MARKSCHEME

November 2006

PHYSICS

Standard Level

Paper 3

19 pages

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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.
- 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 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) moment of weight about the hinge $= 80 \times 0.6$;
moment of F about hinge $= F \times 1.2 \times \sin 50$;
equate and solve;
to give $F = 52\,\text{N}$ ***[3]***
Award full credit for answers using symmetry.

(b) resolve vertically, $V = 52 \sin 50 = 40\,\text{N}$;
resolve horizontally, $H = 52 \cos 50 = 33\,\text{N}$;
$R = (V^2 + H^2)^{\frac{1}{2}} = 52\,\text{N}$;
angle to horizontal $= \tan^{-1} \dfrac{V}{H} = \dfrac{40}{33}$ to the vertical / by symmetry angle to horizontal is 50°;

or

Accept answer from drawing triangle of forces.
appropriate scale;
correct position of $80\,\text{N}$ and $52\,\text{N}$ force;
completion of triangle to give answer $52\,\text{N}\ (\pm 10\,\%)$;
correctly specified angle $\pm 10\,\%$; ***[4]***

A2. (a) the work done per unit mass;
in taking a <u>small</u>/<u>point</u> mass from infinity to that point; ***[2]***

(b) use $\dfrac{mv^2}{R} = G\dfrac{Mm}{R^2}$;
to give $\frac{1}{2}mv^2 = \frac{1}{2}G\dfrac{Mm}{R}$;
$= \frac{1}{2}\langle \text{PE} \rangle$ since $\text{PE} = (-)G\dfrac{Mm}{R}$ ***or*** *OWTTE*; ***[3]***

(c) (i) use $v = \dfrac{2\pi R}{T}$;
to get $v = 1.0 \times 10^3\,\text{m}\,\text{s}^{-1}$; ***[2]***

(ii) KE per kg $= \frac{1}{2}v^2 = \frac{1}{2}(1.0 \times 10^3)^2 = 5 \times 10^5$ <u>$\text{J}\,\text{kg}^{-1}$</u>;
$\text{PE} = -2\text{KE} = -1.0 \times 10^6\,\text{J}\,\text{kg}^{-1}$; ***[2]***
Do not deduct mark if minus sign missing.

A3. (a) use $\frac{1}{2}mv^2 + mgh = \frac{1}{2}mV^2$ ***or*** some statement that conservation of energy is used;

$= \frac{1}{2}(15)^2 + 700 = \frac{1}{2}V^2$;

to give $V = 40\,\text{m}\,\text{s}^{-1}$ ***[2]***

(b) appreciate that the horizontal velocity remains unchanged;

so that $\theta = \cos^{-1}\dfrac{15}{40} = 68^\circ$; ***[2]***

Accept alternative methods of solutions for (a) and (b) based on vertical component of velocity calculations and vector addition of components.

Option B — Quantum Physics and Nuclear Physics

B1. (a) (i) 13.6 eV **[1]**

(ii) $E = \frac{hc}{\lambda}$;

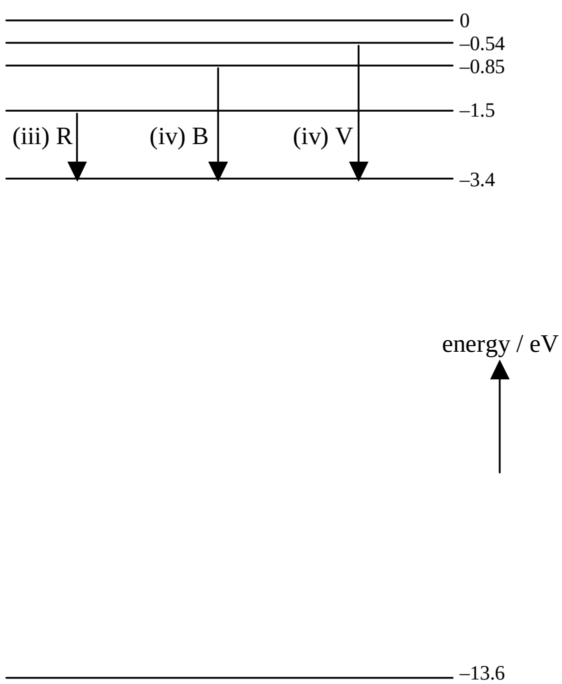
$= \frac{6.6\times10^{-34}\times3\times10^{8}}{6.6\times10^{-7}} = 3\times10^{-19}$ J;

