



MARKSCHEME

November 2007

PHYSICS

Standard Level

Paper 3

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General Marking Instructions

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.
- ♦ 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 underlined 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 penalising 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	<i>reject</i>
1.6	<i>accept</i>
1.63	<i>accept</i>
1.631	<i>accept</i>
1.6314	<i>reject</i>

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) parabola similar to that shown in graph;
starting at (0,0) and ending at $h=0$; [2]
- (b) $V_v = 200\sin\theta$; [1]
Accept $u\sin\theta$ and $200\sin\theta - gt$.
- (c) time to reach maximum height = 10s;
 $200\sin\theta = gt$;
 $200\sin\theta = 100$;
to give $\theta = 30^\circ$
- or*
- time of flight = 20s;
 $200\sin\theta \times t = \frac{1}{2}gt^2$;
 $200\sin\theta = 100$;
to give $\theta = 30^\circ$
- or*
- measurement of gradient at $t = 0$;
 $= 100\text{ m s}^{-1}$;
 $= 200\sin\theta$;
to give $\theta = 30^\circ$ [3]

- A2.** (a) the force exerted per unit mass;
on a small/test mass; [2]
- (b) $g_h = \frac{GM}{(R+h)^2}$; [1]
These symbols must be used.
- (c) $V = \frac{GM}{R+h}$;
therefore $V = g_h(R+h)$;
 $= 1.8 \times 4.6 \times 10^6$;
to give $V = 8.3 \times 10^6 \text{ J kg}^{-1}$ [3]
Do not deduct marks if a minus sign is given.
- (d) recognize that for orbit $\frac{v^2}{(R+h)} = \frac{GM}{(R+h)^2}$;
so $v = \sqrt{\frac{GM}{R+h}} = \sqrt{V} = \sqrt{8.3 \times 10^6}$;
to give $v = 2.9 \times 10^3 \text{ m s}^{-1}$ [2]
- A3.** (a) the sum of the (external) torques/moments acting on the body is zero / *OWTTE*; [1]
- (b) W_p parallel to AB acting through P and in the correct direction, W_R perpendicular
to AB acting through P and in the correct direction; [1]
- (c) anticlockwise moment about X = $W \times h \times \sin 25$;
clockwise moment about X = $W \times 1.2 \times \cos 25$;
(equate clockwise and anticlockwise moments) $h = \frac{1.2}{\tan \theta}$;
to give $h = 2.6 \text{ m}$; [4]
*Do not penalize if anticlockwise and clockwise are the wrong way round.
Accept answers that use a correct vector triangle with W vertical through X.*

Option B — Quantum Physics and Nuclear Physics

- B1.** (a) there exists a frequency of light (incident on a metal surface) below which no electrons are emitted/ejected from the surface / *OWTTE*;
the emission/ejection of electrons from a metal surface (upon which light is incident) is instantaneous / maximum KE of electrons is independent of intensity; [2]
- (b) (i) the threshold frequency is the frequency below which no electrons are emitted / *OWTTE*;
(this corresponds to $E_K = 0$) so $f = 4.5 \times 10^{14}$ Hz; [2]
- (ii) from Einstein's (photoelectric) theory $E_K = hf - hf_0$;
therefore, $h = \text{gradient/slope of graph}$;
 $= \frac{4.8 \times 10^{-19}}{(11.8 - 4.5) \times 10^{14}}$ *or* values consistent with at least half length of line;
 $= 6.7 (\pm 0.2) \times 10^{-34}$ J s; [4]

- B2.** (a) all particles have an associated wavelength / *OWTTE*;
the wavelength λ is given by $\frac{h}{p}$ where h is the Planck constant and p is the momentum of the particle; [2]
- (b) combine $E = \frac{p^2}{2m}$ and $p = \frac{h}{\lambda}$;
to get $E = \frac{h^2}{2m\lambda^2}$;
substitute to get $E = 2.2 \times 10^{-18}$ J; [3]

- B3.** (a) the rate at which atoms decay (in a sample) is proportional to the number of atoms (in the sample) / *OWTTE*; [1]
- (b) ${}_{40}^{81}\text{Zr} = {}_{39}^{81}\text{Y} + \beta^+ + \nu$;
 ${}_{39}^{81}\text{Y}$;
 β^+ *or* e^+ *or* ${}_{+1}^0e$;
 ν ; [3 max]

- (c) $\lambda = \frac{dN}{dt}$;
 $= \left(\frac{7.4 \times 10^{14}}{1.6 \times 10^{16}} \right) = 0.046 \text{ s}^{-1}$;
 $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \left(\frac{0.69}{0.046} \right) = 15 \text{ s}$; [3]

Values in brackets do not need to be shown to gain full credit.

