MARKSCHEME

November 2007

PHYSICS

Higher Level

Paper 3

15 pages

General Marking Instructions

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.
- 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.
- Words that are <u>underlined</u> are essential for 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. Where this point is considered to be particularly relevant in a question it is emphasized by writing *OWTTE* (or words to that effect).
- 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.
- 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.
- Only consider units in the final answer. Omission of units should only be penalized once in the paper.
- Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** 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*

  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 (ratio) $\propto L^3$;

mass of adult $= \left(\dfrac{1.8}{0.5}\right)^3 \times 3.4 = 160\,\text{kg}$; ***[2]***

(b) same shape;
same density/tissue composition;
same bone structure;
same organ structure; ***[2 max]***

(c) not reasonable / (too) large;
(they have) different shapes (with some detail);
e.g. ratio of baby's head size to its body size is greater than that for a person.
the ratio of bone/fat/muscle to body size are different, therefore, the (average) densities are different; ***[3]***
*Award **[0]** for incorrect reference to assumptions or no references.*

D2. (a) intensity level $= 10\lg\left(\dfrac{3.2\times10^{-4}}{10^{-12}}\right)$;

$= 85\,\text{dB}$; ***[2]***

(b) lever action (of the ossicles);
increases the force;
(this force) acts on smaller area (of oval window/cochlear); ***[3]***

D3. (a) simple scattering;
photo-electric effect;
Compton scattering;
pair production; ***[2 max]***

(b) half-value thickness is the thickness of material which will reduce the <u>intensity</u> of a beam of X-rays by one half / *OWTTE*; ***[1]***

(c) (two half thicknesses of fatty tissue reduces the intensity to $\frac{1}{4}$) thickness of tissue $= 12\,\text{mm}$;
$3\times$ half value thicknesses for muscle;
intensity reduces to $(2^{-3}) = \frac{1}{8}$; ***[3]***

(d) X-ray image is shadow/projection in two dimensions/two dimensional image;
CT scan is a three dimensional image / *OWTTE*; ***[2]***

D4. (a) metabolic rate is the total rate at which the body uses/produces energy / *OWTTE*;
bmr is the rate of energy consumption needed by the body when inactive/to maintain operation of basic functions *e.g.* breathing / *OWTTE*; ***[2]***

(b) oxygen consumption per $W = 5.0 \times 10^{-8}$;
therefore $\text{bmr} = \dfrac{4.0 \times 10^{-6}}{5.0 \times 10^{-8}} = 80\,\text{W}$;
energy required for running $= (620 - 80) = 540\,\text{W}$; ***[3]***

D5. (a) biological half-life is the time it takes for the body to eliminate half the amount of a given dose / *OWTTE*;
(whereas) physical half-life is the time it takes for the activity of a sample to halve / *OWTTE*; ***[2]***

(b) β radiation is absorbed over a small volume and therefore the dose is localized / *OWTTE* / comparison with α radiation;
γ radiation will escape from body (and so the dose can be externally monitored);
the effective half-life $\left(\dfrac{8 \times 20}{28}\right)$ is about six days;
the patient will be receiving an effective dose over a reasonable period but not too long to cause other damage / *OWTTE*; ***[3 max]***

Option E — The History and Development of Physics

E1. (a) the Copernican model is heliocentric and the Ptolemaic model is geocentric; ***[1]***

(b) simplifies the motion / is able to reduce epicycles / *OWTTE* / stresses importance of the Sun / any other relevant point; ***[1]***

(c) suggests a miniature solar system;
with planet replacing the Sun;
statement of conclusion; *(e.g. matches the Copernican model of the solar system)*

or

gives Jupiter the same status as Earth;
showing both are planets;
rotating around the Sun while being the centre of a rotation; ***[3]***

(d) (i) all objects irrespective of mass hit the ground at the same time / have same acceleration / *OWTTE*;
Aristotle believed that the heavier the mass, the faster it would fall / so will not hit the ground at the same time / *OWTTE*; ***[2]***

(ii) (Newton's second law of motion) force acting $ma = mg$;
so $a = g$ / acceleration independent of mass; ***[2]***
Accept a good qualitative argument.

