MARKSCHEME

November 2005

PHYSICS

Standard Level

Paper 3

14 pages

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.

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.
- 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.
- 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 A — Mechanics Extension

A1. (a) *horizontally*: zero;
vertically: $9.8(1)\,\mathrm{m\,s^{-2}}$ (downwards); ***[2]***

N. B. *Part (b) and part (c) to be marked independently of part (a).*
Deduct ***[1]*** *if answer uses* $g = 10\,\mathrm{m\,s^{-2}}$*, but only once in* ***either*** *part (a)* ***or*** *part (b) but not both.*

(b) $s = ut + \frac{1}{2}at^2$
$33 = \frac{1}{2}\times 9.8\times t^2$;
$t = 2.6\,\mathrm{s}$; ***[2]***

(c) $s = ut$
$= 18\times 2.6 = 47\ (46.8)\ \mathrm{m}$; ***[1]***

A2. (a) (i) work done per unit mass;
in moving (small mass) from infinity to that point; ***[2]***

(ii) gravitational forces are always attractive;
work got out when moving from infinity;
work done against field is negative; ***[2 max]***

(b) (i) $\frac{M_\mathrm{E}}{M_\mathrm{M}} = 81.4$; *(ratio idea is essential)*

$$\frac{(3.46\times10^8)^2}{(3.84\times10^8 - 3.46\times10^8)^2} = 82.9\,;$$

some comment *e.g.* $\frac{M}{R^2}$ should be same so QED;

or:

$$F_{\mathrm{Earth}} = \frac{(G\times5.98\times10^{24})}{(3.46\times10^8)^2} = 5.00\times10^7\,G\,;$$ *(ratio idea is essential)*

$$F_{\mathrm{Moon}} = \frac{(G\times7.35\times10^{22})}{(0.38\times10^8)^2} = 5.09\times10^7\,G\,;$$

some comment *e.g.* about same so QED;

or:

$$\frac{GM_\mathrm{E}}{r^2} = \frac{GM_\mathrm{M}}{(3.84\times10^8 - r)^2}\,;$$ *(ratio idea is essential)*

$$81.4 = \frac{r^2}{(3.84\times10^8 - r)^2}\,;$$

$r = 3.45\times10^8\ \mathrm{m}$; ***[3 max]***

(ii) indicates in some way that $\Delta\mathrm{GPE}$ is change in kinetic energy;
gravitational potential $= \frac{1}{2}v^2$;
$v = 1.6\times10^3\ \mathrm{m\,s^{-1}}$; ***[3]***
*Award **[2 max]** if the answers uses $m = 1\,kg$.*

A3. (a) force downwards due to weight and upwards along rope;
force in rod towards right; ***[2]***
Labels are not necessary.

(b) $42 = T\sin 35$;
$(T = 73.2\ \mathrm{N})$
$T\cos 35 = \mathrm{force}$;
$\mathrm{force} = 60\ \mathrm{N}$; ***[3]***
*Award **[2 max]** if confusion between sin and cos.*

Option B — Quantum Physics and Nuclear Physics

B1. (a) all particles have a wavelength associated with them;
given by $\lambda = \dfrac{h}{p}$, with h and p explained; ***[2]***

(b) kinetic energy of electron $= qV$;
$= 2.00 \times 10^{-16}$ J;
$E_K = \dfrac{p^2}{2m}$ *or* $v^2 = \dfrac{2E}{m}$ and $p = mv$ $(v = 2.1 \times 10^7\ m\,s^{-1})$
$p = 1.91 \times 10^{-23}$ N s;
$\lambda = \dfrac{h}{p}$
$= 3.47 \times 10^{-11}$ m; *(allow 2 significant digits)* ***[4]***

B2. (a) use of diffraction grating/prism and screen/telescope;
observe diffracted/refracted light or first/second orders; ***[2]***

(b) $E = \dfrac{hc}{\lambda}$ *or* $E = hf$ and $c = f\lambda$;
correct substitution into relevant formula clear; ***[2]***
to give energy $= 4.09 \times 10^{-19}$ J
*Award **[0]** for answer alone.*

(c) (i) ———————— -1.35×10^{-19} J
———————— -2.41×10^{-19} J

———————— -5.44×10^{-19} J

level shown in "reasonable" position (spacing of lines not important); ***[1]***
To receive the mark answers must quote -1.35×10^{-19} J.

