IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M05/4/PHYSI/HP3/ENG/TZ2/XX/M+

MARKSCHEME

May 2005

PHYSICS

Higher Level

Paper 3

17 pages

Subject Details: Physics HL Paper 3 Markscheme

General

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

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in (…) in the markscheme are not necessary to gain the mark.
- The order of points does not have to be as written (unless stated otherwise).
- If the candidate's answer has the same "meaning" or can be clearly interpreted as being the same as that in the markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalizing them for what they have not achieved or what they have got wrong.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded.
- Units should always be given where appropriate. Omission of units should only be penalized once. Ignore this, if marks for units are already specified in the markscheme.
- Deduct **1 mark in the paper** for gross sig dig error *i.e.* for an **error of 2 or more digits**.

e.g. if the answer is 1.63:

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

However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

Option D — Biomedical Physics

D1. (a) $\frac{M_A}{M_B} = \frac{R_A^{\ 3}}{R_B^{\ 3}}$; *[1]*

(b) $\frac{Q_A}{Q_B} = \frac{R_A^{\ 2}}{R_B^{\ 2}}$; *[1]*

(c) relative power loss / power per unit mass $P = \frac{Q}{M}$;

therefore, $\frac{P_A}{P_B} = \left(\frac{Q_A}{Q_B} \times \frac{M_B}{M_A}\right) = \frac{R_A^{\ 2} \times R_B^{\ 3}}{R_B^{\ 2} \times R_A^{\ 3}}$;

$= \frac{R_B}{R_A}$; *[3]*

(d) the answer to (c) suggests that the smaller the linear dimension then the greater is the relative power loss / *OWTTE*; *[1]*

D2. (a) *conductive*: vibrations/sound does not reach the inner ear;
sensory: the inner ear does not pass impulses to the brain; *[2]*

(b) intensity level in decibels $= 10\log_{10}\frac{I}{I_0}$ and $I_0 = 10^{-12}\ \mathrm{W\,m^{-2}}$;
where I is the measured intensity; *[2]*
*Allow **[1]** for "sound intensity in W m^{-2} is related to sound intensity level by a logarithmic scale" / OWTTE.*

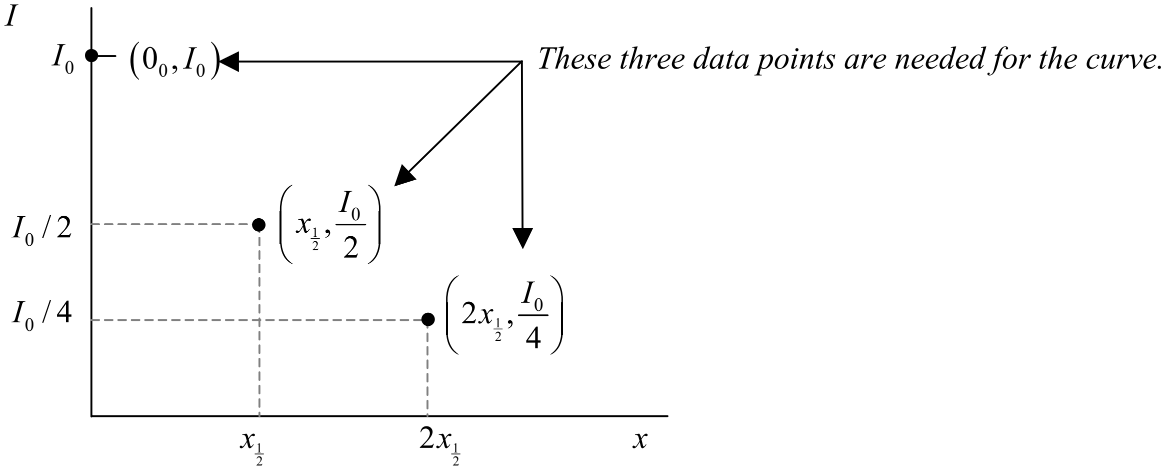
(c) *Frederick*:
conductive – the uniform loss with frequency suggests damage to the ear;
damage could be caused by ear infection, perforation of eardrum *etc.*;

Susanna:
sensory – the hearing loss is increasing with increasing frequency;
damage could be due to old age / continual exposure to excessive noise / disease; *[4]*
*Also accept could be conductive loss. Award **[0]** for just stating the correct loss.*

