INTERNATIONAL BACCALAUREATE
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MARKSCHEME

May 2001

PHYSICS

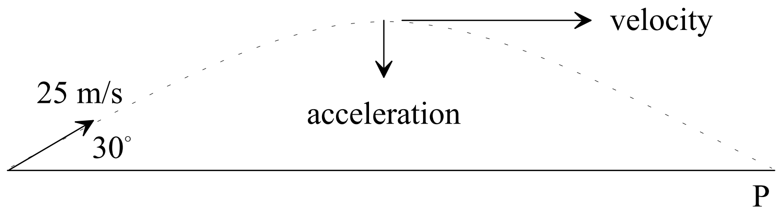
Standard Level

Paper 3

23 pages

OPTION A – MECHANICS EXTENSION

A1. (a)



(i) as diagram; ***[1 max]***

(ii) as diagram; ***[1 max]***

(b) $v \cos 30 = 22 \text{ m s}^{-1}$; ***[1 max]***

(c) 22 m s^{-1}; ***[1 max]***

(d) time to reach maximum height $= \dfrac{v \sin 30}{g} = 1.25$ s; ***[1]***

time to get to P = 2.5 s; ***[1]***

therefore range $= 2.5 \times 22 = 55$ m; ***[1]***

[3 max]

A2. (a) 3.0 N s **[1 max]**

(b)

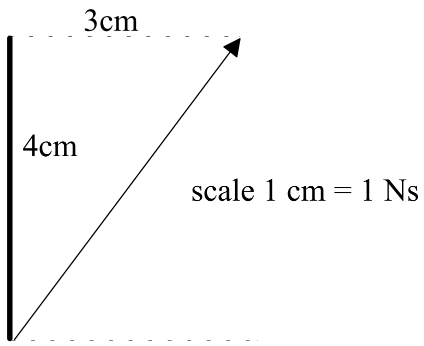


Diagram 2

completion of the scale drawing (bold line); ***[1]***
correct measurement; ***[1]***
to give 4.0 N s; ***[1]***
[3 max]

(c) (i) at 53° to the horizontal; ***[1]***
accept anything that describes the direction as being in the direction of the vector in diagram 2 in the question;
something that suggests that it must be in this direction since the total momentum remains constant (momentum is conserved); ***[1]***
[2 max]

(ii) momentum of A = 5.0 N s; ***[1]***
therefore speed of A is 1.25 *(1.3)* m s^{-1}; ***[1]***
[2 max]

A3. (a) $\frac{mv^2}{r} = \frac{GMm}{r^2}$; ***[1]***

so $v^2 \propto \frac{1}{r}$; ***[1]***

appropriate algebra to show $v_A = v_B \sqrt{2}$; ***[1]***
[3 max]

(b) 2R ***[1]***
more work must be done against the gravitational field of the Earth to put satellite B into orbit / OWTTE; ***[1]***
(Allow **[1]** for *satellite B* even if explanation is wrong;)
(Accept an explanation in terms of $V = \frac{-GM}{R}$*)*
[2 max]

OPTION B – ATOMIC AND NUCLEAR PHYSICS EXTENSION

B1. (a) accept

either: the energy released when the nuclide is assembled from its individual components;

or: the energy required when the nucleus is separated into its individual components; ***[max 1]***

(b) $2 \times$ proton mass = 2.01564 u; ***[1]***
$2 \times$ neutron mass = 2.01734 u; ***[1]***
add these (= 4.03298 u) subtract helium mass to get defect = 0.03038 u; ***[1]***
divide by 4 and multiply by 930 MeV = 7.06 MeV; ***[1]***
[4 max]

(c) (i) *any* ***two*** *of the following*
much higher energy yield per reaction;
negligible (or no) radioactive waste;
hydrogen much more abundant that fissionable elements; ***[2 max]***

(ii) fission is initiated by neutron bombardment so no Coulomb repulsion to overcome; ***[1]***
very high temperatures needed to overcome Coulomb repulsion in order to initiate fusion; ***[1]***

look for an answer that shows an understanding that fusion involves bringing nuclei into contact and so a repulsive force has to be overcome so the nuclei must have a large KE i.e. high temperature; ***[2 max]***