$= \frac{3\times10^{-19}}{1.6\times10^{-19}}$;

$= 1.9$ eV **[3]**

(iii) *see diagram below.* **[1]**

(iv) *see diagram below.* **[1]**
Both must be correct to award ***[1]****.*



(b) $p^2 = 2mE$;

$= 2\times9.1\times10^{-31}\times13.6\times1.6\times10^{-19}$;

to give $p = 2.0\times10^{-24}$ N s;

$\lambda = \frac{h}{p} = \frac{6.6\times10^{-34}}{2.0\times10^{-24}}$;

$= 3.3\times10^{-10}$ m **[4]**

(c) (the model) assumes that electrons are described by wave functions / *OWTTE*;
wave(s) associated with electron(s) is/are bounded by the atom;
this means that for the electron in the ground state the wavelength is $\approx 10^{-10}$ m / *OWTTE*; ***[3]***
These are the basic marking points but candidates might answer with a diagram as well.

B2. (a) the probability that a (particular) nucleus will decay in unit time;

or

$\lambda = \frac{\frac{dN}{dt}}{N}$ with terms defined; ***[1]***

(b) (i) (electro) weak; ***[1]***

(ii) charged vector boson/W boson; ***[1]***
Accept W^+, W^- ***or*** Z^0.

(c) original mass of potassium $= 24 + 5.0 = 29\,\text{mg}$;
recognize to use $N = N_0 e^{-\lambda t}$;
$5.0 = 29\,\text{e}^{-(5.3\times10^{-10}\,t)}$;
to give $t = 3.3\times10^9$ year; ***[4]***

Option C — Energy Extension

C1. (a) the energy transferred between a system and its surroundings;
is equal to the work done by <u>or</u> on the system plus the change in internal energy of the system; ***[2]***
If the candidate uses the formula $\Delta Q = \Delta W + \Delta U$, then they must say something to the effect that "the first law may be expressed mathematically as $\Delta Q = \Delta W + \Delta U$, where ΔW is the work done on the system ΔU is the increase in internal energy…" i.e. terms must be defined.

(b) $(\Delta Q = \Delta W + \Delta U)$
(work is done on the gas, therefore) $\Delta W = -250\ \text{J}$;
$\Delta U = +150\ \text{J}$;
therefore, (from first law) $\Delta Q = -100\ \text{J}$ (the negative sign) showing a transfer of energy from system to surroundings; ***[3]***

(c) (i) work done $=$ area under the graph;
$= 2\times10^{-2}\times14\times10^{5} + 7\times10^{5}\times1.5\times10^{-2}$;
$= 39\times10^{3} \approx 4\times10^{4}\ \text{J}$ ***[2]***

(ii) work done $=$ energy absorbed $-$ energy ejected;
energy absorbed $= 4\times10^{4} + 10\times10^{4} = 14\times10^{4}\ \text{J}$;
$eff = \frac{W}{Q} = \frac{4}{14} \approx 30\,\% / 0.3$; ***[3]***

C2. (a) photovoltaic cell: light energy/energy from the Sun is converted into electrical energy;
active solar heater: light energy/energy from the Sun is converted into thermal energy/heat; ***[2]***

(b) (i) (if x is the power incident on the photovoltaic cell) $x = \dfrac{47\times10^{-3}\times100}{8}$

$= 590\,\text{mW}$;

therefore, power incident per square metre $= \dfrac{590\times10^{-3}}{6.5\times10^{-4}}$;

$\approx 0.90\,\text{kW m}^{-2}$ ***[2]***

(ii) the amount of sunlight varies with season/time of day / *OWTTE*; ***[1]***

(c) (i) (minimum) number of cells required $= \dfrac{3\times10^{3}}{47\times10^{-3}} = 6.4\times10^{4}$;

total area $= 6.4\times10^{4}\times6.5\times10^{-4} = 42\,\text{m}^2$; ***[2]***

(ii) area $= \dfrac{3.0}{0.9\times0.24} = 14\,\text{m}^2$; ***[1]***

(iii) active solar heater;
requires less area / any other relevant reason *e.g.* cost/storage problems; ***[2]***
*Award **[0]** if no reason is given or if reason is incorrect.*