D3. (a) how penetrating different X-rays beams are through a material / reference to photon energy / reference to X-ray wavelength / reference to half-value thickness; ***[1]***

(b) the thickness of the material that reduces the initial intensity by half; ***[1]***

(c)



any reasonable looking curve;
showing at least two "half-thicknesses" to give exponential curve; ***[2]***

(d) correct position of $x_{\frac{1}{2}}$ on the graph; ***[1]***

(e) scattering / photoelectric effect / Compton effect / pair production; ***[1]***

D4. (a)

Mechanism	***% loss***
conduction and convection	*10*
radiation	*8*
evaporation;	*80*
respiration and/or excretion;	*2*

evaporation in correct place;
respiration and/or excretion in correct place; ***[2]***
*Award **[1 max]** for correct names in the wrong place.*

(b) energy lost in 1 hour $= 320 \times 3600 = 1.2 \times 10^6$ J ;

mass loss $= \dfrac{1.2 \times 10^6}{2.4 \times 10^6} = 0.50$ kg ; ***[2]***

D5. (a) a factor that compares (the effectiveness) of different types of radiation to that of X-rays;
some detail *e.g.* because different radiations (of the same intensity) produce different amounts of ionization / cause different amounts of damage; ***[2]***
Second marking point can be implied in first point.

(b) $D = 5 \times 10^{-4}\ \mathrm{J\,kg^{-1}}\ (Q = 1)$;

$E = m \times D = 70 \times 5 \times 10^{-4}$ J ;

1 photon has energy $200 \times 10^3 \times 1.6 \times 10^{-19}$ J ;

number of photons in 1 second $= \dfrac{70 \times 5 \times 10^{-4}}{200 \times 10^3 \times 1.6 \times 10^{-19} \times 120}$

$\approx 10^{10}$; ***[4]***

Option E — The History and Development of Physics

E1. (a) I: the stars are attached to the surface of a sphere;
that rotates about the Earth;

II: the moon is attached to a smaller sphere than that of the stars;
that rotates at a slower (different) rate; ***[4]***

(b) Copernicus suggested that the Earth rotates about the Sun / heliocentric model; ***[1]***

E2. (a) constant force produces constant speed / force proportional to speed / *OWTTE*; ***[1]***

(b) the force is proportional to the rate of change of speed/acceleration; ***[1]***

(c) *Look for these main points.*
since the stone is not accelerating the net force on it must be zero;
which means that a friction force, equal and opposite to the constant force is also acting on the block; ***[2]***

(d) *Aristotle*: used deduction / thought process;
Galileo: used experiments; ***[2]***

E3. (a) Hertz: unable to show that they were deflected by an electric field/magnetic field;
Thompson: able to measure the ratio of their charge to mass / was able to show that they were deflected by electric and magnetic fields; ***[2]***

(b) Thompson: electrons embedded in the nucleus/atom;
Rutherford: electrons orbit the nucleus; ***[2]***

(c) (i) Chadwick measured the thickness of aluminium;
that just absorbed / stopped the protons;
or
ionising effect;
some detail *e.g.* power / energy of ionisation; ***[2]***

(ii) by measuring the length of their (recoil) tracks / ionization effect; ***[1]***

(iii) conservation of energy;
conservation of momentum; ***[2]***

E4. (a) fine structure / relative intensity of the spectral lines; ***[1]***

(b) an electron only changes orbit if it emits or absorbs a photon/energy;
the energy (of the emitted or absorbed photon) is equal to the difference in the energies of the (permitted) orbits / *OWTTE*; ***[2]***

(c) substitute for *r* into $E_n = -\frac{ke^2}{2r}$ to get $E_n = -\frac{2\pi^2 \mathrm{m} k^2 e^4}{n^2 h^2}$;
therefore, $E_n = -\frac{K}{n^2}$;
where $K = -\frac{2\pi^2 \mathrm{m} k^2 e^4}{h^2}$; ***[3]***

(d) energy;
and is the amount required to remove an electron from the orbit $n = 1$ to $n = \infty$;
or
the total energy of the electron;
when $n = 1$ /in the ground state; ***[2]***