E2. (a) electric current produces a magnetic field; ***[1]***

(b) there is a the force between two current carrying wires;
currents in the same direction attract;
currents in opposite direction repel; ***[3]***

E3. (a) (i) *part A*: heated filament/cathode is source of electrons; ***[1]***

(ii) *part B*: (cylindrical) anode that accelerates the electrons (and forms them into a narrow beam); ***[1]***

(iii) *part C*: plates (to which a pd can be applied) to deflect the electrons/beam; ***[1]***

(iv) *part D*: <u>fluorescent</u> screen to detect electrons/beam; ***[1]***

(b) <u>the measurement implied that the electrons are particles with mass</u>;
when the electron charge was measured the mass of the electron could be determined;
electrons from different sources such as ionized gases all have the same value of $\frac{e}{m}$;
electrons shown to be a fundamental particle of matter;
electrons are components of atoms; ***[3 max]***

E4. (a) *m* takes the fixed value 2;
$n = 3, 4, 5$ (*etc.*) gives the value of the wavelengths in the series / *OWTTE*; ***[2]***
Allow responses that give other fixed values of m with appropriate values of n.

(b) recognize that $m = 1$ and $n = \infty$;
$\frac{1}{\lambda} = 1.09 \times 10^{7}\ \text{m}^{-1}$;
$E = \frac{hc}{\lambda} = (1.1 \times 10^{7} \times 6.6 \times 10^{-34} \times 3 \times 10^{8}) = 2.2 \times 10^{-18}\ \text{J}$; ***[3]***
Values in brackets do not need to be shown to gain full marks.

(c) (i) an orbit in which no energy is radiated/lost by the electron / *OWTTE*; ***[1]***

(ii) the angular momentum of the electron is an integral number of $\frac{h}{2\pi}$; ***[1]***

(d) electrons are described by waves/wave functions;
the wave has to fit certain boundary conditions / the waves are essentially standing wave / *OWTTE*;
only certain wavelengths are allowed; ***[3 max]***

Option F — Astrophysics

F1. (a) wavelength peak $= 500\,\text{nm}$;

$T = \dfrac{2.90 \times 10^{-3}}{5 \times 10^{-7}}$;

$= 5800\,\text{K}$ ***[2]***

(b) the dark lines are due to absorption of light/photons;
by electrons within atoms/molecules;
the wavelengths (of the light absorbed) are characteristic of the element associated with the atom/molecule / *OWTTE*;

or

wavelengths of lines;
are compared to emission spectra of elements / *OWTTE*;
since all elements have a characteristic (line) spectrum; ***[3]***

F2. (a) luminosity is the total power emitted (by a star); ***[1]***

(b) use of $L = \sigma A T^4$ to recognize that $\dfrac{L_A}{L_B} = \dfrac{R_A{}^2 T_A{}^4}{R_B{}^2 T_B{}^4}$;

$\dfrac{L_A}{L_B} = \dfrac{(8.7 \times 10^{11})^2 \times (3.0 \times 10^3)^4}{(6.8 \times 10^7)^2 \times (2.0 \times 10^4)^4}$;

$= 8.3 \times 10^4$; ***[3]***

F3. (a) the greater the apparent magnitude the less bright a star appears;
Sirius does not appear as bright as the Sun so has greater apparent magnitude / *OWTTE*; ***[2]***

(b) $d = \sqrt{\dfrac{L}{4\pi b}}$;

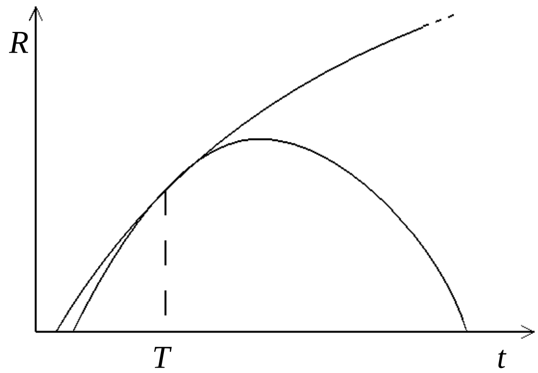
$\dfrac{d_{sir}}{d_{sun}} = \sqrt{\dfrac{L_{sir} b_{sun}}{L_{sun} b_{sir}}}$;

$d_{sir} = \sqrt{\dfrac{23 \times 1.4 \times 10^3}{1.1 \times 10^{-7}}}$;

$= 5.4 \times 10^5\ \text{AU}$ ***[3]***

F4. (a) a closed universe is one which will stop expanding at some future time, and begin contracting (due to gravity) / *OWTTE*; ***[1]***