Option C — Energy Extension

- C1.** (a) (i) $V \propto T$ at constant P ;
 since V decreases, T must decrease;
 T is a measure of U so ΔU is negative; [3]
- (ii) ΔW and ΔU are negative;
 therefore ΔQ is negative so from the gas;
- or*
- U decreases;
 to decrease U , Q must be from the gas; [2]
Award [0] for a bald statement for either.
- (b) work done = $(P\Delta V) = 3.2 \times 10^6 \times 2.5 \times 10^{-4} = 8.0 \times 10^2 \text{ J}$;
 change in internal energy = $12 \times 150 = 1800 \text{ J}$;
 $-W = Q - (-\Delta U)$;
 substitute to give $Q = 2.6 \text{ kJ}$; [4]
- C2.** (a) *renewable*: hydroelectric/wind/wave/solar
non-renewable: nuclear/gas/coal/oil; [2]
- (b) rotation of coils in a magnetic field / rotation of magnets close to coils / *OWTTE*; [1]
- (c) diagram to show each fission neutron colliding with a U-235 nucleus;
 each producing two more fission neutrons; [2]
Do not penalize answers if more collisions are shown.
- (d) fission is favoured by low energy neutrons / *OWTTE*;
 a moderating material (such as graphite/deuterium) slows down the neutrons /
 reduces their energy as they pass through the material / *OWTTE*; [2]
- (e) as the neutrons are slowed down by the moderator, they heat it up / raise its
 temperature / *OWTTE*;
coils carrying flowing water (under pressure) are wrapped round the moderator /
OWTTE;
 the internal energy/heat of the moderator is transferred to the water converting it
 to steam;
 the steam is used to drive a turbine / *OWTTE*; [4]
Essentially look for a description of a heat exchanger.
*Award marks for an appropriately labelled diagram that illustrates the above
 marking points.*

Option D — Biomedical Physics

- D1.** (a) mass (ratio) $\propto L^3$;
 mass of adult = $\left(\frac{1.8}{0.5}\right)^3 \times 3.4 = 160 \text{ kg}$; [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 = $10 \lg\left(\frac{3.2 \times 10^{-4}}{10^{-12}}\right)$;
 = 85 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 intensity 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 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]

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*: fluorescent screen to detect electrons/beam; [1]
- (b) the measurement implied that the electrons are particles with mass;
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]

Option F — Astrophysics

F1. (a) wavelength peak = 500 nm ;

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

$$= 5800 \text{ K}$$

[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 $L = \sigma AT^4$ to recognize that $\frac{L_A}{L_B} = \frac{R_A^2 T_A^4}{R_B^2 T_B^4}$;

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

$$= 8.3 \times 10^4 ;$$

[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) $d = \sqrt{\frac{L}{4\pi b}}$;

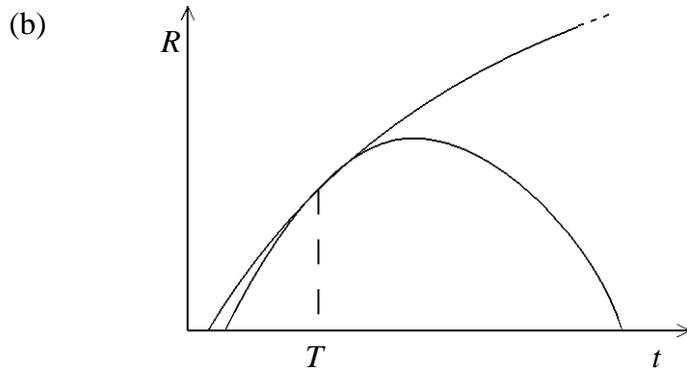
$$\frac{d_{\text{sir}}}{d_{\text{sun}}} = \sqrt{\frac{L_{\text{sir}} b_{\text{sun}}}{L_{\text{sun}} b_{\text{sir}}}} ;$$

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

$$= 5.4 \times 10^5 \text{ AU}$$

[3]

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



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]

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;

Award [0] for incorrect reasoning or no reasoning.

[4]

G2. (a) (i) time interval for Earth observer = $\left(\frac{d}{v}\right) = \frac{5.0 \times 10^{16}}{0.60 \times 3.0 \times 10^8}$;
 $= 2.8 \times 10^8$ s ;

[2]

(ii) $\gamma = 1.25$;

time = $\frac{2.8 \times 10^8}{1.25} = 2.2 \times 10^8$ s ;

or

distance in astronaut frame = 4.0×10^{16} m ;

time = $\frac{4.0 \times 10^{16}}{0.60c} = 2.2 \times 10^8$ s ;

[2 max]

(b) astronaut;

the events of leaving the Earth and arriving at the star occur at the same point according to astronaut;

Award [0] if no explanation or the wrong explanation is given.

[2]

(c) the (biological) age of the astronaut is less than the Earth observer;

because of time dilation;

the situation is not symmetric;

the astronaut experiences forces / accelerations during trip;

[3 max]

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

(b) (i) 6.51MeV (includes rest mass); [1]

(ii) $(E = \gamma m_0 c^2) 6.51 = \gamma \times 0.511$;
 $\gamma = 12.7$;

$$12.7 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad v^2 = 0.994c^2;$$

$$v = 0.997c$$

[3]