(ii) transition $-1.35 \times 10^{-19} \rightarrow -5.44 \times 10^{-19}$ (and labelled 486 m)
transition $-1.35 \times 10^{-19} \rightarrow -2.41 \times 10^{-19}$ (and labelled 1880 m); ***[1]***

B3. (a) $T_{\frac{1}{2}} = 2.0$ hours; *(accept exact answers only)*

$\lambda = \dfrac{\ln 2}{T_{\frac{1}{2}}} = 0.35\,\text{hr}^{-1}$; ***[2]***

(b) (i) rate of decay of R = rate of production of D;
at maximum, rate of decay of D = rate of production of D; ***[2]***

(ii) *e.g.* percentage composition varies very slowly with time; ***[1]***

B4. (a) weak (nuclear) force; ***[1]***

(b) antineutrino; ***[1]***

(c) (W^{-}) boson; ***[1]***

Option C — Energy Extension

C1. (a) piston moves distance x so that $\Delta V = Ax$;
force on piston $= pA$;
work done $= Fx$;
$= pAx = p\Delta V$ ***[3]***

(b) extra energy increases internal energy (of gas);
(hence) temperature (of gas) will rise / mean k.e. of atoms increases; ***[2]***

C2. (a) (i) change in pressure and volume where no thermal energy/heat enters <u>or</u> leaves the gas / *OWTTE*; ***[1]***

(ii) gas should be expanded/compressed rapidly / gas is insulated from the surroundings; ***[1]***

(b) (i) either of the "sides"; ***[1]***

(ii) the "top" / the "bottom"; ***[1]***

(c) (i) $\frac{Q}{T} = \text{constant}$

$\frac{164}{340} = \frac{Q}{280}$;

$Q = 135\,\text{J}$; ***[2]***

To receive the marks answers must use K.

(ii) efficiency $= 1 - \frac{T_C}{T_H}$ *or* efficiency $= 1 - \frac{Q_C}{Q_H}$

$= 1 - \frac{280}{340}$; $= 1 - \frac{135}{164}$;

$= 18\%$; $= 18\%$; ***[2 max]***

Treat the use of °C as an ECF if also used in (c)(i).

(d) additional energy losses;
example given *e.g.* friction between cylinder and piston (not just "friction" – the site must be made clear);

or:
Carnot cycle has maximum theoretical efficiency;
cannot achieve ideal isothermal / adiabatic changes; ***[2 max]***

C3. (a) mass incident per unit time $= A\rho v$;
kinetic energy $= \frac{1}{2}mv^2$ <u>leading to</u> $\frac{1}{2}A\rho v^3$; ***[2]***

(b) (i) power $= (\frac{1}{2} \times 1.2 \times \pi \times 7.5^2 \times 9^3) - (\frac{1}{2} \times 2.2 \times \pi \times 7.5^2 \times 5^3)$;
$= 53\,\text{kW}$; ***[2]***

(ii) electrical power $= 53 \times 0.72 = 38\,\text{kW}$; ***[1]***

Option D — Biomedical Physics

D1. (a) V;
large (area) wings to give lift at low speed / wide tail to provide change of direction; ***[2]***

(b) F;
narrow swept-back wings to give little air resistance / narrow body reduces drag / long narrow tail gives guidance at high speed only; ***[2]***

D2. (a) force $=$ pressure (difference) $\times$ area;
pressure (difference) $= p_{\mathrm{S}} - p_{\mathrm{M}}$;
force $= (p_{\mathrm{S}} - p_{\mathrm{M}}) \times A_{\mathrm{T}}$; ***[3]***

(b) (i) ossicles act as a lever system; ***[1]***

(ii) force $= (p_{\mathrm{M}} - p_{\mathrm{I}}) \times A_{\mathrm{O}}$; ***[1]***
to give $(p_{\mathrm{M}} - p_{\mathrm{I}}) = \frac{3}{2} \times \frac{A_{\mathrm{T}}}{A_{\mathrm{O}}} \times (p_{\mathrm{S}} - p_{\mathrm{M}})$
*Award **[0]** for 2nd line only.*

(c) ossicles produce pressure amplification / pressure amplification is $\times 30$ explained;
so that there is transmission, not reflection of the vibrations / there is impedance matching; ***[2]***

D3. (a) (i) curve sloping correct way;
reasonable shape relating *I* and *x i.e.* minimum two cases showing halving *I* for equal increments of *x*; ***[2]***

(ii) $I = I_0 e^{-\mu x}$
I_0 is intensity at $x = 0$;
μ is the attenuation coefficient; ***[2]***

(iii) thickness to reduce intensity to half of its original value; ***[1]***
Do not accept equation.

(b) all tissues in abdominal cavity have about the same value for μ;
without barium meal, little contrast on photo-plate;
"barium meal" has higher / very different value of μ;
giving a clear <u>outline</u> of organ; ***[4]***

Option E — The History and Development of Physics

E1. (a) planet "stops";
and then moves westwards / reverses direction of (apparent) motion; ***[2]***
Marks can be awarded to a clearly drawn and correctly labelled diagram.

