International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2008

PHYSICS

Standard Level

Paper 3

16 pages

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 20 marks]**.
Maximum total = **[40 marks]**

1. A markscheme often has more marking points than the total allows. This is intentional. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity 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).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the mark scheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

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 writing **–1(SD)** at the first point it occurs and **SD** on the cover page.

Option A — Mechanics Extension

A1. (a) (i) $v_x = \dfrac{40}{5.0} = 8.0\,\mathrm{m\,s^{-1}}$; ***[1]***

Accept use of other values leading to the same answer.

(ii) $v_y = 0 = u_{0y} - 10 \times 2.5$;

$u_{0y} = 25\,\mathrm{m\,s^{-1}}$; ***[2]***

Accept use of other values leading to the same answer.

(iii) the *x* and *y* components of displacement at 3.0 s are 24 m, 30 m;

so the magnitude is $\sqrt{24^2 + 30^2} = 38\,\mathrm{m}$; ***[2]***

(b) maximum height reached is less;

asymmetric with shorter range; ***[2]***

A2. (a) there is an attractive force between any two point/small masses;

proportional to the product of their masses;

and inversely proportional to the square of their separation; ***[3]***

Accept formula with all terms defined.

(b) equating gravitational force to centripetal force;

$\dfrac{GM}{r} = v^2$;

$v = \dfrac{2\pi r}{T}$;

$\dfrac{4\pi^2 r^2}{T^2} = \dfrac{GM}{r}$;

hence $T^2 = \dfrac{4\pi^2 r^3}{GM}$ ***[4]***

Accept combination of more than one marking point in one statement.

A3. (a) idea of torque = force × perpendicular distance;

torque of each force is = $15.0 \times 0.120 = 1.80\,\mathrm{N\,m}$;

torques must be added to give 3.60 N m; ***[3]***

(b) moment of F about $\mathrm{M} = \mathrm{F} \times \sin 65^\circ \times 0.180$;

$\mathrm{F} \times \sin 65^\circ \times 0.180 = 3.60$;

$\mathrm{F} = 22.1\mathrm{N}$; ***[3]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) the electron in the hydrogen atom exists in states of specific energy;
a photon is emitted every time a transition to a lower energy state is made, of energy equal to the difference in energy between the levels involved in the transition;
since the photon energy is given by $E = hf$ the frequency of the emitted photon is specific / *OWTTE*; ***[3]***

(b) (i) the energy can only have the values given on the diagram / energy corresponds to $n = 1$, 2 *etc.*; ***[1]***

(ii) the energy difference is 10.2 eV;
$\frac{hc}{\lambda} = 10.2 \Rightarrow \lambda = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{10.2\times1.60\times10^{-19}}$;
$= 1.22\times10^{-7}$ m ***[2]***

(iii) as *n* increases energy levels become closer together;
energy transitions (between levels) become more equal hence wavelengths become more equal / *OWWTE*; ***[2]***

(c) particles have an associated wavelength;
the electron in the atom has an undefined position;
the square of the wavefunction gives the probability of locating the electron;
the electron wavefunction has to fit boundary conditions that leads to energy levels; ***[4]***

B2. (a) $^{207}_{81}\text{Tl} \rightarrow {}^{207}_{82}\text{Pb} + {}^{0}_{-1}e + \bar{v}$
inclusion of electron ${}^{0}_{-1}e$;
inclusion of antineutrino $\bar{v}$; ***[2]***
Do not accept beta plus decay.

(b) (i) the nucleus is in an excited state;
drops to the ground state by emission of gamma ray photons; ***[2]***

(ii) beta decay involves the emission of antineutrinos;
energy is shared between the produced particles; ***[2]***

(c) (i) the weak interaction; ***[1]***
Accept the electromagnetic interaction for those who concentrated on the photon emitted.

(ii) W boson; ***[1]***
Accept the photon for those who have the electromagnetic interaction in (i).

