INTERNATIONAL BACCALAURÉAT BACHILLERATO IBO BACCALAUREATE INTERNATIONAL INTERNACIONAL

M03/430/H(3)M+

MARKSCHEME

May 2003

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 penalising 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) mass of water carried out is proportional to surface area, $m \propto r^2$;
mass of sphere is proportional to volume therefore $M \propto r^3$;
therefore $\frac{m}{M} \propto \frac{r^2}{r^3} \propto \frac{1}{r}$; ***[3]***

(b) (i) for the sphere $\frac{k}{0.8} = 0.020$;
$k = 1.6 \times 10^{-2}$;
for the insect $\frac{m}{M} = \frac{1.6 \times 10^{-2}}{4.0 \times 10^{-3}} = 4$; ***[3]***

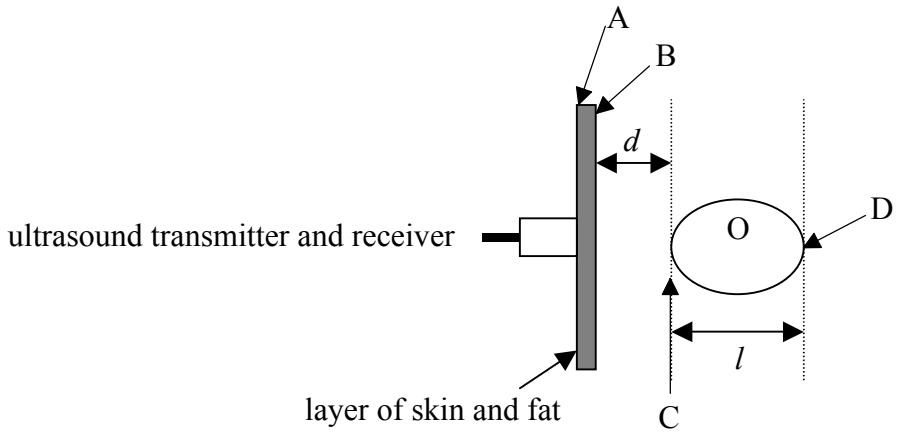
(ii) the constant k is the same for the sphere and the insect / the thickness of water carried out by insect and sphere is the same; ***[1]***

(iii) if it carries out four times its body mass then it is unlikely to be able to get airborne again;
OWTTE; ***[1 max]***

D2. (a) 1 MHz → 20 MHz***;*** ***[1]***

(b) (i) to ensure that no air is trapped between transmitter and skin;
otherwise nearly all the transmitted pulse will be reflected at the surface of the skin; ***[2]***

(ii)



A and B correct;
C and D correct; ***[2]***

(iii) pulse takes 50 μs to travel 2*d*;
therefore $d = \frac{ct}{2} = \frac{1.5\times10^{3}\times50\times10^{-6}}{2}$;
to give *d* = 38 mm;
similarly $l = \frac{1.5\times10^{3}\times175\times10^{-6}}{2} = 130\,\text{mm}$; ***[4]***
Allow for ECF here e.g. if "d" is marked as being between A and B.

(c) B-scan gives a three-dimensional image;
OWTTE; ***[1 max]***

(d) *advantage*:
non-ionising *(not as harmful as X-rays / OWTTE)*;

*Any **one** of the following:*
disadvantages:
small depth of penetration;
limit to size of objects that can be imaged;
blurring of images due to reflection at boundaries; ***[2 max]***

D3. (a) energy required $= mgh = 800 \times 3\,000 = 2.4$ MJ;
mass of potatoes $= \frac{2.4}{2.5} = 0.96\,\text{kg}$; ***[2]***

(b) *Any **one** of the following sensible reasons.*
energy needed just to keep the body alive *e.g.* heart beating;
body loses energy as heat *(do not accept something like "not 100 % efficient")*;
total distance walked;
doesn't take in to account the pace at which the mountain is climbed *etc.*; ***[1 max]***

D4. (a) *exposure*: total ionised charge produced in unit mass of air by a particular radiation;
absorbed dose: energy absorbed per unit mass; ***[2]***

(b) dose equivalent is the amount of energy absorbed;
but a quality factor is introduced to describe the effects of different types of radiation;
α is absorbed more that γ radiation and so has a much higher Q factor; ***[3]***
Do not look for this precise wording but look for the understanding.