(b)



a line starting to left of drawn curve;
touches at present time;
overall shape curved (showing reducing rate of increase); ***[3]***

(c) the only known data point is at the present time;
extrapolation of curves for different models gives different ages / *OWTTE*; ***[2]***

F5. (a) 1. (the gas cloud must be) sufficiently dense / high temperature;
2. (the gas cloud must be) sufficiently massive / high pressure; ***[2]***

(b) (i) mass; ***[1]***

(ii) in a red giant helium is fused;
if mass is between about four and eight stellar masses / red giants of large mass, then carbon is fused;
in a red supergiant successively heavier elements than helium are fused *e.g.* neon, oxygen, silicon;
until iron core is finally reached and core is stable / *OWTTE*; ***[3 max]***

F6. (a) from Hubble's law relative recession speed is Hd;

$T = \frac{d}{v} = \frac{d}{Hd} = \frac{1}{H}$; ***[2]***

(b) $T = \frac{1}{H} = 0.013\,\text{km}^{-1}\,\text{s}\,\text{Mpc}$;

$= \frac{3.9\times10^{17}}{3.2\times10^{7}}$;

$\approx 10^{10}$ yrs ***[2]***

Option G — Relativity

G1. no;
when the light from end B reaches Lucinda it will not have reached Simon / light from end A will reach Lucinda after it has reached Simon;
Simon will see the bird land at B before he sees the one land at A;
because the speed of light is independent of the speed of source / Simon and Lucinda both measure the same value of c/speed of light; ***[4]***
*Award **[0]** for incorrect reasoning or no reasoning.*

G2. (a) (i) time interval for Earth observer $= \left(\dfrac{d}{v}\right) = \dfrac{5.0\times10^{16}}{0.60\times3.0\times10^{8}}$;

$= 2.8\times10^{8}\ \text{s}$; ***[2]***

(ii) $\gamma = 1.25$;

$\text{time} = \dfrac{2.8\times10^{8}}{1.25} = 2.2\times10^{8}\ \text{s}$;

or

distance in astronaut frame $= 4.0\times10^{16}\ \text{m}$;

$\text{time} = \dfrac{4.0\times10^{16}}{0.60\text{c}} = 2.2\times10^{8}\ \text{s}$; ***[2 max]***

(b) astronaut;
the events of leaving the Earth and arriving at the star occur at the same point according to astronaut; ***[2]***
*Award **[0]** if no explanation or the wrong explanation is given.*

(c) <u>the (biological) age of the astronaut is less than the Earth observer</u>;
because of time dilation;
<u>the situation is not symmetric</u>;
the astronaut experiences forces / accelerations during trip; ***[3 max]***

G3. (a) mass increases with increasing speed/velocity;
mass is infinite when $v = \mathrm{c}$;
infinite force/energy needed; ***[3]***

(b) (i) $6.51\,\mathrm{MeV}$ (includes rest mass); ***[1]***

(ii) $(E = \gamma m_0 \mathrm{c}^2)\, 6.51 = \gamma \times 0.511$;
$\gamma = 12.7$;
$12.7 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{\mathrm{c}^2}}} \quad v^2 = 0.994\mathrm{c}^2$;
$v = 0.997\mathrm{c}$ ***[3]***

G4. *use of* $E^2 = p^2c^2 + m_0{}^2c^4$

$E = mc^2 = Ve + m_0c^2 = 2.511\,(\text{MeV})$;

$(2.511)^2(\text{MeV})^2 = p^2c^2 + (0.511)^2(\text{MeV})^2$;

$p^2c^2 = 6.04\,(\text{MeV})^2$;

$p = 2.46\,(\text{MeV c}^{-1})$;

*To award **[4]** intermediate and/or final units are not required.*

or

calculation of γ *from* $(\gamma - 1)\,m_0c^2 = Ve$;

$\gamma = 4.91$;

use of γ *to calculate*

$v = 0.979c$;

$p = \gamma m_0 v = (4.91 \times 0.511 \times 0.979) = 2.46\,(\text{MeV c}^{-1})$; ***[4]***