Option D — Biomedical Physics

D1. (a) (i) 4; *[1]*

(ii) 8; *[1]*

(b) $\frac{\text{needs}}{\text{absorption}} \propto \frac{L^3}{L^2} = L$;
as an insect becomes larger, absorption cannot keep pace with needs / *OWTTE*; *[2]*

D2. (a) intensity is power incident per unit area;
loudness is the response of the ear to intensity; *[2]*

(b) substitution into $\beta = 10db\lg\left(\frac{I}{1\times10^{-12}}\right)$
$82 = 10\lg\left(I \times 10^{12}\right)$;
$I = 1.58\times10^{-4}\ \text{W m}^{-2}$;
$I = \frac{2.4}{4\pi r^2}$;
rearrange to give $r^2 = \frac{2.4}{4\pi\times1.58\times10^{-4}}$;
$r = 35\ \text{m}$; *[5]*

D3. (a) the thickness needed to cause a beam to attenuate/be reduced in intensity by 50% / *OWTTE*; *[1]*

(b) indication that the ratio between the linear attenuation coefficients must be the same as the ratio between attenuation coefficients / $\mu_T x_T = \mu_B x_B$;
(therefore) linear attenuation coefficient $= 150\times0.035$;
$= 5.3\ \text{cm}^{-1}$ *[2]*

(c) (i) substitution into $I = I_0 e^{-\mu x}$
$I_B = I_A\ e^{-0.035\times5.0}$;
$\frac{I_B}{I_A} = 0.84$; *[2]*

(ii) substitution to give $\frac{I_C}{I_B} = 3.1\times10^{-12}$; *[1]*

(d) all X-rays stopped by bone so total shadow;
few X-rays stopped by soft tissue/muscle;
so (good) contrast between (air), muscle and bone; *[3]*

Option E — The History and Development of Physics

E1. (a) *Moon*:
moves constantly from west to east;
moves faster than Mars / Mars moves slower than the Moon;

Mars:
sometimes moves east-west / exhibits retrograde motion; ***[3]***

(b) Geocentric model;
Moon, Mars and background stars at different levels above the Earth;
Moon is closer than Mars so moves faster;
Mars moves on <u>epicycles</u> on its path; ***[4]***
Award marks for the use of a diagram with explanation.

(c) Newton realized that the planets were accelerating;
therefore needed a force on the planet;

or

there is a force of attraction between Sun and planets;
that provides a centripetal force / *OWTTE*; ***[2]***

E2. (a) a second charged sphere is brought close to the sphere (in diagram);
such as to cause the insulating rod to deflect / *OWTTE*
the deflection and separation of charges is measured;
deflection is proportional to force; ***[4]***

(b) a series of identical spheres;
one is charged, then the others charged by repeated sharing of charge with the first sphere / *OWTTE*;

or

two identical spheres;
one charged, then charge shared, one discharged and process repeated / *OWTTE*; ***[2]***

E3. (a) diagram with labels to show the glass envelope, (region of vacuum), anode <u>and</u> cathode;
high voltage between the anode and cathode;
shadow seen on glass behind anode; ***[3]***

(b) with the application of magnetic field/electric field (normal) to rays;
rays were deflected, meaning they must be charged; ***[2]***

Option F — Astrophysics

F1. (a) between Mars and Jupiter; ***[1]***

(b) as the Earth orbits the Sun, the Sun moves against the background of stars;
constellations cannot be seen when they are behind the Sun / *OWTTE*; ***[2]***
Award ***[1]*** *for realization that the Earth-Sun-star line falls on different stars through the year and* ***[1]*** *for realization that we cannot see those stars at that time.*

