MARKSCHEME

November 2002

PHYSICS

Standard Level

Paper 3

19 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:

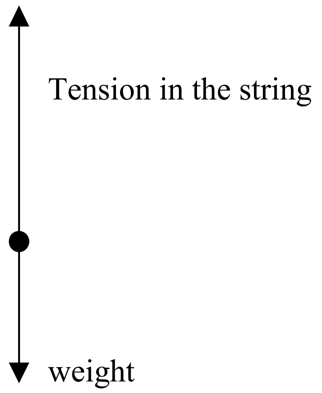
2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

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) not zero;
because the ball is accelerating so there must be a net force acting on it;
OWTTE; ***[2 max]***
*Award **[0]** for "no" and wrong reason.*

(b)



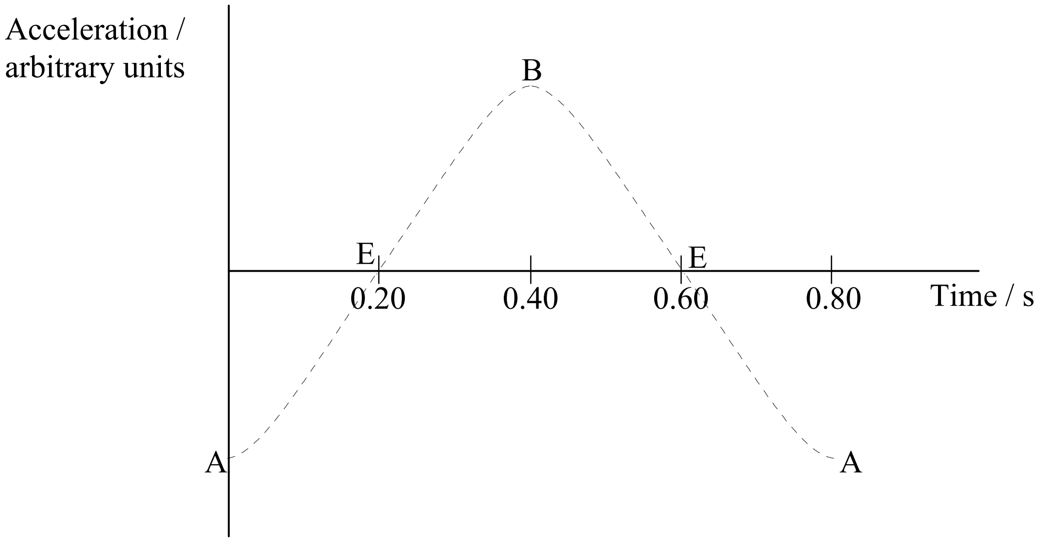
two forces T > mg;
*Award **[1]** if the answer is "yes" above and it shows $T = mg$.*
naming forces tension and weight ***[1]*** each; ***[2]***
[3 max]

(c) (i) use $v = \sqrt{2gh}$;
$= \sqrt{20 \times 0.45} = 3.0\ \text{m s}^{-1}$; ***[2]***

(ii) recognize that $a = \frac{v^2}{r}$;
to give $a = \frac{9.0}{0.45} = 20\ \text{m s}^{-2}$; ***[2]***

(iii) recognize that $T = \frac{mv^2}{r} + mg$; ***[2]***
to give $T = 0.20 \times 20 + 0.2 \times 10 = 6.0\text{N}$; ***[3 max]***
*If mg term missing then award a maximum of **[1]**.*

A2.



two correct A's;
two correct E's;
correct B; ***[3 max]***
Accept A and B interchanged.
*Essentially: 5 correct award **[3]**, 4 correct award **[2]** and for 3 correct award **[1]**.*

A3. (a) V at surface $= 18\times10^{8}\ \text{J kg}^{-1}$, V at moon $= 6\times10^{8}\ \text{J kg}^{-1}$;
$\Delta V = 12\times10^{8}\ \text{J kg}^{-1}$;
energy $= m\Delta V$;
24×10^{12} J; ***[4 max]***

(b) less — the moon will exert an appreciable attractive force on the rocket;
OWTTE; ***[1 max]***
*Award **[0]** for the right answer but wrong reason.*

OPTION B — ATOMIC AND NUCLEAR PHYSICS EXTENSION

B1. (a) number of neutrons in the nucleus (accept just number of neutrons); ***[1 max]***

(b)

N	Fr	Ra	Ac	Th	Pa	U	Np	Pu
143						$^{235}_{92}U$ •		
142								
141				***P***				
140					***Q***			
139								
138			***R***					
Z	87	88	89	90	91	92	93	94

[1] for each position; ***[3 max]***

(c) $Z = 89$;
A = 227; ***[2 max]***

B2. (a) the energy of a light wave depends on its intensity and is independent of frequency;
so energy of electrons would be expected to depend on intensity; ***[2 max]***
Look for some understanding that in wave theory energy does not depend on frequency but on intensity.