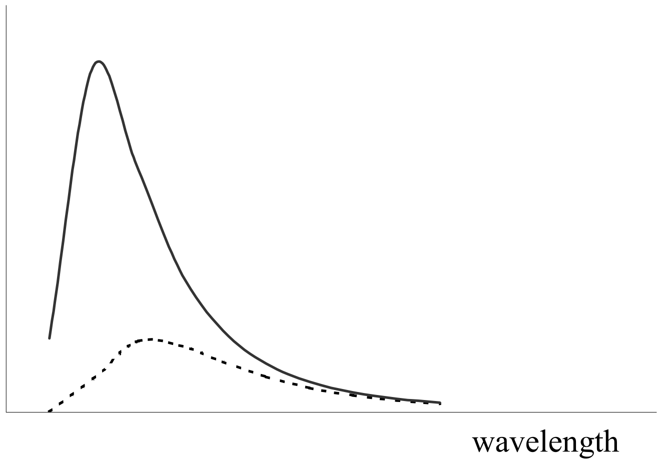
(e) the electrons are described by wave functions;
the wave functions can only have certain values because they have to fit boundary conditions / the wave functions behave like standing waves so can only have certain values / *OWTTE*; ***[2]***
*Be generous – award **[1]** for the idea of wave function and **[1]** for some other related physics.*

Option F — Astrophysics

F1. (a) the radiation emitted by a perfect emitter/perfect absorber/cavity / emits radiation in accordance with the Planck law; ***[1]***

(b) wavelength/λ; ***[1]***

(c) intensity



lower intensities;
maximum shifted to the longer wavelength; ***[2]***

(d) $T = \dfrac{2.90\times10^{-3}}{\lambda} = \dfrac{2.90\times10^{-3}}{9.70\times10^{-7}} = 3000\,K$; ***[1]***

(e) (i) the total radiant power of the star; ***[1]***

(ii) the (radiant) power (from the star);
incident per square metre of the Earth's surface; ***[2]***

(iii) $L = 4\pi d^2 b$;

therefore, $\dfrac{L_{sun}}{L_{bet}} = \dfrac{d_{sun}{}^2 b_{sun}}{d_{bet}{}^2 b_{bet}}$;

therefore, $d_{bet}{}^2 = \dfrac{L_{bet}}{L_{sun}}\dfrac{d_{sun}{}^2 b_{sun}}{b_{bet}} = \dfrac{4.1\times10^4\times(1)^2\times1370}{2.1\times10^{-8}}$;

to give $d_{bet} = 5.17\times10^7$ AU;

or

$L_{sun} = 4\pi\times1.37\times10^3\times(1\,\text{AU})^2$;

$L_{bet} = 4\pi\times2.10\times10^{-8}\times(d_{bet})^2$;

$= 4.10\times10^4\times4\pi\times1.37\times10^3\times(1\,\text{AU})^2$;