*To award **[4]** intermediate and/or final units are not required.*

G5. (a) curved line (striking the wall) below Rosemary; ***[1]***

(b) Einstein's principle states that it is impossible to distinguish between a system that is accelerating and one that is at rest in a gravitational field / *OWTTE*; *(do not accept "gravity and acceleration are the same/indistinguishable")*

if the spaceship were at rest on the surface of a planet for example / *OWTTE*;
the ball would follow the same path / *OWTTE*; ***[3]***

(c) (i) the frequency of Tony's light will (be seen to) be lower (than Rosemary's); ***[1]***

(ii) <u>gravitational</u> redshift; ***[1]***

Option H — Optics

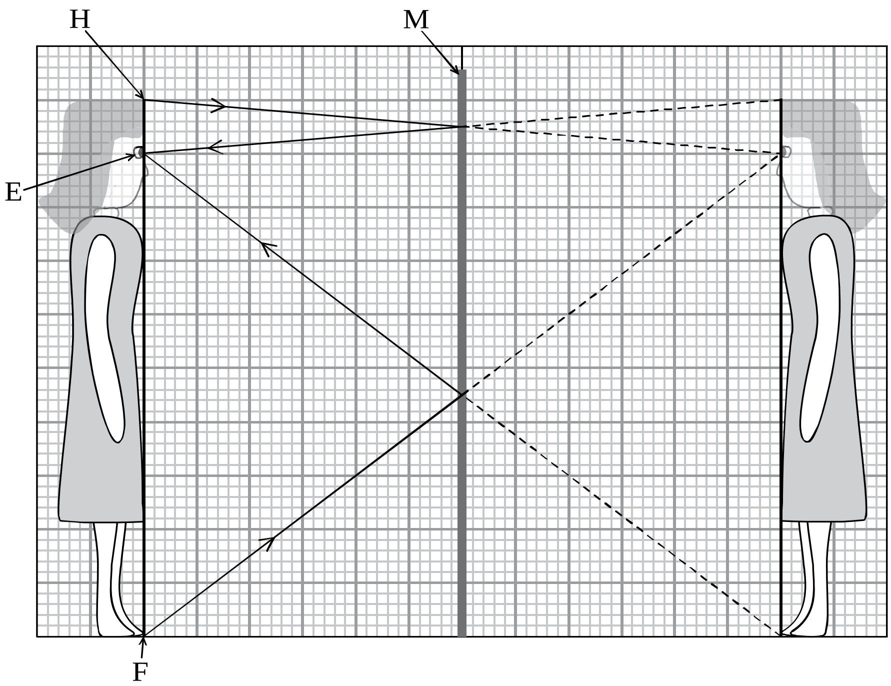
H1. (a) $\frac{\sin i}{\sin r}$ ***or*** $\frac{c}{v}$ with terms for each expression defined; ***[1]***

(b) $= \frac{3.0\times10^{8}}{2.1\times10^{8}}$;
$=1.4$; ***[2]***

(c) speed of light in a medium depends on frequency;
the refractive index depends on frequency;
light of different frequencies refracted by different amounts / *OWTTE*; ***[3]***

H2. (a) 1. the angle of incidence is equal to the angle of reflection;
2. incident ray, reflected ray and normal are coplanar/in the same plane; ***[2]***

(b) (i)