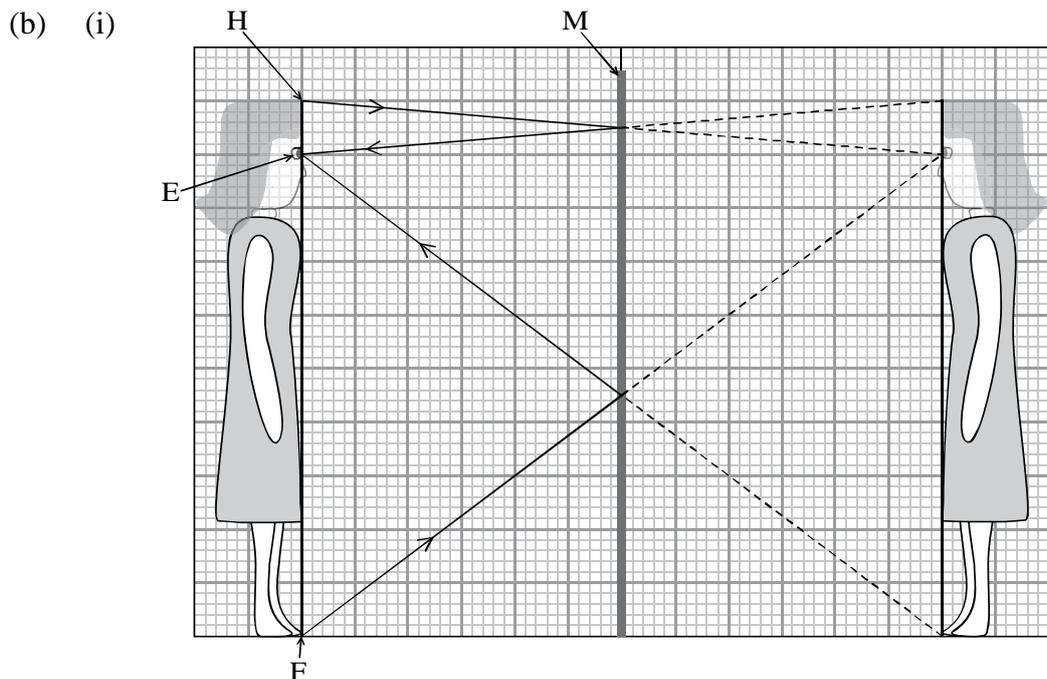
Option H — Optics

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

(b) $= \frac{3.0 \times 10^8}{2.1 \times 10^8}$;
 = 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]



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

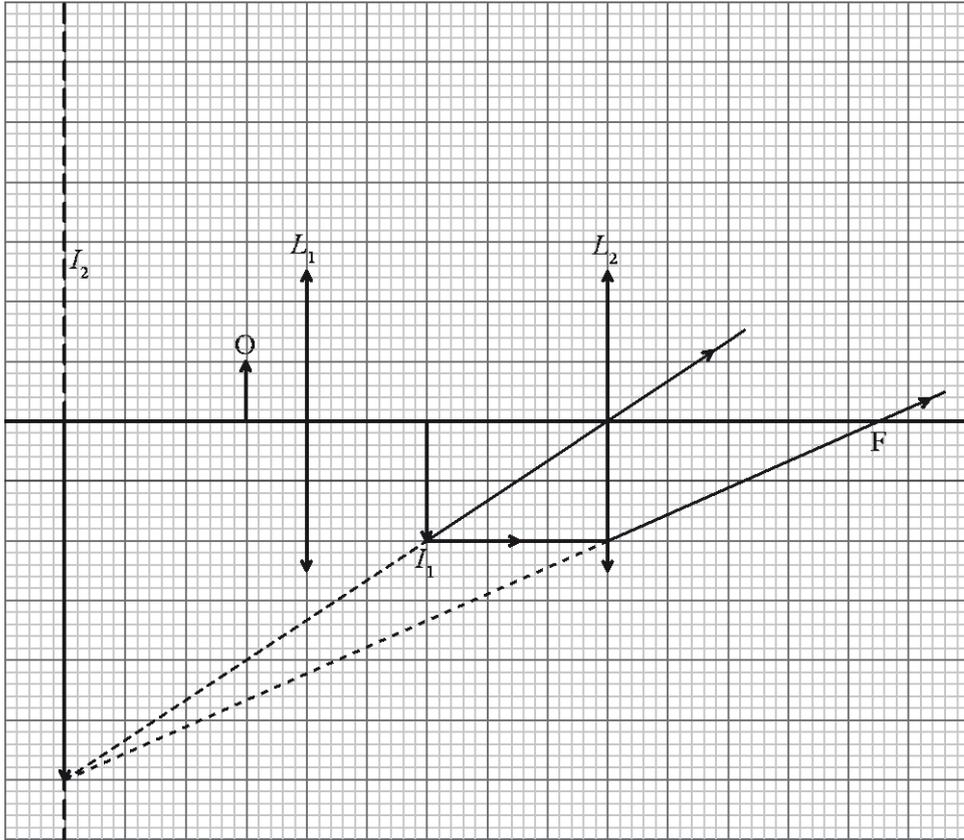
(ii) correct ray construction for F;
 correct ray construction for H;
*The rays should be shown with equal angles at mirror judged by eye.
 Arrows on rays are not required.* [2]

(c) (i) 0.75 (± 0.03) m; [1]

(ii) 0.68 (± 0.03) 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]