(c) if the biological half-life is long then the tracer can do a lot of damage to healthy cells;
with a short biological half-life and long physical half-life the tracer will have a high activity during the time it is in the body; ***[2]***
Again do not look for this precise wording but look for the understanding.

OPTION E — HISTORICAL PHYSICS

E1. (a) retrograde; ***[1]***

(b) (i) Mars rotates about the Earth;
but as it does so it also moves around epicycles; ***[2]***

(ii) the different angle of sight between Earth and Mars;
as they both rotate about the Sun with different periods; ***[2]***

E2. (a) *situation 1*: EE / GG;
situation 2: EG / GE; ***[2]***

(b) equal amounts of each type are produced in electrification by friction;
and the normal state of matter is neutral;
OWTTE; ***[2 max]***
Accept each cancels the other out.

(c)

	Hypothesis / theory	***Explanation***
Franklin	all matter contains an electrical fluid;	fluid is transferred from one object to another by friction; two objects with excess fluid or less fluid will repel and excess and less will attract;
Modern atomic theory	protons and electrons carry equal and opposite charges;	electrons are transferred during friction; two objects with excess or less electrons will repel and excess and less will attract; or electron transfer leaves on + the other object –; two like charges repel, unlike attract;

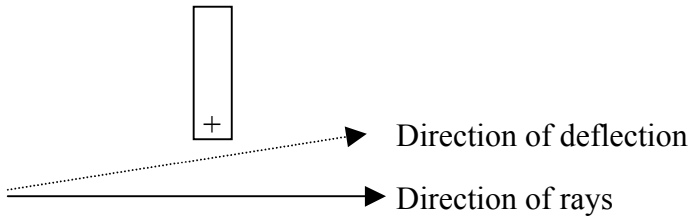
*Award **[1]** each for sensibly worded hypothesis and **[2]** each for an explanation in terms of the hypothesis which shows that they have an understanding of what is going on up to **[6 max]**.*

[6 max]

E3. (a) at right hand end of tube; ***[1]***

(b) (i) because they appear to originate from the cathode; ***[1]***

(ii) *Marked on the diagram.*
direction of cathode rays;
correct deflection of rays consistent with a magnet or charged rod;



e.g. ***[2 max]***

(iii) electrons; ***[1]***

E4. (a) according classical theory, the orbiting electron will emit radiation;
according to Bohr, whilst the electron is in an allowed orbit, it does not emit radiation – hence stable; ***[2]***
Look for: Bohr – no radiation emitted (stable) but classically, radiation will be emitted.

(b) E_{n_2} the energy of the electron when in an orbit defined by $n = n_2$;
E_{n_1} the energy of the electron when in an orbit defined by $n = n_1$;
f the frequency of the photon emitted;
when the electron makes a transition between the orbits $n = n_2$ and $n = n_1$; ***[4]***

(c) for the longest wavelength $m = 3$;
correct substitution to get $\lambda = 6.5 \times 10^{-7}$ m; ***[2]***

(d) *Look for any **two** of the following **[1]** each.*
the electron no longer has a well defined orbit / doesn't orbit about the proton;
the KE of the electron is determined by its de Broglie wavelength;
energy levels within the atom depend on the values that the de Broglie wavelength of the electron can take;
the probability of locating the electron at a point within the atom is determined by the amplitude of its wave function; ***[2 max]***
Be generous!

OPTION F — ASTROPHYSICS

F1. (a) (i) spectral class; ***[1]***
Accept colour sequence.

(ii) absolute magnitude; ***[1]***

(b)

Star	***Type of star***
A	Main sequence;
B	Super Red Giant;
C	White Dwarf;
D	Main sequence;