B2. (a) electrons make glancing collisions with lattice atoms; ***[1]***
and lose their energy gradually; ***[1]***
each time they lose energy a photon is emitted whose wavelength is dependent on the energy lost in each collision; ***[1]***

*the general idea that energy is lost gradually so a whole spread of wavelengths is possible should be here for **[3]**. They might mention 'braking radiation' which is fine if they give a bit of detail;*

[3 max]

(b) (i) from the graph $\lambda_{\min} = 5 \times 10^{-11}$ m; ***[1]***

$V = \dfrac{hc}{e\lambda_{\min}}$; ***[1]***

correct substitution to give $V = 25$ kV; ***[1]***

[3 max]

(ii) from the graph λ for the K_α line $= 7.5 \times 10^{-11}$ m; ***[1]***

$eV = \dfrac{hc}{\lambda}$; ***[1]***

to give 2.6×10^{-15} J; ***[1]***

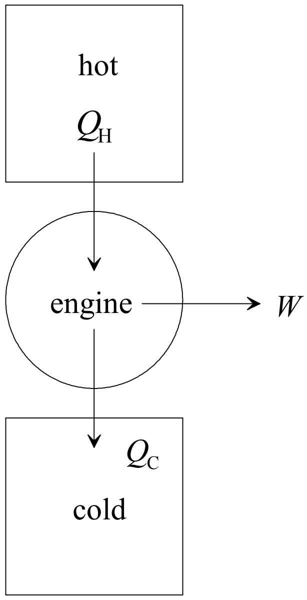
[3 max]

(c) *sketch should show*
smaller maximum intensity and no characteristic spectrum; ***[1]***
$\lambda_{\min} = 10 \times 10^{-11}$ m; ***[1]***

[2 max]

OPTION C – ENERGY EXTENSION

C1. (a) (i) three correct; *[2]*
two correct; *[1]*
*i.e. if Q_H goes the wrong way and so does W then **[0 marks]**;*
[2 max]



(ii) $W = Q_H - Q_C$; ***[1 max]***

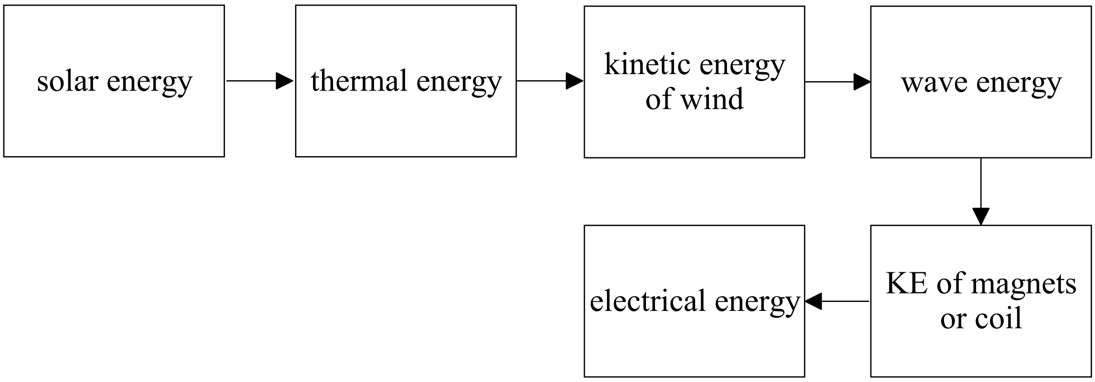
(iii) the first law of thermodynamics; ***[1 max]***
accept 'conservation of energy';

(b) (i) recognise as $\frac{ms\Delta\theta}{\Delta t}$; ***[1]***
$= 0.05 \times 5 \times 4200 = 1050$ W; ***[1]***
allow 1 SD (1000 W) ***[2 max]***

(ii) recognise as $W = Q_H - Q_C$; ***[1]***
$= 3000 - 1050 = 1950$ W; ***[1]***
efficiency $= \frac{1950}{3000} = 0.65$; ***[1]***
[3 max]

(c) the maximum theoretical efficiency is given by $1 - \frac{T_C}{T_H}$; ***[1]***
in winter T_C is smaller therefore efficiency is larger; ***[1]***
[2 max]

C2.