Option C — Energy Extension

C1. (a) use of $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;

$T_2 = \frac{V_2}{V_1} T_1 = \frac{6}{2} \times 300 = 900$ K; ***[2]***

(b) $W\left(= p\Delta V = 12\times10^5 \times 4.0\times10^{-3} = 4.8\times10^3\,\text{J}\right) = 4.8\,\text{kJ}$;

$Q = \left(4.8\,\text{kJ} + 7.2\,\text{kJ}\right) = 12\,\text{kJ}$; ***[2]***

Award full marks for correct answer without work shown.

(c) the (magnitude of the) temperature change is the same;
the gas is ideal and so the change in internal energy depends only on temperature; ***[2]***

(d) (i) for the full cycle $\Delta U = 0$;
therefore the net work is $4.8 - 2.6 = 2.2$ kJ;

or

net thermal energy in is 12 kJ and net thermal energy out is $7.2 + 2.6 = 9.8$ kJ;
so work done is $12 - 9.8 = 2.2\,\text{kJ}$;

or

work is area in loop;
area $= 4.8 - 2.6 = 2.2$ kJ ; ***[2]***

(ii) efficiency is
$\frac{2.2}{12}$;
$= 0.18 / 18\%$; ***[2]***

C2. (a) non renewable since the stocks of uranium cannot be replenished/will run out; ***[1]***

(b) (i) $x = 2$; ***[1]***

(ii) each neutron can fission another uranium nucleus;
The neutrons produced in this fission can produce further fissions and so on; ***[2]***
Accept the use of an appropriate diagram.

(iii) use of control rods to absorb excess neutrons;
some further detail *e.g.* lowering or raising control rods to control rate of absorption; ***[2]***

(c) K.E. of fission fragments and neutrons;
transferred to thermal energy in core and moderator;
thermal energy carried away by coolant / reference to heat exchange in reactor; ***[3]***

(d) no greenhouse gases are emitted / fuel source will last longer / no need for tall chimneys / any other suitable point; ***[1]***

Option D — Biomedical Physics

D1. (a) $D \propto L^3$;
$R \propto L^2$;
$\frac{D}{R} \propto L$; ***[3]***

(b) as L increases demand cannot keep up with rate of absorption / *OWTTE*;
hence upper limit to size; ***[2]***

D2. (a) conductive: vibrations are not passing from outer to inner ear;
sensory: no nerve response; ***[2]***

(b) line always above given line;
limits close up to give smaller range; ***[2]***

(c) $10\lg(\text{ratio}) = 15\,\text{dB}$;
and so ratio $= \left(10^{1.5}\right) = 32$; ***[2]***

D3. (a) the transmitted intensity is reduced to $\frac{1}{e}$ of the incident intensity when the distance through the material is the inverse of the attenuation coefficient / the constant in $I = I_0 e^{-\mu x}$ where the symbols are all defined / $\frac{\ln 2}{x_{\frac{1}{2}}}$ with $x_{\frac{1}{2}}$ defined / stated as half value thickness; ***[1]***

(b) recognize to use $x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$;
the half-value thickness is about 1.12 mm;
and so the attenuation coefficient is $\frac{\ln 2}{1.12} = 0.62\,\text{mm}^{-1}$; ***[3]***
Accept answers in the range 0.618 to 0.630.

(c) the attenuation coefficient for bone is greater than that for muscle;
more attenuation for bone so lighter image for bone / *OWTTE;* ***[2]***

(d) X-ray image of section taken at different angles;
these images combined using computers;
to form a two-dimensional image of section;
images of many sections obtained;
image can be rotated for viewing from any angle; ***[3 max]***

Option E — The History and Development of Physics

E1. (a) (i) the stars were permanently fixed on the (celestial sphere);
which rotated around the Earth; ***[2]***

(ii) the Earth rotates around its axis so stars appear to move on arcs; ***[1]***

(b) 6 ± 2 hours; ***[1]***

E2. (a) Brahe made very extensive observations of the motion of the planets (which were characterized by extraordinary accuracy);
Kepler used Brahe's observations to work out the path of the planets (that gave agreement with the observations); ***[2]***

(b) Newton used his laws of gravitation and mechanics;
to derive Kepler's laws;
the derivation implies application to all bodies including comets / *OWTTE*; ***[3]***

E3. (a) caloric is a massless, frictionless fluid;
flows from hot to cold;
amount determines the temperature of the body; ***[2 max]***

(b) heating by friction / change of phase / change of mass in burning; ***[2]***
Award second point for any explanation appropriate to example given.