(b) (i) *Award* ***[2 max]*** *for an answer that shows a good understanding.*
the minimum energy;
required to eject an electron from the surface of the metal; ***[2 max]***

(ii) to get energy of photon use $E = hf = \dfrac{hc}{\lambda}$;
$= (6.6\times10^{-34}\times3\times10^{8})/4\times10^{-7}$;
to give $E = 5\times10^{-19}$ J;
work function $= 3.2\times10^{-19}$ J;
therefore maximum energy $= 1.8\times10^{-19}$ J;
essentially using $KE_{\text{max}} = hf - \phi$ ***[5 max]***

(c) calculation of velocity from $v = \sqrt{\dfrac{2E}{m}}$;
$= \sqrt{\dfrac{2\times1.8\times10^{-19}}{9\times10^{-31}}}$;
to give $v = 6\times10^{5}\ \text{m s}^{-1}$;
$\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$;
$= \dfrac{(6.6\times10^{-34})}{(9\times10^{-31}\times6\times10^{5})} \approx 10^{-9}\ \text{m}\ (1.2\times10^{-9}) = 1\ \text{nm}$; ***[5 max]***

OPTION C — ENERGY EXTENSION

C1. (a) a heat engine converts heat into work;
a heat pump uses work;
to transfer energy (heat) from a region of cold temperature to a region of higher temperature; ***[3 max]***
*Award **[1]** for answer such as "it pumps heat from cold to hot" .*

(b) first law of thermodynamics (accept conservation of energy); ***[1 max]***

(c) (i) efficiency $= \frac{T_1 - T_2}{T_1}$
$T_1 = 1143\ \text{K}, T_2 = 593\ \text{K}$;
efficiency = 48 %;
*Award **[1]** for 63 % if not converted to K.*
efficiency $= \frac{W}{Q_1}$;
to give $Q_1 = 210$ kW;
(160 kW for 63 % efficiency – ECF) ***[4 max]***

(ii) $Q_2 = Q_1 - W$;
to give $Q_2 = 110$ kW; ***[2 max]***
(60 kW for 63 % efficiency – ECF)

C2. (a) *Look for these points in the answer.*
water is pumped through copper pipes;
embedded in a blackened copper plate;
the plate is covered with a sheet of glass; ***[3 max]***

(b) total energy required $= 1000 \times 25 \times 4200$ J;
let area of panels = A
energy provided in 1 second by solar heater = $600A$;
energy provided in 3 hours $= 600\ A \times 3 \times 3600$;
therefore $\text{A} = \frac{(1000 \times 25 \times 4200)}{(600 \times 3 \times 3600)}$;
$\approx 16\ \text{m}^2$; ***[5 max]***

(c) not much use if the Sun is not shining;
OWTTE;
large area needed for any reasonable power output; ***[2 max]***
Any other reasonable comment.

OPTION D — BIOMEDICAL PHYSICS

D1. (a) area of leg bone $= 3.14 \times 1 \times 10^{-4}$;
stress on one leg bone $= 500 / (3.14 \times 1 \times 10^{-4}) = 1.6 \times 10^{6}\ \text{N m}^{-2}$; ***[2 max]***
*Award **[1]** if 1000 N used and then watch for subsequent ECF.*

(b) $8.0 \times 10^{6}\ \text{N m}^{-2}$; ***[1 max]***

(c) (i) "volume" increases by a factor of x^3 ;
therefore new weight $= 1000x^3$ N ; ***[2 max]***