(b) (i) plants (move around) epicycles / epicentres; ***[1]***

(ii) (all) planets circle the Sun / heliocentric;
different periods give rise to different angles of sight; ***[2]***

(c) Venus shows phases;
moons of Jupiter;
rotation of the Sun; ***[2 max]***
*Award **[1]** for any other observation.*

E2. (a) (i) caloric flows from high to low temperature regions;
any other relevant comment *e.g.* total quantity of caloric is constant / caloric is indestructible; ***[2]***

(ii) caloric enters into combination with particles / becomes hidden;
and so becomes inactive in raising temperature / *OWTTE*; ***[2]***

(b) (i) boring cannons; ***[1]***

(ii) assumption that amount of caloric in a body is limited is "wrong";
assumption that amount of caloric is related to size of body is "wrong"; ***[2]***

E3. (a) compass needle near current-carrying wire is affected;
showed a link between electric current and magnetism / showed electric current produces magnetic field; ***[2]***

(b) force exerted between (two parallel) current-carrying conductors;
magnetic effect derived from current alone / *OWTTE*; ***[2]***

(c) showed that electric current can be induced by changing magnetic field;
basis for the production / source of electrical energy (on which modern society is dependent); ***[2]***

Option F — Astrophysics

F1. (a) (i) Jupiter; ***[1]***

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

(b) between orbits of Mars and Jupiter / $2\,\text{AU} \rightarrow 3\frac{1}{2}\,\text{AU}$ from Sun; ***[1]***

(c) highly elliptical;
most of orbit outside orbits of furthest planets / large orbits;
orbits are in many different planes; ***[2 max]***

F2. (a) (i) blue (– white); ***[1]***

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

(b) line absorption spectra;
give information on composition (of outer layers);

or:
Doppler Shift / red shift / blue shift;
gives information of speed relative to Earth / gives information as to rotational speed;

or:
intensity-wavelength distribution;
gives information on (surface) temperature;
stellar magnetic fields;
through splitting of emission spectrum lines; ***[4 max]***
*Award **[1]** each for any two sensible comments, plus **[1]** for some detail on each.*

F3. (a) how bright an object appears to be <u>from Earth</u>; ***[1]***
Do not award marks for "magnitude".

(b) (apparent) magnitude if star were to be a "given" distance from Earth;
distance of 10 pc; ***[2]***

(c) by definition, apparent magnitude 1 is 100 times brighter than apparent magnitude 6;
so change in apparent magnitude of 1 is $100^{-5} = 2.5$;
and brightness is proportional to light power output; ***[3]***

(d) at 10 pc, brightness would be $\left(\dfrac{14}{10}\right)^2$ times greater $(=1.96)$;

so magnitude changes by $\dfrac{1.96}{2.5}(=0.78)$;

absolute magnitude $= +0.05 - 0.78 = -0.73$; ***[3]***
Allow full marks for use of $M - m = -5\,lg(d/10)$ leading to -0.68.

Option G — Relativity

G1. (a) frame of reference is at rest <u>or</u> moving at constant velocity / reference frame within which Newton's first law is valid; ***[1]***

(b) laws of physics are the same in all inertial frames of reference;
speed of light in a vacuum is the same in all inertial frames of reference; ***[2]***

(c) (i) larger;
smaller;
larger; ***[3]***

(ii) volume decreases and mass increases; *(do not award "heavier")*
density $= \frac{\text{mass}}{\text{volume}}$;
density increases; *(award this mark only if the first mark is awarded)* ***[3]***
*Award **[0]** for stating "density increases" only.*

G2. (a) $\gamma = 9.14$;
$T_{\frac{1}{2}} = 9.14 \times 1.52 = 13.9\,\mu\text{s}$; ***[2]***

(b) (i) distance $= \frac{4150}{9.14} = 454\,\text{m}$; ***[1]***

(ii) time $= 1.52\,\mu\text{s}$; ***[1]***

(c) (i) observers in different frames of reference measure different times;
(discusses times of $1.52\,\mu s$ and $13.9\,\mu s$ w.r.t. frames of reference *e.g.*) observed time is shortest in rest frame; ***[2]***

(ii) observers in different frames of reference measure different lengths;
(discusses distances of 4150 m and 454 m w.r.t. frames of reference *e.g.*) observed distance is shortest in moving frame; ***[2]***

G3. $u_x{}' = \frac{(u_x - v)}{\left(1 - \frac{u_x v}{c^2}\right)}$

identifies u_x as $0.8c$;
identifies v *as* $-0.8c$;
to give answer of $0.98c$; ***[3]***

Option H — Optics

H1. (a) produced by oscillations of electrically charged particles;
produced by de-excitation of electrons in atoms;
consists of varying electric and magnetic fields;
these fields are normal to each other;
same speed in vacuum as all other e.m. waves; ***[3 max]***

(b) wavelength depends on the medium in which it is being measured;
frequency does not vary; ***[2]***

H2. (a)