*award **[1]** for each correct form in the correct position;* ***[4 max]***

C3. (a) semiconductors; ***[1 max]***

(b) electrons need energy to transfer to the conduction band;
(or *to be released for conduction* or *just to be released*); ***[1]***
this energy is supplied by the photons in the incident radiation and each photon has energy *hf*; ***[1]***
so *hf* has to be equal to or be greater than the energy required to move the electrons to the conduction band *(or to release the electrons);* ***[1]***
i.e. the three points to look for are:
electrons need energy;
energy supplied by photons of energy hf;
so hf has to be greater than or equal to energy needed to release electrons / OWTTE;
[3 max]

(c) look for something along the lines of charging batteries or heating up a concrete block (storage heater) *i.e.* some means of storing the electrical energy either as electrical or thermal energy. Something like *the electricity can be stored* would not be worth any marks. They must suggest how it is stored; ***[1 max]***

OPTION D – BIOMEDICAL PHYSICS

D1. (a) systolic: maximum blood pressure produced by a heartbeat; ***[1]***
diastolic: the pressure when the heart relaxes between beats; ***[1]***
*(award **[1]** for just maximum and minimum. For **[2]** some reference should be made to the heart beating. Something like 'the pressure of the blood leaving the heart and the pressure of the blood returning to the heart' would be OK;)*
[2 max]

(b) recognise that $p = \rho g h$; ***[1]***
correct substitution to give 1.1×10^4 Pa; ***[1]***
[2 max]

(c) the upper arm is at nearly the same level as the heart; ***[1]***
hence hydrostatic pressure will not effect the reading; ***[1]***
i.e. the reading will be equal to that of the pressure at the heart;
[2 max]

(d) estimated height of aorta above the ankle = 1.2 m (allow 1 m to 1.6 m); ***[1]***
hydrostatic pressure difference $\Delta p = 1000 \times 10 \times 1.2$ Pa = 90 mm of Hg; ***[1]***
pressure reading at ankle = 90 + 140 = 230 mm of Hg (138 to 254); ***[1]***
answer in kPa acceptable = 32 kPa (19 to 35);
assumptions: ignore any pressure drops due to fluid flow resistance; ***[1]***
assume blood has same density as water; ***[1]***
[4 max]

D2. (a) energy loss is proportional to surface area; ***[1]***
mass is proportional to volume; ***[1]***

$$\frac{M_{toby}}{M_{susie}} = \frac{7}{5} = \frac{\left(1_{toby}\right)^3}{\left(1_{susie}\right)^3};$$ ***[1]***

$$\frac{1_{toby}^{\;2}}{1_{susie}^{\;2}} = \left(\frac{7}{5}\right)^{\frac{2}{3}} = 1.25;$$ ***[1]***

*(accept Susie to Toby = 0.8 but deduct **[1]** if this is not made clear;)*
[4 max]

(b) *any sensible assumption;*
e.g. same build *i.e.* same overall shape, identical clothing ***[1 max]***

D3. (a) use $\beta = 10 \log \dfrac{I}{10^{-12}}$ to show that 10^{-8} W m^{-2} = 40 dB; ***[1]***

from the graph frequency range = 50 → 10 000 (±1 000)Hz; ***[1]***

[2 max]

(b) minimum of the graph at about 1 500 Hz (±500)Hz; ***[1 max]***

(c) 200 Hz is at about 10 dB, 10 000 at 40 dB; ***[1]***

$40\ \text{dB} = 10^{-8}\ \text{W m}^{-2},\ 10\ \text{dB} = 10^{-11}\ \text{W m}^{-2}$

therefore 200 Hz must be 1 000× less intense; ***[1]***

*(allow **[1]** if answer is 4×)*

[2 max]