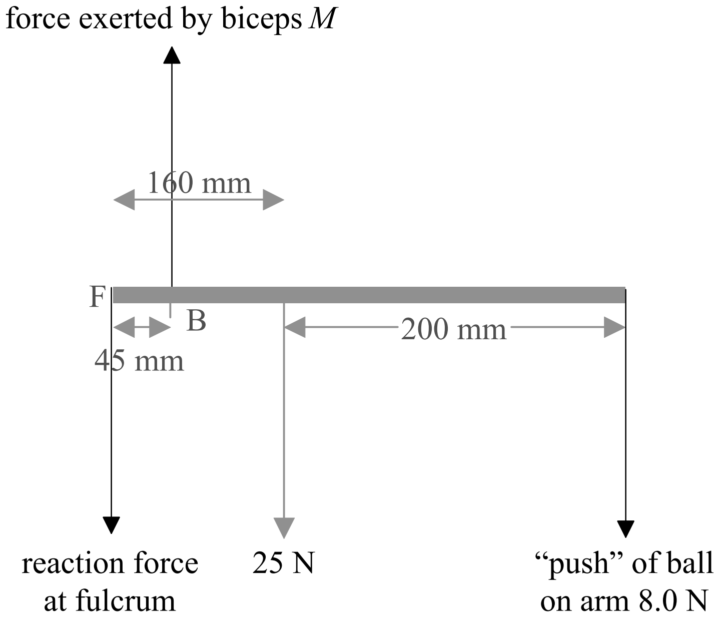
(ii) new area of cross-section of leg bone $= x^2 \times \pi \times 1 \times 10^{-4}$;
therefore new stress $= 500x^3 / (\pi x^2 \times 10^{-4})$;
$= 1.6x \times 10^{6}\ \text{N m}^{-2}$; ***[3 max]***

(d) (i) $x = 10^7 / 8 \times 10^6 = 1.3$;
therefore height $= 1.3 \times 2 = 2.6$ m ; ***[2 max]***

(ii) *Any sensible suggestion such as:*
the estimate doesn't allow for very "fat" tall persons;

if this were the maximum height the person wouldn't be able to:
- jump without the leg bone snapping;
- carry any heavy objects; ***[1 max]***

D2. (a)



force exerted by biceps;
reaction force at fulcrum;
"push" of ball on arm 8.0 N; ***[3 max]***

(b) take moments about F
$M \times 45 = (8 \times 360) + (25 \times 160)$;
to give $M = 150$ N; ***[2 max]***

D3. (a) sound from an external source travels through air to the eardrum and inner ear;
sound is prevented from reaching the inner ear *(note that no cause is asked for)*; ***[2 max]***

(b) down by 50 dB $= 10\log(I/10^{-12})$;
to give $I = 10^{-7}\ \mathrm{W\,m^{-2}}$; ***[2 max]***

OPTION E — HISTORICAL PHYSICS

E1. (a) caloric is a fluid;
the amount of caloric in a body determines its temperature;
caloric flows from the hot body to the colder body;
until the both have the same temperature; ***[4 max]***

(b) caloric is released as latent heat/or that the theory assumed that this process involves a change of phase (state) ***[1 max]***

(c) (i) the potential energy of the water is converted into KE;
the KE of the water is converted into thermal energy at the bottom of the fall; ***[2 max]***

(ii) $mgh = ms\Delta T$;
so $h = s\Delta T/g$;
to give h ≈ 420 m; ***[3 max]***

E2. (a) the stars keep a fixed distance apart;
and appear to be attached to the surface of a sphere that rotates about the Earth;
OWTTE; ***[2 max]***

(b)

Observation	**Explanation of observation in terms of the Aristotle model**	**Explanation of observation in terms of the Copernican model**
Change in the pattern of the fixed stars over a period of one night	the Earth is fixed at the centre of the Universe; and the stars are attached to the surface of a sphere that rotates about the Earth every 24 hours; *Do not penalize if 24 hours is missing from the answer.*	stars are at great distances from the Earth; apparent motion is due to the rotation of the Earth about its axis;
Change in the pattern of the fixed stars over a period of one year	the stars are actually attached to another sphere as well; which rotates eastwards about the Earth once a year; *Do not penalize if once a year is missing*	the rotation of the Earth about the Sun; which takes a year for one orbit;

*Be flexible here. Award up to **[3]** for a good explanation. There are **[8]** total but they need not divide equally. For example a good description of Copernicus for one observation could get **[3]** and if say mentioning the orbital period is omitted in the other then the two together should still get **[4]**.* ***[8 max]***

OPTION F — ASTROPHYSICS

F1. (a) *apparent magnitude*: is a measure of the relative brightness of stars as seen from Earth;
measured on an arbitrary scale;