to give $d_{bet} = 5.17\times10^7$ AU; ***[4]***

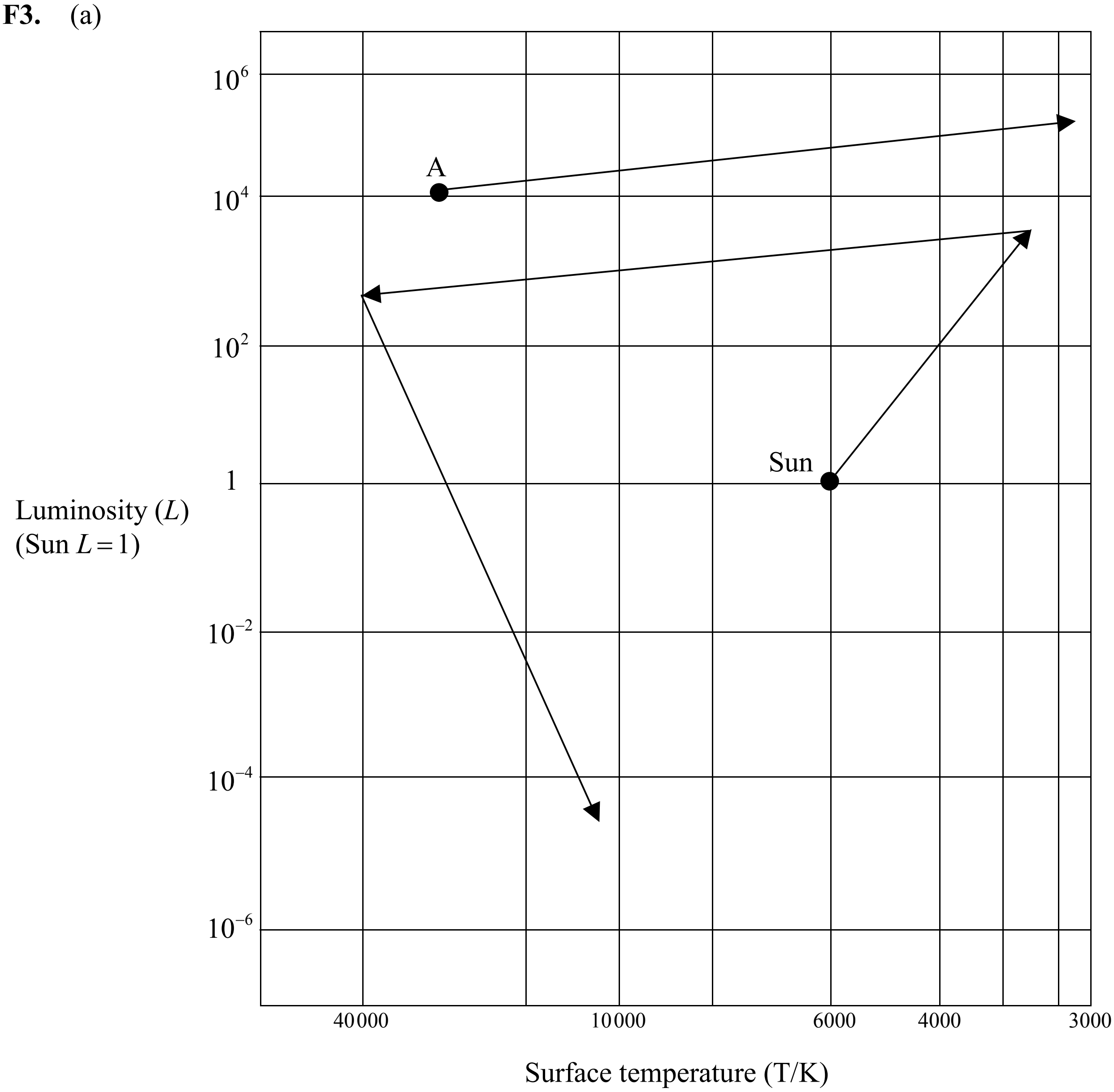
F2. (a) the universe is infinite in extent;
the stars are uniformly distributed; ***[2]***

(b) *Look for these points.*
if the stars are uniformly distributed the number of stars shining their light on the Earth increases with the square of the distance from the Earth / *OWTTE*;
so number of stars is proportional to R^2;
but the intensity of illumination varies as $\frac{1}{R^2}$;
therefore, everywhere in the universe would be equally bright;

*Allow **[2]** for the following argument.*
if universe is infinite and static;
every line of sight will end on a star so night sky is bright; ***[4]***

(c) light from distant galaxies is red-shifted;
(from the Doppler effect) this suggests the universe is expanding / galaxies are moving away from each other; ***[2]***

F3. (a)



Sun: to region of red giants approx luminosity $10 \rightarrow 10^3$, temperature $3000 \rightarrow 4000$;
luminosity stays reasonably constant as temperature increases;
Accept horizontal straight-line.
then to region of white dwarfs approx luminosity $10^{-2} \rightarrow 10^{-5}$, temperature $10\,000 \rightarrow 30\,000$;

Star A: to super red giant region approx luminosity $10^3 \rightarrow 10^5$, temperature $3000 \rightarrow 4000$; ***[4]***

Note*: None of the lines need be straight.*

(b) *Look for these main points.*
the Sun ends up as a white dwarf;
the Chandrasekhar limit fixes the maximum mass of a white dwarf as $1.4\,M_{sun}$;
during the red giant and planetary nebula phases of evolution;
the star can eject up to 80-90 % of its original mass; ***[4]***

(c) hydrogen fusion is replaced/followed by helium fusion;
helium fusion is replaced/followed by carbon/oxygen/neon/sodium/silicon/sulphur fusion; ***[2]***

Option G — Relativity

G1. (a) *Award **[2]** for good understanding and **[1 max]** for some understanding.*
a means by which the position of an object can be located / *OWTTE*;
some detail *e.g.* reference to origin/axes; ***[2]***
Answers will be open-ended.