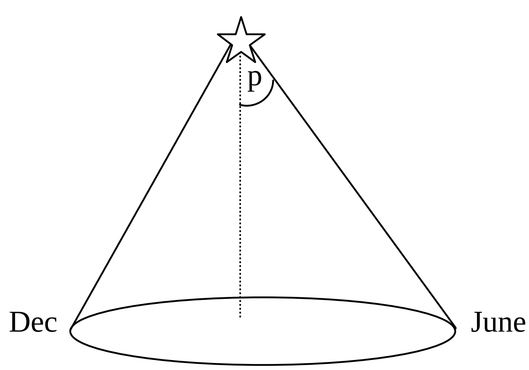
F2. (a) (i) the total power emitted (by the star); ***[1]***

(ii) the (incident) power per unit area on/received at the (surface of) Earth; ***[1]***

(b) (i) spectroscopic parallax; ***[1]***

(ii) use of $b = \dfrac{L}{4\pi d^2}$ to give $d = \sqrt{\dfrac{L}{4\pi b}}$;
$d = 5.3 \times 10^{19}\ \text{m}$;
unit conversion gives 1700 pc; ***[3]***

(c) (i) measure angular position of star (against background of fixed stars);
at six month intervals;
$d = \dfrac{1}{p}$;
p identified; ***[4]***



(ii) $d = \dfrac{1}{5 \times 10^{-3}} = 200\ \text{pc}$; ***[1]***

F3. (a) spectral lines/frequency/wavelength of light from galaxies/distant objects are Doppler shifted to the red;
suggesting that galaxies/distant objects are moving away from each other;

or

Accept argument of Cosmic Microwave Background radiation.
everywhere in space there is a (uniform) radiation corresponding to a (black-body) temperature of 3K / *OWTTE*;
(suggesting) an initially hot universe that has cooled has it has expanded / *OWTTE*; ***[2]***

(b) (the critical density) is the density of the universe for which the expansion rate (of the universe) will slow to zero but never reverse / produces a flat universe; ***[1]***

(c) a knowledge of the density gives knowledge of the future/past of the universe / *OWTTE*;
if $\rho < \rho_C$ then universe will expand forever;
if $\rho > \rho_C$ then universe will eventually reverse its expansion/contraction; ***[3]***

Option G — Relativity

G1. (a) a coordinate system (in which measurements can be made);
that is not accelerating / Newton's first law holds; ***[2]***

(b) there is no preferred inertial reference frame / the laws of physics are the same for all inertial observers;
the speed of light in a vacuum is constant;
in all inertial reference frames/for all inertial observers; ***[3]***

(c) (i) calculation of $\gamma = \frac{1}{\sqrt{1-0.80^2}} = 1.7$;
substitution into $L = \frac{L_0}{\gamma} = 140\,\text{m}$; ***[2]***

(ii) substitution into $u_x{}' = \frac{u_x - v}{1 - \frac{u_x v}{c^2}}$
$u_x{}' = +0.60\text{c}$ and $v = -0.80\text{c}$;
calculation to give $u_x = -0.38\text{c}$;

or

$u_x{}' = -0.60\text{c}$ and $v = +0.80\text{c}$;
(signs are irrelevant, as long as they are opposite)
calculation to give speed $= 0.38\text{c}$ ***or*** $u_x = -0.38\text{c}$; ***[2]***
*Award **[0]** if non-relativistic kinematics is used.*

(iii) towards the star / to the left; ***[1]***

(d) $E = \gamma m_0 c^2 = (5.1\times10^3\,\text{kg})\times(9.0\times10^{16}\,\text{m}^2\,\text{s}^{-2})$;
$E = 4.6\times10^{20}\,\text{J}$; ***[2]***
Allow calculation from $E^2 = p^2c^2 + m_0{}^2c^4$.
Do not deduct unit mark.

G2. (a) the time between any two events that occur at the same place in an inertial reference frame / the proper time in particular reference frame will be measured to be longer;
by observers in any other inertial reference frame; ***[2]***

(b) muons (are produced in the upper atmosphere and) can be detected on the ground;
the half-life/life/average life of a muon in its own frame of reference is not long enough according to an observer on the ground for many of the muons to survive long enough to reach the ground / *OWTTE*;
the observed (ratio of) number detected on the ground (to number detected in the upper atmosphere) is higher than expected;
because the half-life/life/average life of a muon as measured by the an observer on the ground is long enough to for the muons to reach the ground / *OWTTE*;

or

muons (are produced in the upper atmosphere) and can be detected on the ground;
the half-life/life/average life of a muon in its own frame of reference is less than the time it takes to travel through the atmosphere as measured by an observer on the ground / *OWTTE*;
the measured lifetime of such a muon by an observer on the ground is longer than would be measured if the observer were moving with the muon / *OWTTE*;
the difference indicates that time has been dilated (from the short lifetime to the long transit time); ***[4]***