*Award **[1]** for each correct name.* ***[4 max]***

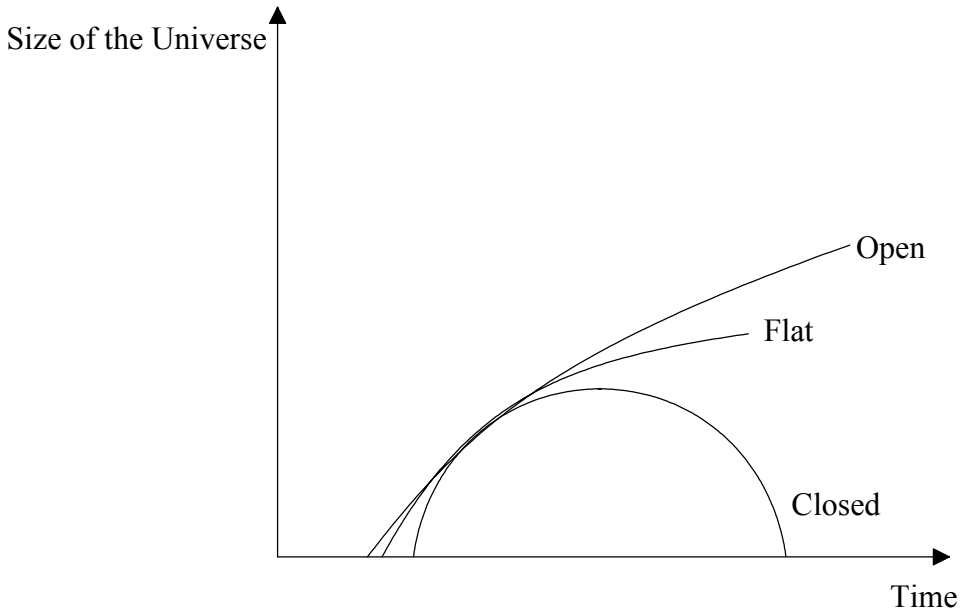
(c) B more luminous than A;
and has lower temperature than A;
so from the Stefan-Boltzmann law;
B has greater area (radius); ***[3 max]***

(d) use of $L = 4\pi bd^2$;
from the H-R diagram $L_B = 10^6 L_{Sun}$;
therefore $\frac{L_B}{L_{Sun}} = 10^6 = \frac{7.0\times10^{-8}\times {d_B}^2}{1.4\times10^3}$;
to give $d_B = 1.4\times10^8\ AU\ (\approx 700\,\text{pc})$; ***[4]***

No mark is awarded for the conversion from AU to pc.

(e) at this distance the parallax angle is too small to be measured accurately;
OWTTE; ***[1 max]***
Do not accept "it's too far away" .

F2. (a)



*Award **[1]** for each correct label.* ***[3 max]***

(b)

Type of Universe	*Relation between* ρ *and* ρ_0
Open	$\rho < \rho_0$
Flat	$\rho = \rho_0$
Closed	$\rho > \rho_0$

*Award **[1]** for each correct entry.* ***[3 max]***

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

(b) Chandrasekhar limit defines the maximum mass that a white dwarf can have;
at a mass equal to the limit the core of the star is prevented from contracting further by electrons;
above this mass the electrons cannot support the core and it further contracts causing the electrons to combine with protons to form neutrons;
OWTTE; ***[3 max]***

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

F4. (a) the universe is expanding; ***[1]***

(b) any sensible straight line; ***[1]***

(c) Slope of the graph; ***[1]***

(d) $T = H^{-1}$;
correct conversion of units to get $T \approx 10^{10}$ years; ***[2]***

OPTION G — SPECIAL AND GENERAL RELATIVITY

G1. (a) *proper time:* the time interval measured by an observer of an event that happens at the same place according to that observer;

proper length: the length of an object as measured by an observer who is at rest relative to the object; ***[2]***

Do not look for precise wording but look for the understanding of the quantities in the sense of the words.