(b) $c - v$; ***[1]***

(c) c; ***[1]***

(d) $u' = \dfrac{u - v}{1 - \dfrac{uv}{c^2}}$;

substitute $u = c$ to get $u' = \dfrac{c - v}{1 - \dfrac{cv}{c^2}}$;

$= \dfrac{c - v}{1 - \dfrac{v}{c}} = \dfrac{c(c - v)}{c - v} = c$; ***[3]***

Accept answers using $+$ *instead of* $-$.
*Award **[1]** for recognition of correct formula to use and **[1]** for correct substitution and **[1]** for at least some arithmetic.*

(e) (i) time interval of an event that is observed to happen at the same place / *OWTTE*; ***[1]***

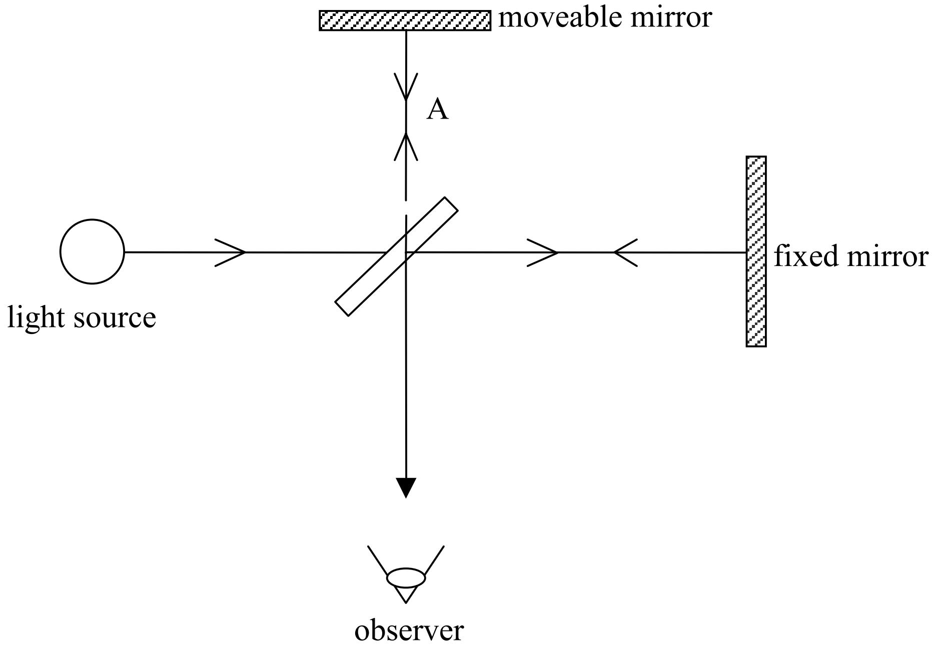
(ii) $\gamma = 2.0$;

$2.0 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$;

arithmetic to give $v = 0.87\,\text{c}$; ***[3]***

G2. (a) to measure the speed of the Earth through the ether / to search for an absolute frame of reference / *OWTTE*; ***[1]***

(b)



line and arrows to show reflection from the moveable mirror;
line and arrows to show reflection from the fixed mirror;
ray from A to observer; ***[3]***

(c) light from the two mirrors will (should) now take different times to reach the observer / *OWTTE*;
hence there will be a shift in the interference pattern; ***[2]***

(d) by moving the mirror (backwards or forwards), any shift in the pattern can be measured / *OWTTE*; ***[1]***

(e) no shift in interference pattern observed;
supports the idea that the speed of light does not depend on the speed of the source/speed of observer/that there is no absolute reference system; ***[2]***

G3. (a) $mc^2 = m_0c^2 + Ve$;
therefore, $\gamma m_0c^2 = m_0c^2 + Ve$;
therefore, $\gamma = 1 + \frac{Ve}{m_0c^2}$; ***[3]***