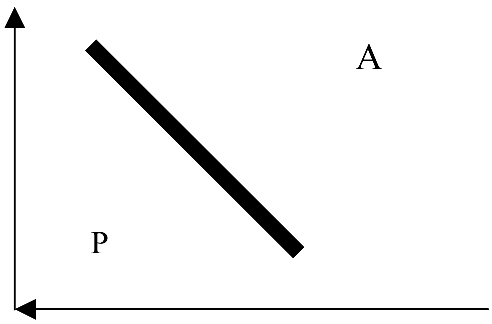
apparent brightness: is how much energy from the star falls on $1\,m^2$ of the Earth's surface every second;
OWTTE; ***[3 max]***

(b) Aldebaran;
smaller apparent magnitude; ***[2 max]***
*Award **[0]** for right star wrong reason.*

(c) Aldebaran;
although further away it has a greater apparent brightness; ***[2 max]***
*Award **[0]** for right star wrong reason.*

(d) (i) luminosity or absolute magnitude; ***[1 max]***

(ii)



approximate position of P and A; ***[1] + [1]***
[2 max]

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

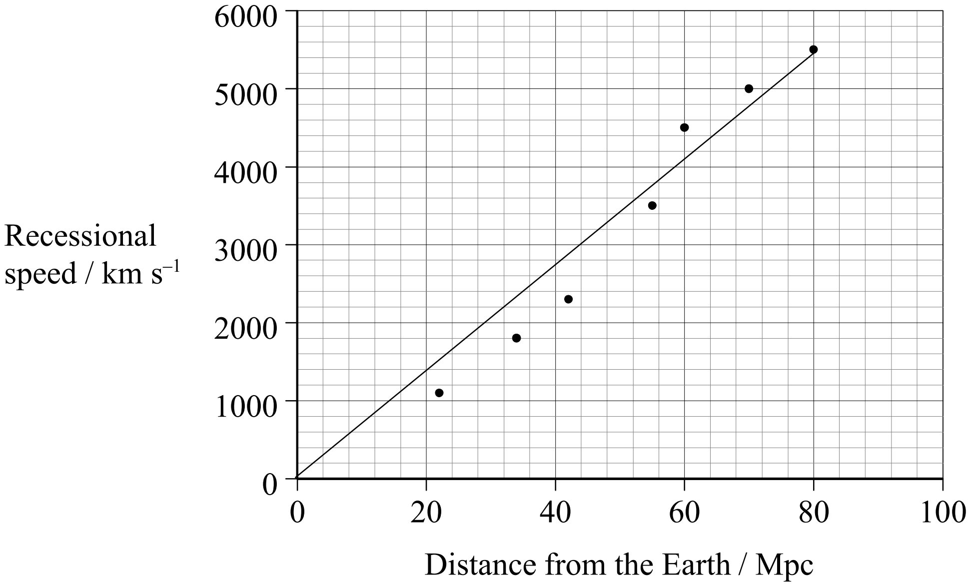
$\frac{L_{sun}}{L_p} = \frac{d_{sun}{}^2 b_{sun}}{d_p{}^2 b_p}$;

$\frac{L_{sun}}{L_p} = \frac{(1)^2 \times 1.4\times10^3}{(11.4\times6.3\times10^4)^2 \times 1.5\times10^{-14}}$;

$\approx 2\times10^5$; ***[4 max]***

F2. (a) from the red-shift in the spectrum from the galaxy;
the Doppler effect;
predicts that light from sources moving away will be red-shifted; ***[3 max]***

(b)



best fit line *(be generous but the line must go through the origin)*;
measurement of slope $= 70(\pm 10)\ \mathrm{km\,s^{-1}\ Mpc^{-1}}$;
= Hubble's constant; ***[3 max]***

OPTION G — SPECIAL AND GENERAL RELATIVITY

G1. (a) (i) an observer at rest or moving with constant velocity (accept just constant velocity); ***[1 max]***

(ii) the laws of physics are the same for all inertial observers; ***[1 max]***

(b) the time as measured in the pion's reference frame; ***[1 max]***

(c) (i) calculation of $\gamma = 5$;
$t = \gamma t_0$;
$= 5 \times 2.55 \times 10^{-8} = 1.28 \times 10^{-7}$ s; ***[3 max]***