OPTION E – HISTORICAL PHYSICS

E1. (a)

Aspect of the observations	*Aristotle's view*	*Galileo's view*
The time for books of different mass to reach the ground when dropped from the same height.	heavier objects reach the ground first *(or fall faster);*	all objects will reach the ground at the same time;
The relationship between a constant force applied to a book and the velocity of the book.	a constant force produces constant velocity;	a constant force produces a constant acceleration (constant changing velocity);

[1]** for each correct answer;* ***[4 max]

(b) Aristotle just assumed *(or reached his conclusion by thinking)* whereas Galileo carried out measurements *(or verified his views experimentally or by observation)*; ***[1 max]***

(c) Newton proposed that the rate of change of momentum of the book is equal to the force *(accept Force = mass $\times$ acceleration);* ***[1 max]***

E2. (a) Tycho Brahe; ***[1 max]***

(b) because the planets actually have elliptical orbits; ***[1 max]***

(c) recognise that the orbital period of the Earth is 1 year; ***[1]***
use Kepler's 3rd law $T^2 \propto R^3$; ***[1]***
to give 5.2 years; ***[1]***
[3 max]

(d) (i) that the force acts along a line joining the centre of the planets; ***[1 max]***

(ii) that the planet acts as a particle; ***[1]***
equal in mass to the planet; ***[1]***
or something to the effect that the mass of the planet acts as though it were concentrated at the centre of the planet;
[2 max]

(iii) use $\frac{mv^2}{R} = \frac{GMm}{R^2}$; ***[1]***

to give $\frac{T^2}{R^3} = \frac{4\pi^2}{GM}$; ***[1]***

from which $M = \frac{4\pi^2 R^3}{T^2 G}$; ***[1]***

correct substitution to get $M \approx 3\times10^{30}$ kg; ***[1]***
[4 max]

(iv) look for an answer along the lines that if the position and velocity of all the particles in a system are known at some instant then it is possible to predict all future configurations of the system;

they will probably quote the universe as the system and that is fine. Use your discretion - if they have got the idea then award ***[2]****;*
[2 max]

OPTION F – ASTROPHYSICS

F1. (a)

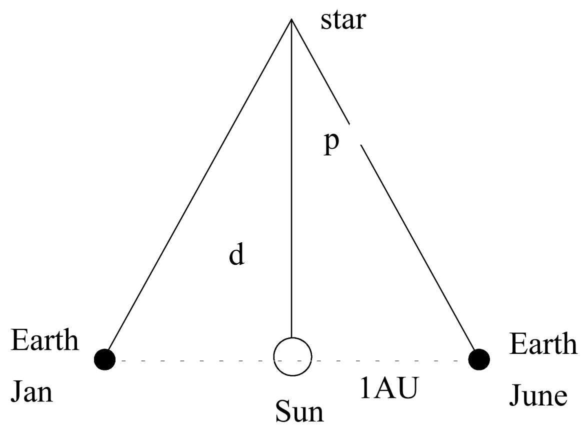


diagram:
position of Sun and star; ***[1]***
1 AU; ***[1]***
Earth in two positions separated by 6 months; ***[1]***

description:
measure angular position of star at two positions separated by 6 months; ***[1]***
to find angle p; ***[1]***
$d = \frac{1}{p}$; ***[1]***

[max 6]

although the scheme shows a split of ***[3]*** + ***[3]*** *between diagram and explanation do not be too rigorous about this - essentially look for a good description of parallax bearing in mind the points mentioned in the scheme;*

(b) (i) Sirius has a shorter wavelength maximum; ***[1]***
and is therefore hotter than the Sun; ***[1]***
[2 max]

(ii) use $\frac{\lambda_{sun}}{\lambda_{sirius}} = \frac{T_{sirius}}{T_{sun}}$ or $\lambda_{\max} = \frac{2.9 \times 10^{-3}}{T}$; ***[1]***

($\lambda_{\text{sun}} = 480$ nm, $\lambda_{\text{sirius}} = 280$ nm);

to give $T_{sirius} = 10\,000$ K (± 500 K); ***[1]***
[2 max]

