IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

MARKSCHEME

May 2005

PHYSICS

Standard Level

Paper 3

20 pages

Subject Details: Physics SL 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 mark scheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalising them for what they have not achieved or what they have got wrong.
- Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
- 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. Indicate this with **"ECF"**, error carried forward.
- Units should always be given where appropriate. Omission of units should only be penalized once. Indicate this by **"U-1"** at the first point it occurs. 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**.

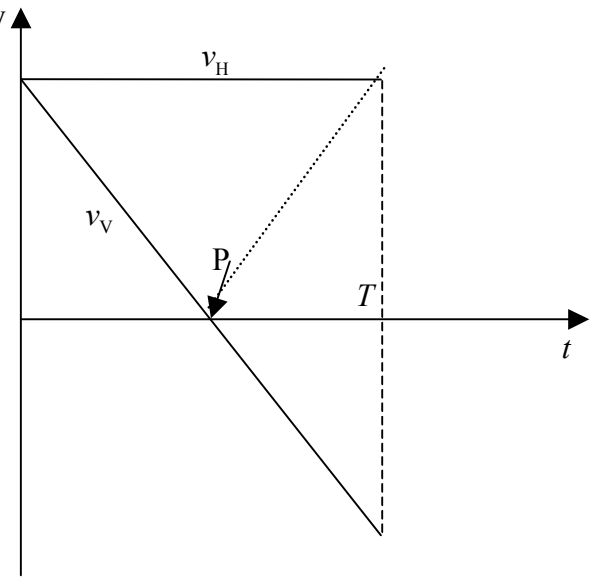
e.g. if the answer is 1.63:

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

Indicate the mark deduction by **"SD-1"**. 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 A — Mechanics Extension

A1. (a)



v_V and v_H start from the same point;
correct v_V;
correct v_H;
both ending at $t = T$; ***[4]***
Award full marks if they use the magnitude of v_v (to P and then dotted line).

(b) correct position of P; ***[1]***

(c) the vertical speed will be greater;
so more of the initial KE is used to overcome gravity / more KE converted to PE; ***[2]***

A2. (a) the force exerted per unit mass;
on a point / small mass; ***[2]***

(b) (i) use of $g = \frac{F}{m}$ and $F = G\frac{Mm}{R^2}$;
combine to get $g = G\frac{M}{R^2}$; ***[2]***

(ii) $M = \frac{gR^2}{G}$;
substitute to get $M = 1.9 \times 10^{27}$ kg; ***[2]***

A3. (a) the net force (acting on the body) is zero;
the net couple / torque (acting on the body) is zero; ***[2]***

(b) by taking moments about P / using the principle of moments;
$wa + Wb = 10c$; ***[2]***

(c) new condition for equilibrium is $(w + X)a + Wb = 10(c + 2.4a)$;
subtract $wa + Wb = 10c$ from this to give $Xa = 24a$;
to get $X = 24\,\text{N}$; ***[3]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) A negative (–) B positive (+); ***[1]***

(b) *Answers will be opened ended but look for these main points.*
light consists of photons;
each photon has energy *hf*;
a certain amount of energy is required to eject an electron from a metal;
if *hf* is less than this energy, then no electrons will be emitted;
and so no current will be registered by the microammeter; ***[4 max]***

(c) (i) intercept of f axis $= 4.6\times10^{14}$ Hz ; ***[1]***

(ii) intercept on V_s axis;
$= 2.0(\pm0.2)$ eV ;
or
slope of graph $= 4.2\times10^{-15} = \frac{h}{e}$ to give $h = 4.2\times10^{-15}$ eV s ;
$W = hf_0 = 4.6\times10^{14}\times4.2\times10^{-15} = 1.9\,(\pm0.2)$ eV ; ***[2]***

B2. (a) $^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + \beta^+(e^+) + v$
β^+ / e^+ ;
v; ***[2 max]***

(b) $8.2\times10^{-6}\,g$; ***[1]***

(c) (i) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$;
$= \frac{0.69}{1.3\times10^9} = 5.3\times10^{-10}$ year^{-1} ; ***[2]***