same height;
image distance equal object distance; ***[2]***

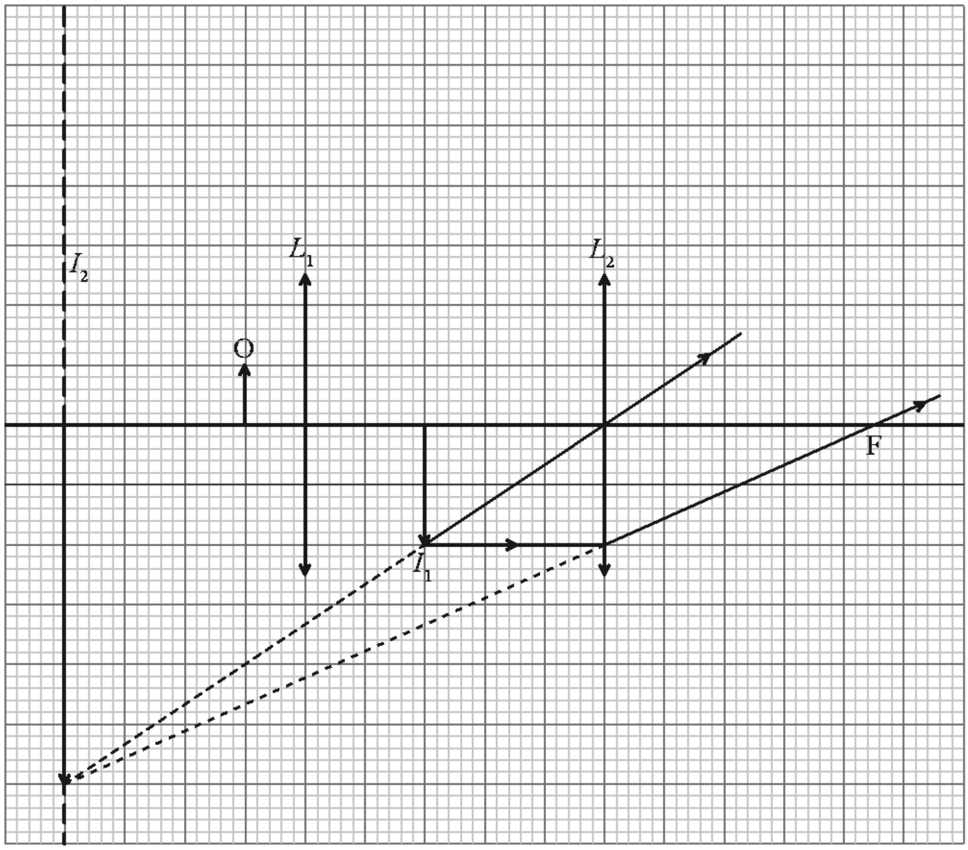
(ii) correct ray construction for F;
correct ray construction for H; ***[2]***
The rays should be shown with equal angles at mirror judged by eye. Arrows on rays are not required.

(c) (i) $0.75\,(\pm0.03)\,\text{m}$; ***[1]***

(ii) $0.68\,(\pm0.03)\,\text{m}$; ***[1]***

(d) no effect; ***[1]***

H3. (a)



two correct construction rays;
dotted lines back to I_2 to give F, $4.5(\pm 1)$ cm from L_2; ***[2]***

(b) (i) 2; ***[1]***

(ii) 3; ***[1]***

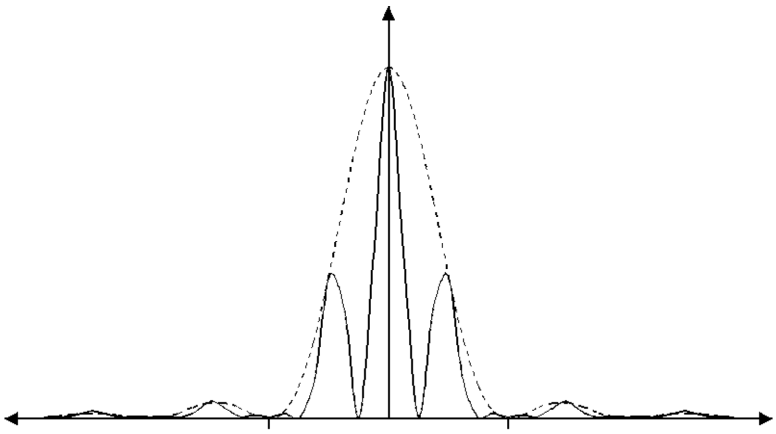
(c) 6; ***[1]***

H4. (a) each element of the slit acts as a point source of light;
the light from these sources interfere;
there will be a zero of intensity (on the screen) when the sum of the path differences between the sources is an integral number of half wavelengths / a maximum when an integral number of wavelengths; ***[3]***

(b) $\theta = \frac{d}{D} = \frac{\lambda}{b}$;

rearrange to get $d = \frac{D\lambda}{b}$; ***[2]***

(c)



central maximum same intensity as single slit maximum;
two other maximum either side about half-intensity of central maximum; ***[2]***
Award ***[1 max]*** *if lines do not touch x-axis.*
There is no need to show maxima within secondary maxima. Do not penalize responses if more than two maxima are shown but they must be symmetrical and with realistic relative intensities.

H5. (a) changes by $\pi/180^{\circ}$; ***[1]***

(b) *use of* $2\mathrm{nd}\cos\phi = \ m + \frac{1}{2}\ \lambda$

$n = 1 \cos\phi = 1$ and m changes by 1;

therefore $d = \frac{\lambda}{2} = 280\,\mathrm{nm}$; ***[2]***