(ii) $s = vt$;
$= 0.98 \times 3 \times 10^{8} \times 1.28 \times 10^{-7} = 37.6\,\text{m}$; ***[2 max]***

(d) length of tube that passed a pion before it decays $L_0 = L / \gamma$;
= 37.6/5 = 7.52 m (choosing length of tube = distance travelled before pions decay – *no need for answers to state this, they could use other lengths*);
speed of tube $v = d / t = 7.52 / 2.55 \times 10^{-8}$;
$= 2.95 \times 10^{8}\ \text{m s}^{-1}$;
= 0.98c; ***[5 max]***

G2. (a) the effect of a gravity;
and the effect of accelerated motion cannot be distinguished; ***[2 max]***
*i.e. Award **[2]** for answers that shows a good understanding. Answer such as "gravity and accelerated motion are the same" and would only be worth **[1]**.*

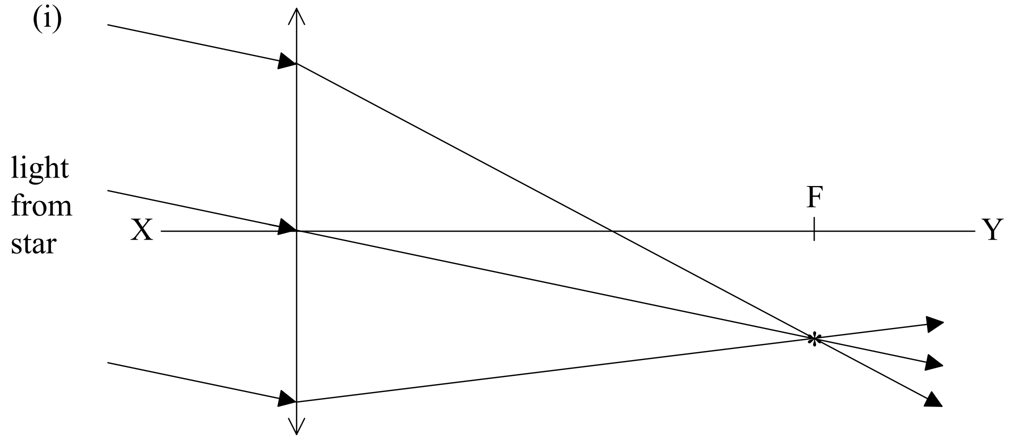
(b) (i) straight line between A and B; ***[1 max]***

(ii) curved path;
hitting the opposite wall lower down; ***[2 max]***

(iii) yes;
because of the principle of equivalence; ***[2 max]***

OPTION H — OPTICS

H1. (a) (i)



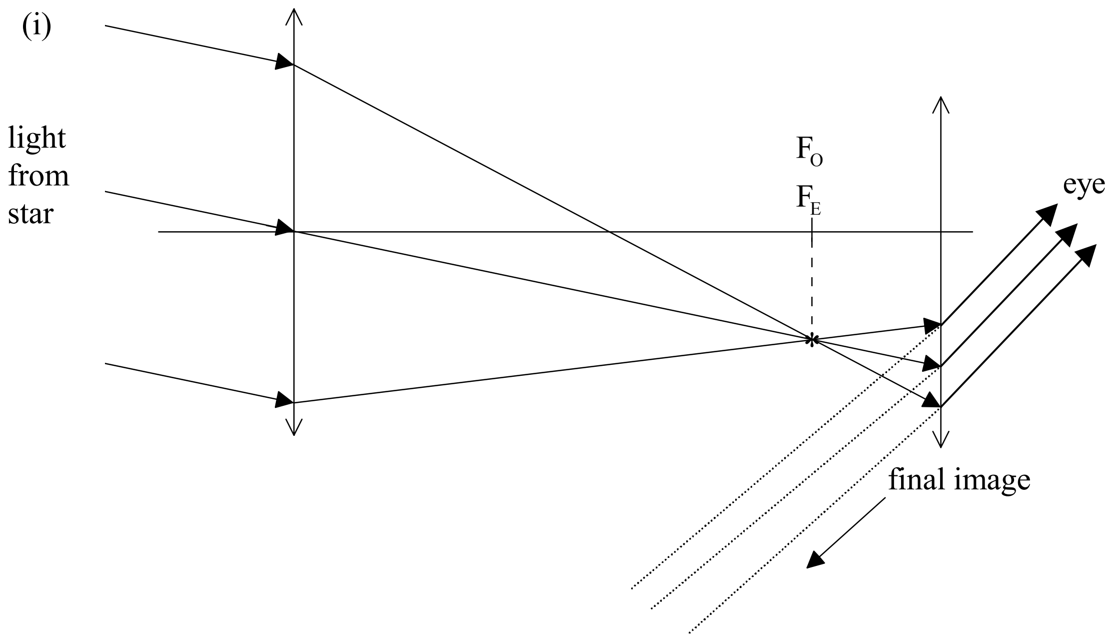
since the star is a long way, away wavefronts arriving at the lens will be virtually parallel; ***[1 max]***