(ii) from $N = N_0e^{-\lambda t}$ $\qquad t = \frac{1}{\lambda}\ln\left(\frac{N_0}{N}\right)$;
$= 1.9\times10^9\times\ln(6.8) = 3.6\times10^9$ years ;
or
$\frac{1.2}{8.2} = \left(\frac{1}{2}\right)^n$
$n = 2.77$;
age $= 2.77\times1.3\times10^9 = 3.6\times10^9$ years ; ***[2]***

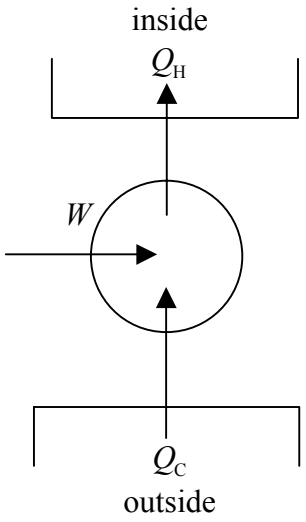
B3. (a) (i) colour force / weak force; ***[1]***

(ii) gluon / charged vector boson / W boson; ***[1]***

(b) in the interaction $\bar{v} + p = n + e^+$ charge, lepton number and baryon number are conserved / all conservation laws are conserved;
in the interaction $v + p = n + e^+$ charge and baryon number are conserved / all conservation laws except lepton number are conserved;
lepton number, +1 on the left –1 on the right; ***[3 max]***
Essentially look for some detail of the conservation laws and some substantiation of the violation of lepton number to achieve ***[3 max]****.*

Option C — Energy Extension

C1. (a)



correct direction of Q_H;
correct direction of Q_C;
correct direction of W; ***[3]***

(b) $Eff = \frac{Q_H - Q_C}{Q_H} = \frac{W}{Q_H}$;

therefore, $\frac{1}{4} = \frac{1.0}{Q_H}$ so $Q_H = 4.0\,\text{kW}$; ***[2]***

(c) (i) a process in which there is no energy / heat exchange;
between system and surrounding;
or
all the work done;
either increases or decreases the internal energy of the system; ***[2]***

(ii) a process that takes place at constant temperature and pressure; ***[1]***

(d) $\text{A} \rightarrow \text{B}$;
expansion at constant temperature so substance is doing work;
in order that temperature remain constant, energy must be absorbed / *OWTTE*; ***[3]***

C2. (a) $\text{power} = \frac{\text{energy}}{\text{time}} = \frac{120 \times 10^{12}}{60 \times 60 \times 24 \times 365}$;

$= 3.8 \times 10^{6}\, W$;

therefore, for one turbine $= 0.19\,\text{MW}$; ***[3]***

(b) using $p = \frac{1}{2}\rho A v^3$, $A = \frac{2p}{\rho v^3}$;

therefore, $A = \frac{2 \times 1.9 \times 10^5}{1.2 \times 9.0^3} = 4.3 \times 10^2\,\text{m}^2$;

use $A = \pi r^2$ to give $r = 12\,\text{m}$; ***[3]***

(c) the wind speed varies over the year / not all the wind energy will be transferred into mechanical power / energy loss due to friction in the turbine / energy loss in converting to electrical energy / density of air varies with temperature; ***[1]***

Do not accept something like "turbines are not 100 % efficient".

(d) take up so much room;
that not possible to produce enough energy to meet a country's requirements;

noisy;
and this could have an effect on local fauna;
OWTTE; ***[2 max]***

*Award **[1]** for statement of disadvantage and **[1]** for some justification of statement.*

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 $I_0 = 10^{-12}\ \text{W m}^{-2}$;

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.*

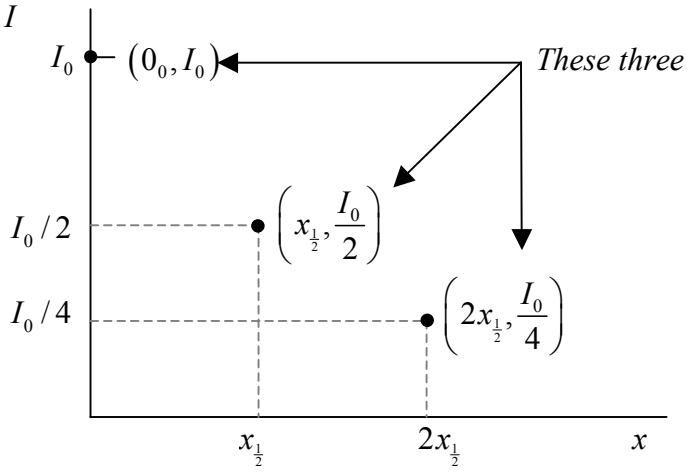
(c) *Frederick*:
conductive – the uniform loss with frequency suggests damage to the ear;
damage could be caused by ear infection, perforation of eardrum *etc*.;