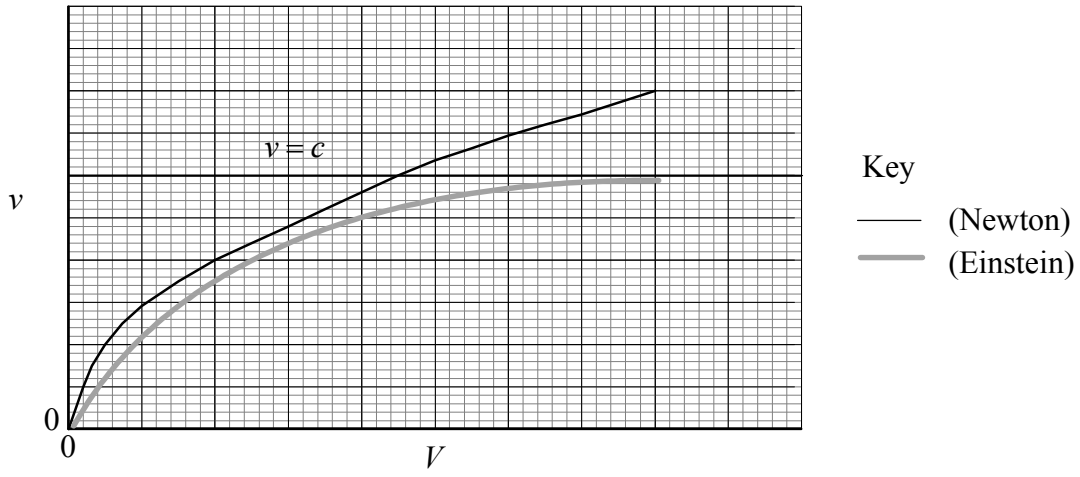
(b) (i) no they will not appear to be simultaneous;

Look for a discussion along the following lines.
Carmen sees Miguel move away from the signal from A and since Miguel receives the two signals at the same time;
and since the speed of light is independent of the motion of the source;
Carmen will see the light from A first / light from B will reach Carmen after light from A */ OWTTE*; ***[4 max]***

(ii) $\gamma = 2$;
to give $u = 0.87\text{c}\ (2.6\times10^{8}\ \text{m s}^{-1})$; ***[2]***

(iii) both measure the correct distance;
SR states that there is no preferred reference system / laws of physics are the same for all inertial observers;
OWTTE; ***[2 max]***

G2. (a)



correct general shape;
asymptotic to *c*; ***[2 max]***

(b) as the speed of the electrons increases SR predicts that the mass of the electrons will increase;
SR also predicts that at speed *c* the mass will be infinite;
so effectively the electrons can never reach the speed of light; ***[3]***

Look for an answer that shows that mass increases and why the electrons cannot travel at the speed of light. They might quote $m = \gamma m_0$ *and this is fine.*

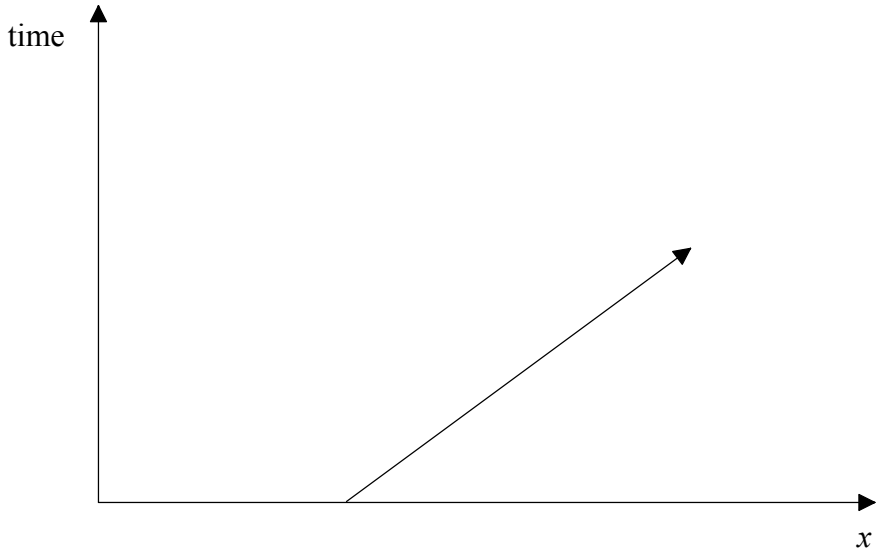
(c) (i) $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}} = \dfrac{1}{\sqrt{1-0.97^2}}$

to give $\gamma = 4.1$;
$m = \gamma m_0 = 4.1 \times 0.51 = 2.1\,\text{MeV}\,\text{c}^{-2}$;
Accept $m = 3.7 \times 10^{-30}\ kg$.

could also solve from KE = 1.5 MeV;
rest mass = $0.51\,\text{MeV}\,\text{c}^{-2}$;
therefore total mass = $2.1\,\text{MeV}\,\text{c}^{-2}$; ***[3 max]***