Just saying a "long way away" is not sufficient, some explanation of why the large distance means that the rays will be parallel.

(ii) three correct rays; ***[1 max]***

(iii) correct position of F; ***[1 max]***

(b) (i)

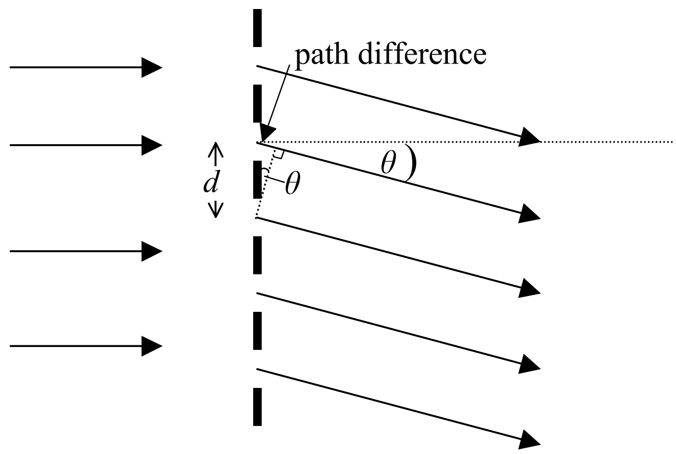


correct position of F_E and F_O; ***[1 max]***

(ii) three correct rays to eyepiece;
three rays from eyepiece;
position of image at infinity; ***[3 max]***

(iii) position of eye (anywhere to right of eyepiece) ***[1 max]***

H2. (a) (i)



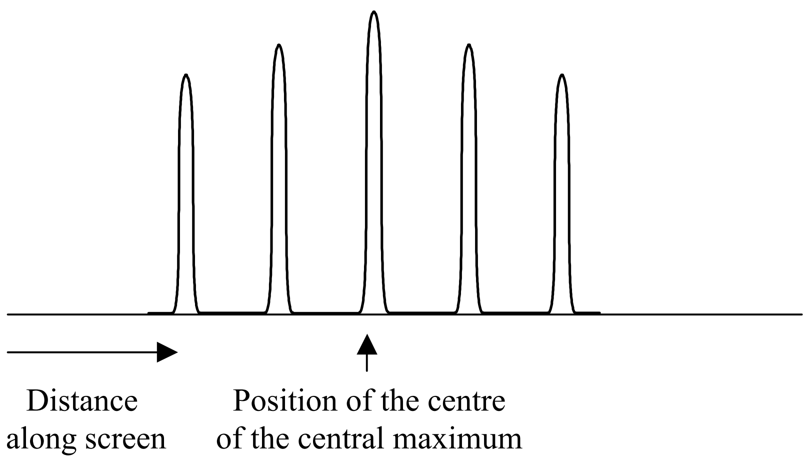
path difference marked on diagram; ***[1 max]***

(ii) path difference = $d \sin \theta$;
must show the other θ and the 90° should be clear to achieve this mark.
= nλ for a maximum; ***[2 max]***

(b) (i) sinθ = λ/d;
800 slits $\text{mm}^{-1} = 8\times10^{5}\ m^{-1}$, therefore $d = 1/(8\times10^{5})$;
therefore $\theta = \arctan\ (5\times10^{-7})\times(8\times10^{5}) = 24^{\circ}$; ***[3 max]***

(ii) maximum $\theta = 90^{\circ}$;
to give $\sin\theta = 1$ so that $n = d/\lambda$;
to give n = 2.5 so total number of maxima either side of central maximum = 2; ***[3 max]***

(iii)



correct shape of intensity curves;
two maxima either side of central maximum *(use ECF from (ii))*;
with slight decrease in intensity; ***[3 max]***