(c) distance $= 2.64 \times 2.1 \times 10^5 = 5.5 \times 10^5$ AU; ***[max 1]***

(d) use $L = 4\pi d^2 b$; ***[1]***

to give $\dfrac{L_{sun}}{L_{sirius}} = \dfrac{d_{sun}{}^2 b_{sun}}{d_{sirius}{}^2 b_{sirius}}$; ***[2]***

to give $L_{sirius} = 3.1 \times 10^3 L_{sun}$; ***[1]***

(i.e. ***[3]*** *for sorting out the right equation to use and transforming it appropriately and* ***[1]*** *for the arithmetic;)*

[4 max]

(e) accept *either* radius *or* surface area (*or* size); ***[1 max]***

(f) *any two (****[1]*** *for each) sensible differences e.g.* White dwarf;
has smaller radius;
more dense;
higher surface temperature;
energy not produced by nuclear fusion;

[2 max]

(g) (i) the two stars can actually be observed as single, separate stars; ***[1 max]***
(any simple answer like this will suffice that shows that the candidates realise that the two stars can actually be observed;)

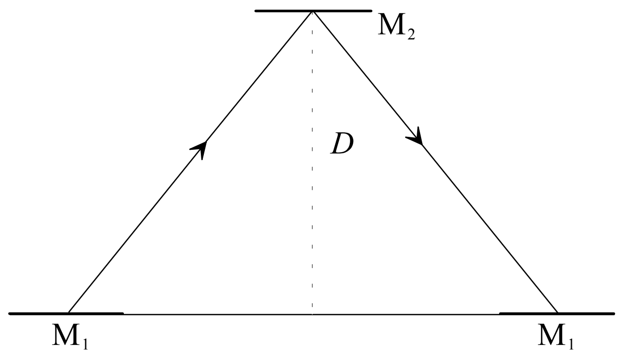
(ii) the orbital period of the two stars (or just period of orbit will do); ***[1 max]***

OPTION G – SPECIAL AND GENERAL RELATIVITY

Gl. (a) (i) a reference frame that is moving with constant velocity;
(or uniform speed in a straight line); ***[1 max]***

(ii) all inertial observers; ***[1]***
will measure the same value for the speed of light; ***[1]***
*(i.e. only **[1]** if inertial observers are not mentioned)*;
[2 max]

(b) (i)



correct position of D; ***[1]***
correct shape; ***[1]***
(note that M_1 and M_2 need not be shown)
[2 max]

(ii) *look for an answer along these lines:*
if they measure the same time then Jane will measure a different value for c; ***[1]***
and this violates the given postulate of special theory; ***[1]***
(i.e. both observers must measure the same value for c)
or
if the given postulate of special theory is correct *(i.e. both observers must measure the same value for c);* ***[1]***
the time as measured by Jane must be greater than that measured by Peter; ***[1]***
(answers can refer to the postulate given in answer to (a) (i) and need not be restated)
[2 max]

(c) $\gamma = 2.3$; ***[1]***
therefore 2.3 revolutions; ***[1]***
[2 max]

(d) (i) *look for an answer that mentions the following points:*
their short half-life means that most of them should decay before reaching the surface of the Earth; ***[1]***
however, a significant number of muons are detected at the surface of the Earth; ***[1]***
because of the high speed of the muons; ***[1]***
relative to an Earth observer the half-life of the muons will be longer and so they have sufficient time to reach the Earth; ***[1]***
*(use your judgement i.e. good idea of what's happening **[4]** some idea **[2]**;)*

[4 max]

(ii) recognise that $\gamma = 2.3$; ***[1]***
so that half-life as measured by laboratory observer = 7.1×10^{-6} s; ***[1]***
therefore distance travelled = $0.9\,c\times7.1\times10^{-6} = 1920$ m; ***[1]***
[3 max]