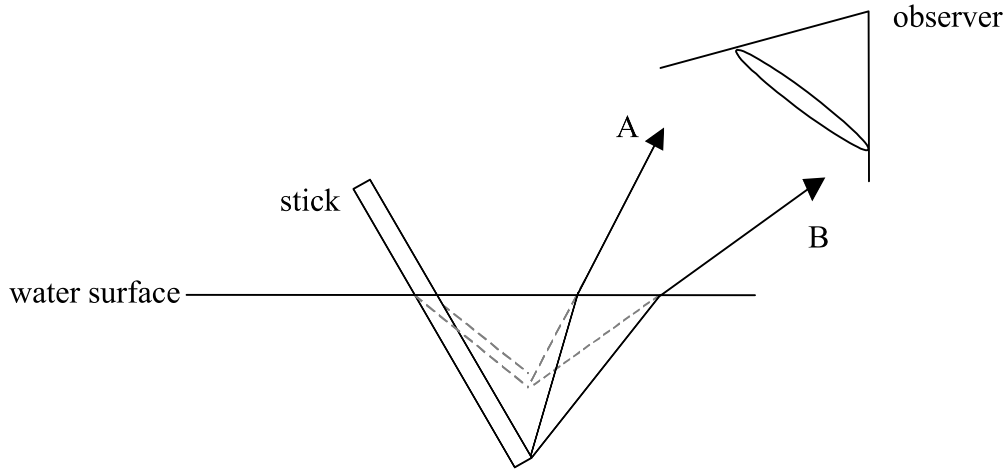
(b) $\gamma = 1 + \frac{500}{938} = 1.53$;
substitute into $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ to give $v = 0.76c$; ***[2]***

G4. (a) since the speed of light is independent of the speed of the source;
Alex's source will appear to be moving away from Elspeth;
so according to the Doppler effect the light will appear to be redshifted; ***[3]***

(b) because of the principle of equivalence;
the situation is the same as if Elspeth were observing light emitted from the surface of a planet / *OWTTE*; ***[2]***

Option H — Optics

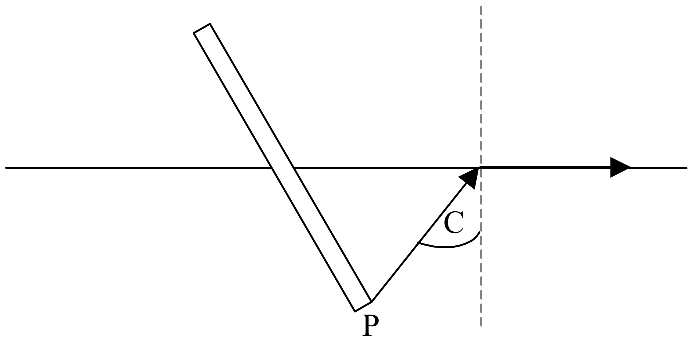
H1. (a) (i)



correct ray A;
correct ray B; ***[2]***

(ii) (rays extrapolated back to show) where stick will appear to be; ***[1]***

(b)



correct path of ray;
correct C; ***[2]***

(c) $\sin\phi_c = \frac{1}{n}$;

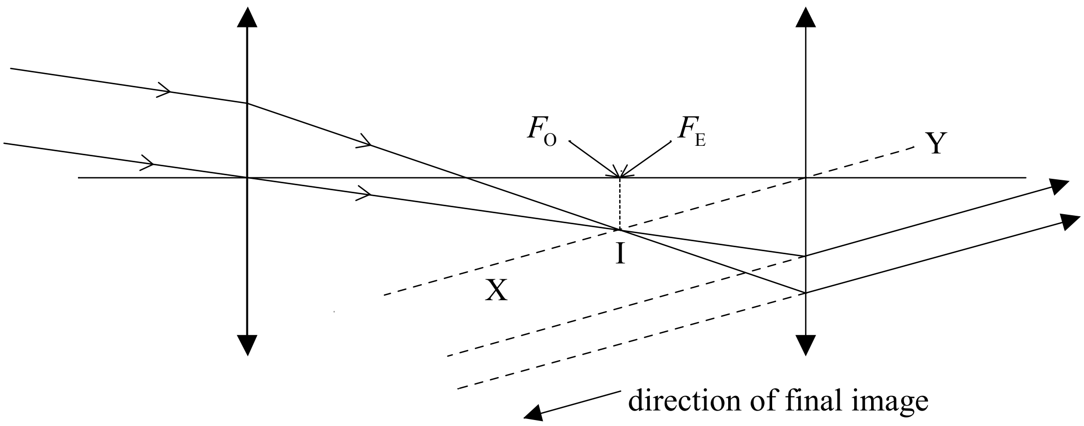
to give $\phi_c = 50^0$;