(ii) $E = mc^2$;
= 2.1 MeV;
Accept $3.20 \times 10^{-13}\ J$. ***[2]***

G3. (a)



correct labelling of the axes;
any sensible straight line path;
some sensible brief description *e.g.* " particles move in both space and time and so the motion of the particle can be represented by a path in spacetime"; ***[3]***

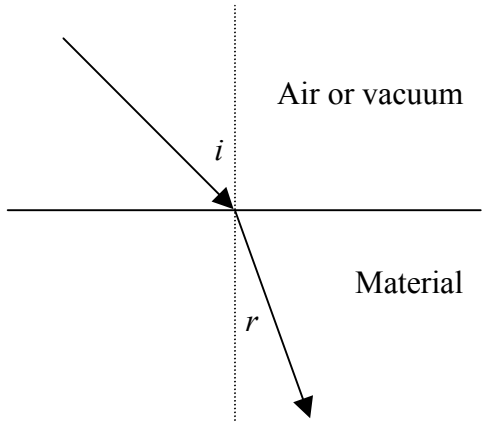
(b) *Look for an explanation that contains the following points.*
all particles follow the shortest path in spacetime;
if the Earth were not present the satellite would move in a straight line;
the warping of spacetime forces the satellite to follow an orbital path; ***[3]***
The description can of course be aided by use of a diagram.

(c) if an object is dense enough it will cause extreme warping of spacetime;
such that any light leaving the surface will not be able to escape the spacetime surrounding the object;
OWTTE; ***[2 max]***
If the explanation is given in terms of Newtonian gravity then award ***[1]*** *mark only.*

(d) recognize to use $R_{sch} = \frac{2GM}{c^2} = \frac{2 \times 6.6 \times 10^{-11} \times 2 \times 10^{30}}{9 \times 10^{16}}$;
≈ 3000 m; ***[2]***

OPTION H — OPTICS

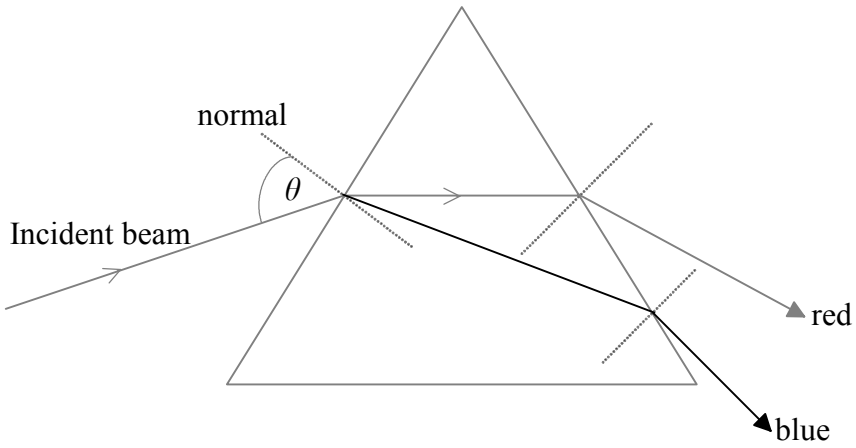
H1. (a)



definition consistent with diagram $n = \frac{\sin i}{\sin r}$;

with i in air or vacuum; ***[2]***

(b) (i)



refraction at first surface;
refraction at emergent surface;
deviation greater than red light; ***[3]***

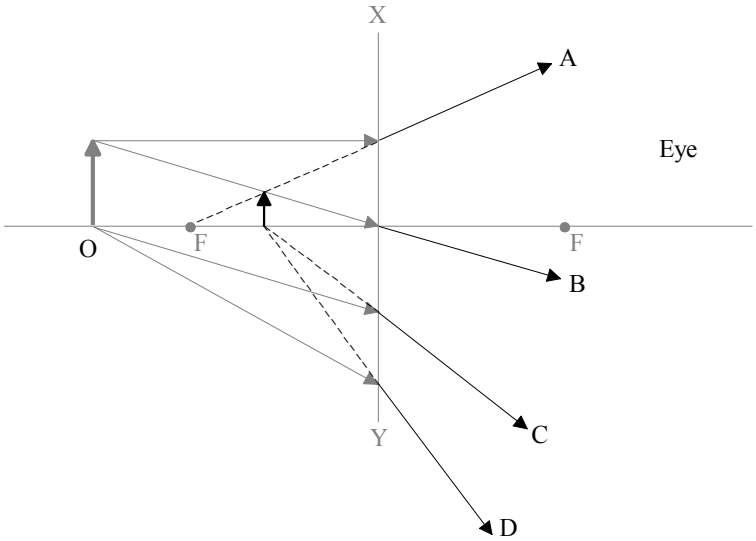
If the refraction's are correct but the angle of refraction is less than that for red light award ***[2]****.*