G2. *answers will be open-ended but look for something along these lines:*
the acceleration of an object by a given force is inversely proportional to the objects inertial mass; ***[1]***
the gravitational force on an object is proportional to the gravitational mass of the object; ***[1]***
if objects accelerated by a gravitational force have the same acceleration it follows that $m_g = m_i$; ***[2]***

or a mathematical argument might be given

$F_G = km_G$; ***[1]***
$F_G = m_I a$; ***[1]***
therefore $a = k\frac{m_G}{m_I} = \mathrm{k}$; ***[1]***
if $m_G = m_I$; ***[1]***

*(essentially any verbal argument should be a summary of the above mathematical argument. If they know the difference between inertial and gravitational mass but can't get any further then **[1]** out of **[4]**;)*

[4 max]

OPTION H – OPTICS

H1. (a) (i)

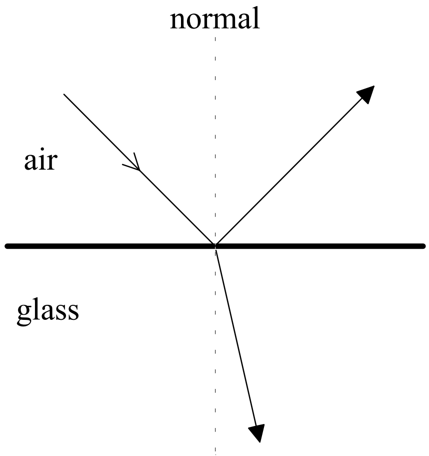


Diagram 1

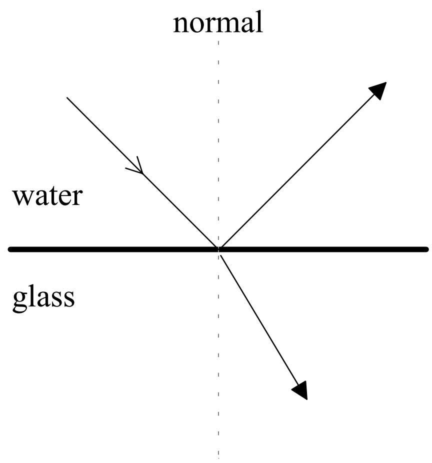


Diagram 2

reflected rays; ***[1]***
refraction of the rays; ***[1]***
much less refraction in diagram 2; ***[1]***
[3 max]

(ii) $\phi_c = \sin^{-1}\left(\frac{1.3}{1.5}\right) = 60^\circ$; ***[1 max]***

(iii)

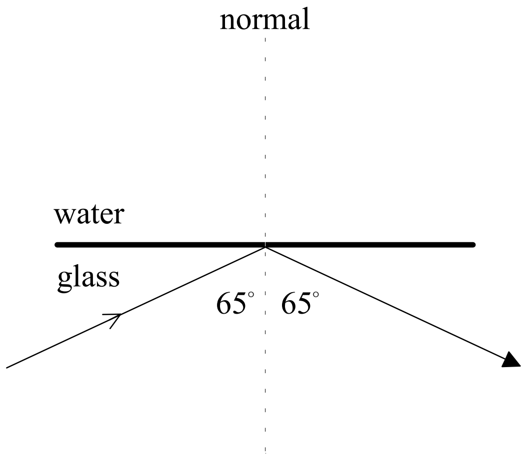
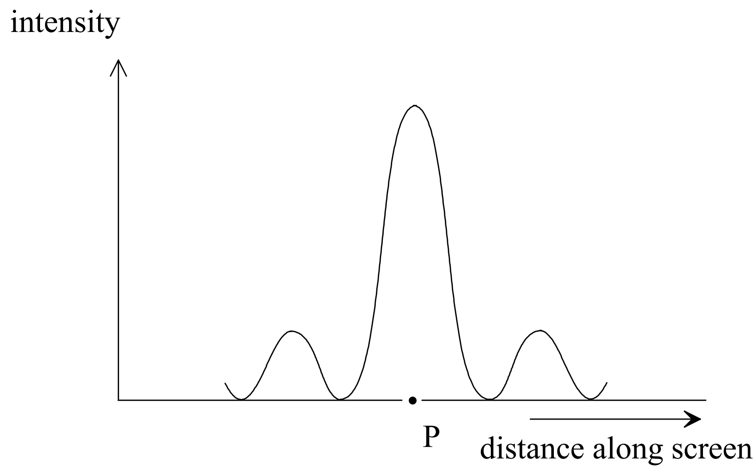


diagram to show total internal reflection; ***[1]***
reflected angle looking equal to incident angle; ***[1]***
[2 max]