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]***

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]***

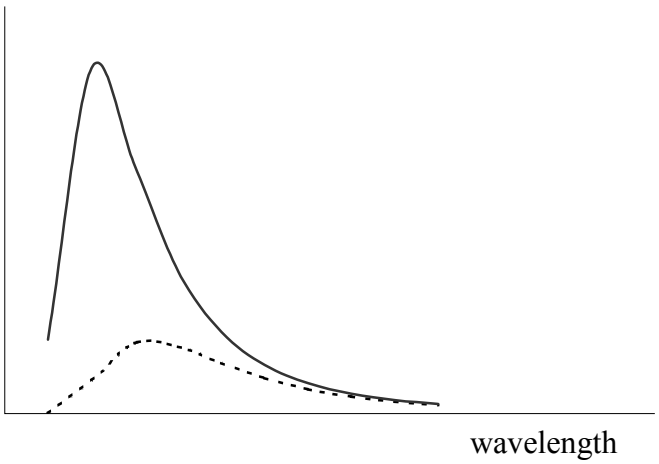
(iii) conservation of energy;
conservation of momentum; ***[2]***

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) $T = \frac{2.90\times10^{-3}}{\lambda} = \frac{2.90\times10^{-3}}{9.70\times10^{-7}} = 3000\,K$; ***[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, $\frac{L_{sun}}{L_{bet}} = \frac{{d_{sun}}^2 b_{sun}}{{d_{bet}}^2 b_{bet}}$;

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

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]***

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 max]***

(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]***

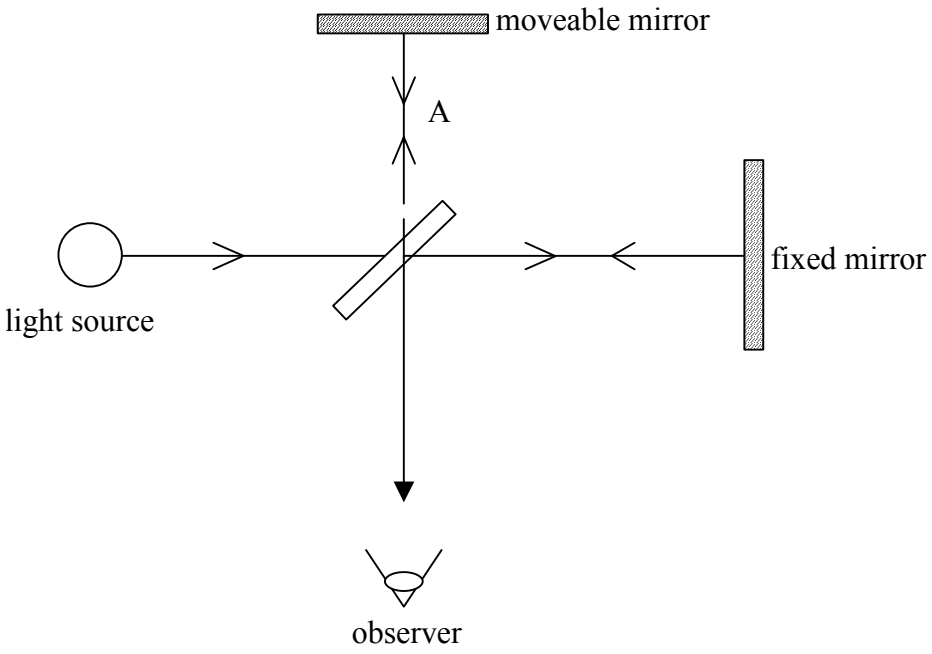
(ii) $\gamma = 2.0$;