(ii) less — refraction angle is greater therefore $\sin i$ / $\sin r$ is smaller; ***[1]***

H2. (a) focal point: the point on the principal axis to which rays parallel to the principal axis are brought to a focus after refraction by the lens / it is a point on the PA from which rays will be parallel to the PA after refraction by the lens. ***[2 max]***

*Look for a precise definition to gain **[2 max]** – award **[1]** for an inexact definition. Use discretion.*

(b) (i)



correct ray A;
correct ray B;
correct rays C and D;
correct location of the image; ***[4 max]***

*If a correct diagram is given for a **convex** lens award **[1]** but then use ECF for the rest of the question.*

(ii) anywhere to the right of the lens; ***[1]***

(c) virtual;
because any two rays from any one point of the object are not brought to a focus by the lens;
OWTTE; ***[2 max]***
*Virtual with incorrect explanation award **[1]** with no explanation **[0]**.*

(d) *Award marks either by calculation or drawing.*

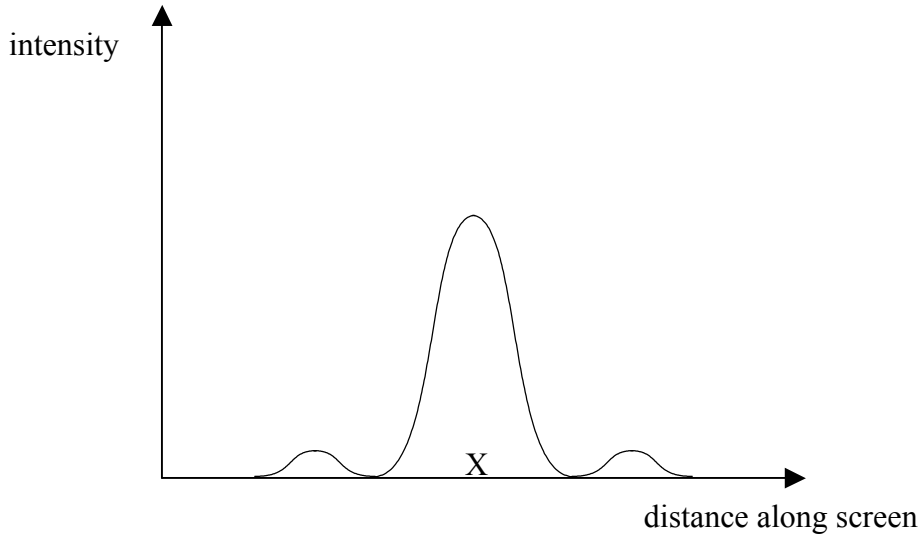
calculation:
use $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ with $f=-50$;
to give $v=-30.0$ cm;
to give $m=\frac{-30}{75}=-0.4$;
Only penalise once for incorrect sign.

drawing:
suitable scale;
correct rays;
correct measurement; ***[3 max]***

(e) no effect on linear magnification;
only effect on appearance is that image will be fainter; ***[2]***

H3. (a) each point on the slit acts as a source of secondary waves;
it is the interference between these waves that produces the maxima and minima;
OWTTE; ***[2 max]***

(b)



central maximum around X;
correct overall shape (only two secondary maxima need be shown);
secondary maxima much less intense than the central maximum; ***[3]***
Accept anything less than half the principle maximum.

(c) show $\frac{d_1}{d_2} = \frac{\lambda_1}{\lambda_2}$ from $d = \frac{f\lambda}{b}$;

substitute to get $\lambda = \frac{6.5 \times 500}{5} = 650\,\text{nm}$; ***[2]***

(d) (i) the first minimum of one image should coincide with the first maximum of the other image;
OWTTE; ***[1 max]***

(ii) use $\frac{\lambda}{b} = \frac{d}{D}$;
to give $b = 0.15$ mm; ***[2]***