H2. (a)



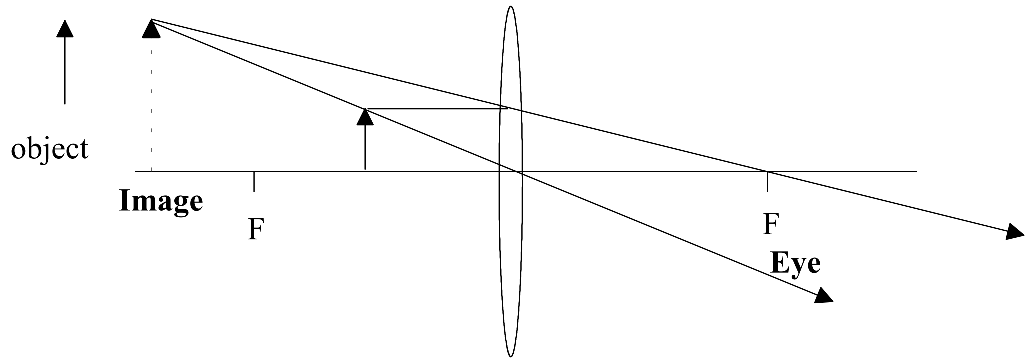
overall shape; ***[1]***
correct position of central maximum; ***[1]***
secondary maxima significantly smaller than principal maximum; ***[1]***
(should be $\frac{1}{9}$ the size but don't look for this accuracy or accuracy in the relative widths of the maxima - the above diagram certainly isn't!)

[3 max]

(b) $\theta = \frac{\lambda}{b} = \frac{d}{D}$ (*b* = slit width, *d* = half-width of central maximum, *D* = distance from slit to screen); ***[1]***
correct substitution to give d = 5 mm; ***[1]***
therefore width of central maximum = 10 mm; ***[1]***

[3 max]

H3. (a)

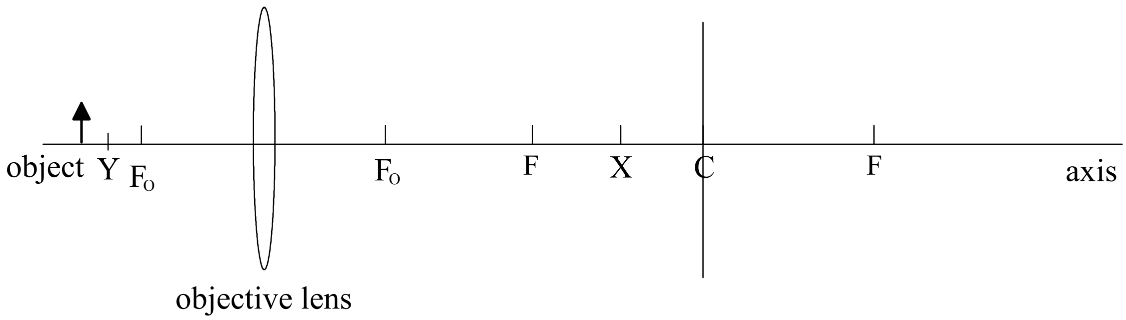


(i) object between F and centre of curvature of the lens; ***[1 max]***

(ii) the two appropriate rays; ***[1]***
position of image; ***[1]***
[2 max]

(iii) position of eye (anywhere on the side of the lens opposite to the object); ***[1 max]***

(b)



(i)→(iv) ***[1]*** for each correct position. The F to the left of the eyepiece is the important one. The other important thing to look for is that the image formed by the objective is within the PF of the eyepiece; ***[4 max]***