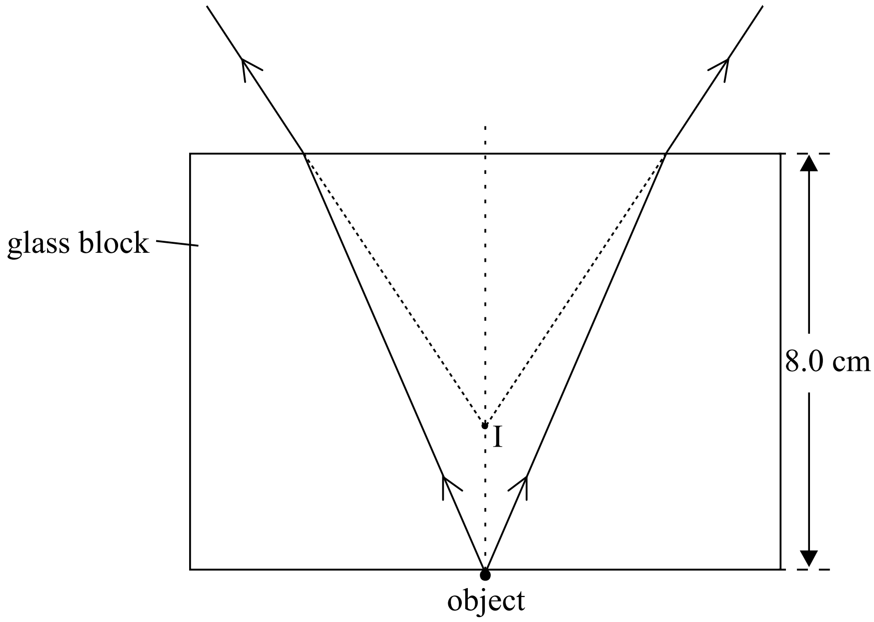
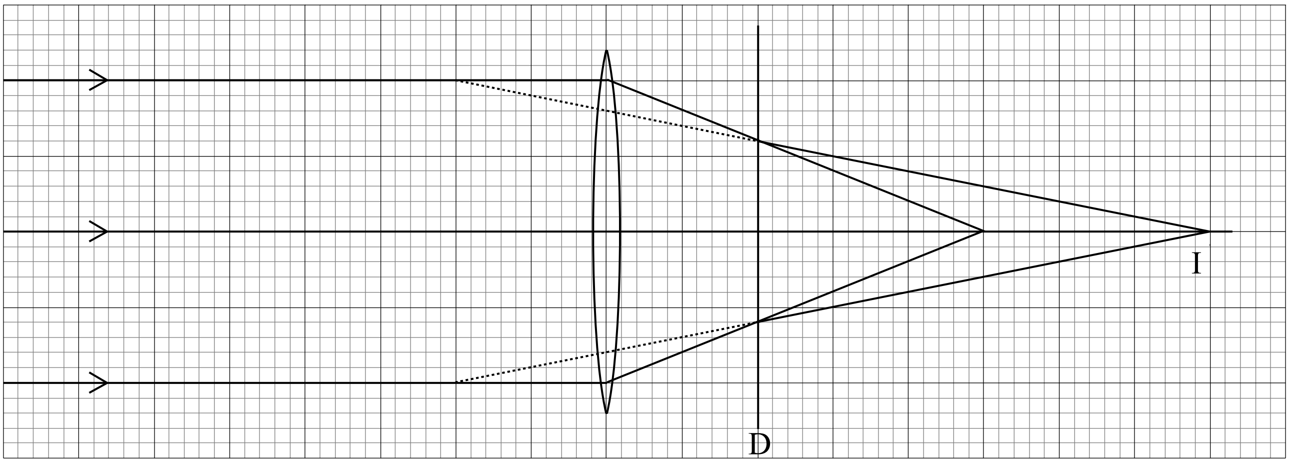


diagram showing correct refraction of one ray at surface;
second ray to give image above object and in lower half of block; ***[2]***

(b) refractive index $= \dfrac{\text{real depth}}{\text{apparent depth}}$;
apparent depth $= 5.4$ cm
image is 5.4 cm below upper surface;
vertically above the object; *(allow mark if also clearly drawn on the diagram)* ***[3]***

(c) assumes $\sin\theta = \theta$ / assumes small angles of incidence; ***[1]***

H3. (a) rays converge to point on axis, 5.0 cm from centre of lens; *(ignore arrows)* ***[1]***



(b) (i) lens position correct; ***[1]***

(ii) $-\frac{1}{15}+\frac{1}{v}=-\frac{1}{30}$;
$v = 30.0\,\text{cm}$; ***[2]***

(iii) correct ray construction shown with *I* labelled; ***[1]***

(c) extrapolated rays shown correctly;
with reasonable estimate of 50.0 (±5.0) cm; ***[2]***

(d) change separation of lenses;
closer together, longer focal length; ***[2]***