(c) lifetime as measured by Earth observer $\gamma \times 2.20\,\mu\text{s} = 2.20 \times 10^{-5}$ s ;
$\text{distance} = 0.995 \times 3 \times 10^{8} \times 2.20 \times 10^{-5} = 6.57 \times 10^{3}$ m ; ***[2]***

Option H — Optics

H1. (a) splitting/separation (of white light) into its component colours;
because different frequencies have different refractive indices; ***[2]***

(b) (i) both bending away from the normal;
blue greater deviation than red; ***[2]***

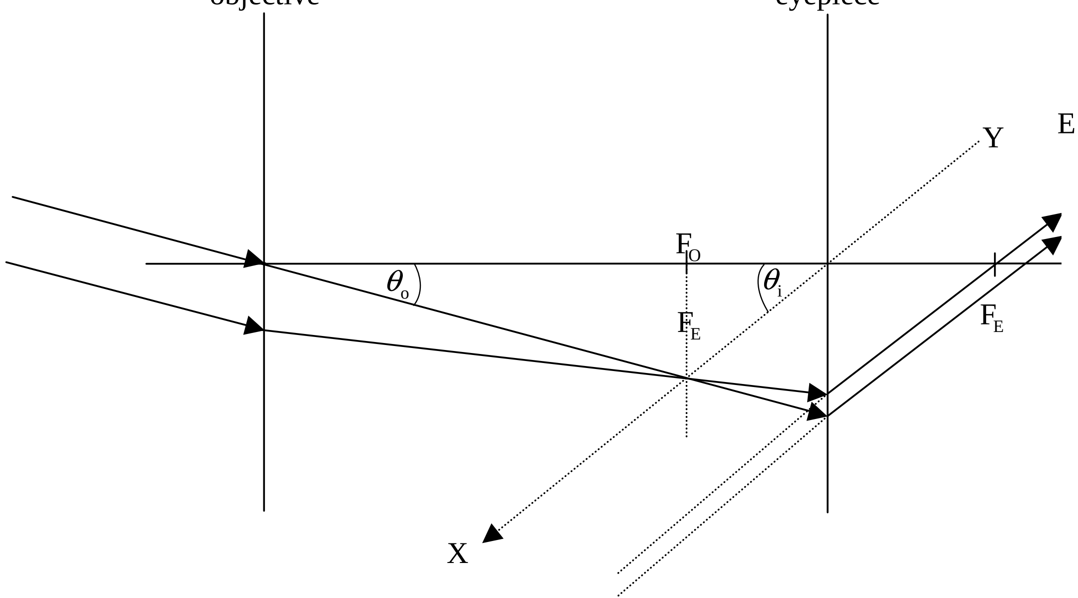
(ii) recognize maximum angle $=$ critical angle, $\sin c = \frac{1}{n}$;

$c = \sin^{-1}\frac{1}{n} = 41.1^{\circ}$; ***[2]***

(iii) the blue light would not pass into the air;
since the refractive index for blue light is greater, therefore critical angle is smaller; ***[2]***
Award ***[0]*** *for wrong explanation or no explanation.*

H2. (a) θ_i – the angle that the image subtends at the eye / at which rays enter/exit the eyepiece lens;
θ_o – the angle that the object subtends at the eye / at which rays enter/exit the objective lens; ***[2]***

(b)



(i) F_E coincident with F_O and correct position on other side of lens-judge by eye; ***[1]***

(ii) two rays passing through focal plane of F_O;
line XY showing direction of final image;
rays emerging from eyepiece parallel to XY; ***[3]***

(iii) to the right of the eyepiece lens; ***[1]***

(iv) correct positions of the angles; ***[1]***

(c) (i) outside edges curve inwards/outwards;
no change to cross; ***[2]***

(ii) no distortion;
all four outside edges appear coloured / *OWTTE*; ***[2]***