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

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

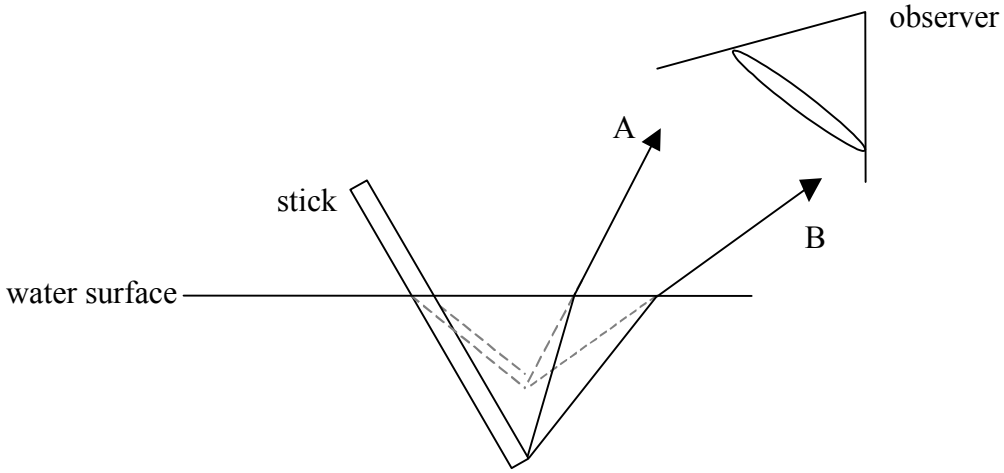
(c) light from the two mirrors will (should) now take different times to reach the observer / *OWTTE*;
hence there will be a shift in the interference pattern; ***[2]***

(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]***

Option H — Optics

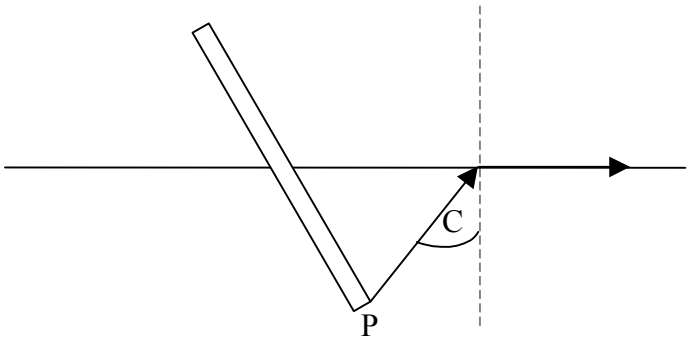
H1. (a) (i)



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

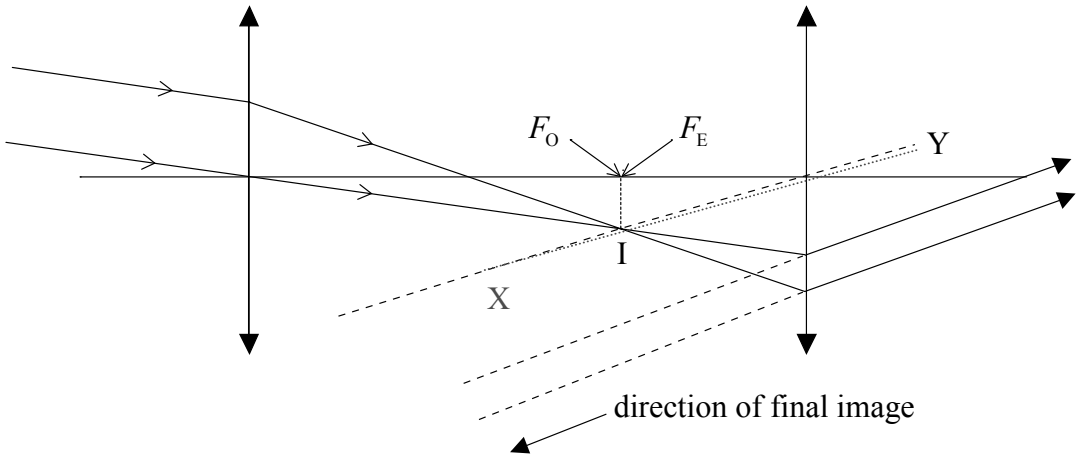
to give $\phi_c = 50^0$;

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

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 max]***

(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]***