$\tan 50 = \frac{r}{2.0}$;

to give $r = 2.4\,\text{m}$; ***[4]***

H2. (a) that point (on the principal axes) to which rays parallel to the principal axis; are brought to a focus after refraction at the lens / *OWTTE*; ***[2]***

(b)



(i) at F_O / other side of eyepiece; *(judge by eye)* ***[1]***

(ii) as shown on diagram; ***[1]***

(c) at infinity; ***[1]***

(d) two rays parallel to XY; *(judge by eye)*
extrapolated to show direction of final image; ***[2]***

(e) object distance $u = f_O + f_e = 100\,\text{cm}$;

$\frac{1}{v} + \frac{1}{100} = \frac{1}{f_e} = \frac{1}{2}$;

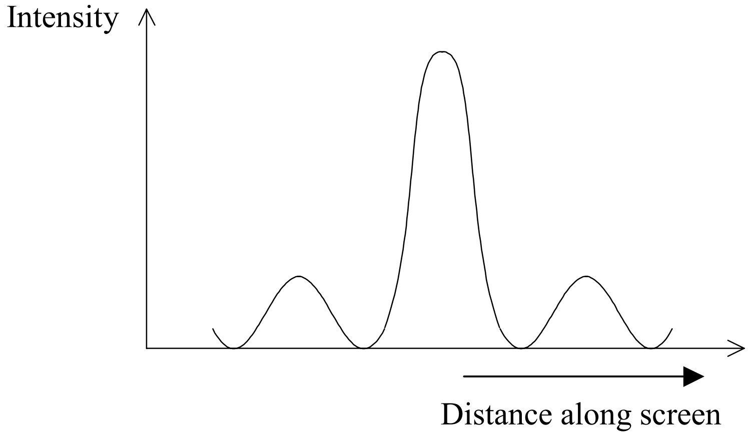
$\frac{1}{v} = \frac{1}{2} - \frac{1}{100}$ to give $v = 2.04\,\text{cm}$;

beyond eyepiece lens / between eyepiece lens and eye;

or

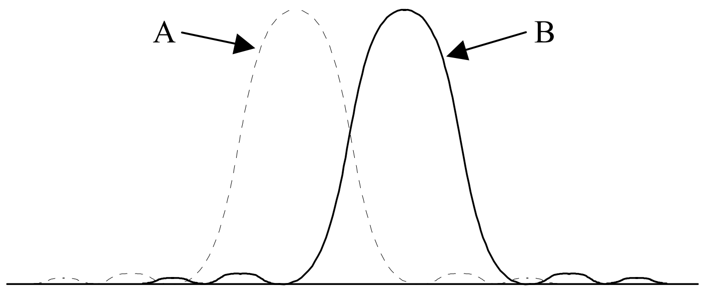
scale drawing:
suitable scale;
object distance;
rays to locate image;
image distance 2 cm beyond eyepiece lens; ***[4 max]***

H3. (a)



general shape;
relative position of secondary maxima / relative heights of secondary maxima; ***[2]***
*Award **[1 max]** if not touching x-axis.*

(b)



maximum of B coincides with first minimum of A; ***[1]***

(c) $\theta = \frac{1.2\lambda}{b} = \frac{1.2 \times 5 \times 10^{-7}}{25 \times 10^{-2}} = 2.4 \times 10^{-6}$ rad;
$= \frac{x}{8.1 \times 10^{16}}$;
to give $x = 2.0 \times 10^{11}$ m; ***[3]***
*1.6×10^{11} m if 1.2 not used, award **[2 max]**.*

H4. (a) same number of maxima at the same place but much sharper;
greater intensity than double slit / presence of small maxima in between maxima; ***[2]***

(b) $\sin\theta = \frac{\lambda}{d}$;
$= 0.36$ to give $\theta = 21^0$; ***[2]***