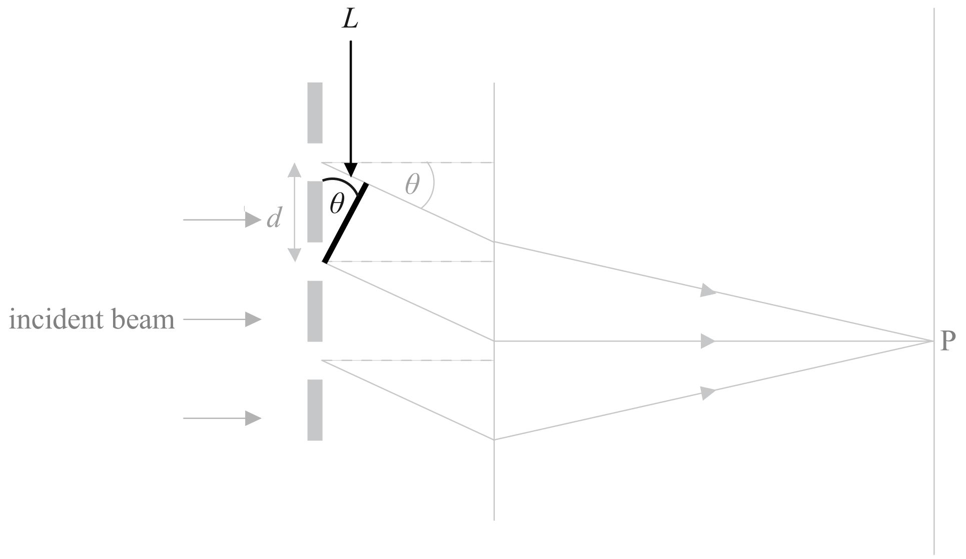
(ii) coincident with F_E as labelled in (a)(i); ***[1]***

(iii) three rays meeting at focal plane of the two lenses;
construction line XY;
rays refracted at eyepiece;
extrapolation to indicate final image at infinity with label; ***[3 max]***

(b) $f_e = \left(\frac{1}{40} =\right) 2.5\text{ cm}$ and $f_o = \left(\frac{1}{0.80} =\right) 125\text{ cm}$;
$M = \left(\frac{f_o}{f_e} =\right)\left(\frac{125}{2.5} =\right) 50$; ***[2]***

(c) *objective lens*: to eliminate/minimize chromatic aberration;
eyepiece lens: to eliminate/minimize spherical aberration; ***[2]***

G3. (a) (i)



appropriate line and labelling of L and θ; ***[1]***

(ii) for constructive interference path difference = $n\lambda$ where $n = 0, 1, 2$ *etc.*;
path difference between adjacent rays $= d\sin\theta = n\lambda$; ***[2]***

(b) $n = \left(\dfrac{d}{\lambda} =\right)\left(\dfrac{2.0\times10^{-6}}{5.2\times10^{-7}} =\right)3.85$;
so max $= 3$; ***[2]***