E4. (a) one metal sphere is charged and placed at the end of the horizontal rod;
another charged sphere is brought close to it;
the angle of twist is measured;
angle of twist is proportional to force;
separation of spheres measured;
the separation was varied and the force measured again $\left(\text{to reveal that } F \propto \frac{1}{d^2}\right)$; ***[5 max]***

(b) two identical spheres, one with charge Q and the other neutral, will have equal charges $\frac{Q}{2}$ when touched;
this process is repeated to get a charge $\frac{Q}{4}$ and so on; ***[2]***

Option F — Astrophysics

F1. (a) comets have long periods;
the orbits are very elliptical;
many have orbits off the plane of the ecliptic; ***[1 max]***

(b) volume occupied by a star is about $2^3 = 8\ \text{pc}^3$;
so number of stars is $\frac{10^{12}}{8} \approx 10^{11}$; ***[2]***
Accept any answer from 1.0×10^{11} *to* 2.4×10^{11} *(for those using sphere packing) to at most 2 s.f.*

F2. (a) power received (from a star) by an observer (on Earth) per unit area (of the detector);

a measure of the brightness of a star as it appears from Earth (in a relative classification system); ***[2]***

(b) (i) Delta Cephei because it has a larger apparent brightness; ***[1]***

(ii) Delta Cephei is closer;
because although (intrinsically) dimmer, appears brighter; ***[2]***
Award the first marking point only if second is also awarded.

(c) the surface of the star is pulsating / getting larger and smaller;
the luminosity varies because the surface area changes; ***[2]***

(d) (i) locate a Cepheid in the galaxy;
measure period to find luminosity;
distance may be determined from the relation between apparent brightness and luminosity; ***[3]***

(ii) the period is 10 days and so the peak luminosity is
$3000 \times 3.9 \times 10^{26} = 1.17 \times 10^{30}$ W;
correct substitution $d = \sqrt{\frac{L}{4\pi b}} = \sqrt{\frac{1.17 \times 10^{30}}{4\pi \times 7.2 \times 10^{-10}}}$;
$d = 1.1 \times 10^{19}\ \text{m}\ (= 1200\ \text{ly} = 370\ \text{pc})$ ***[2]***

F3. (a) electromagnetic radiation/(blackbody) radiation in the microwave region that fills the universe;
and is received from all directions in the universe / is essentially isotropic / *OWTTE*; ***[2]***

(b) CMB is characteristic of black body radiation at 3 K;
the universe was hot in its early stages;
and has cooled down because of the expansion of the universe; ***[3]***

Option G — Relativity

G1. (a) (i) 1.90 c; ***[1]***

(ii) $u = \dfrac{u' + v}{1 + \dfrac{u'v}{c^2}}$;

correct substitution to get $u = \dfrac{c + 0.900\,c}{1 + \dfrac{c \times 0.900\,c}{c^2}}$;

$u = c$; ***[3]***

Do not accept bald answer $u = c$.

Award ***[1 max]*** *for use of incorrect formula.*

$u' = \dfrac{u - v}{1 - \dfrac{uv}{c^2}}$ *leading to answer* $u' = c$.

G2. (a) (i) time is $\dfrac{6.0\text{ ly}}{0.80\,c} = 7.5\text{ y}$; ***[1]***

(ii) calculation of gamma factor $\gamma = \dfrac{1}{\sqrt{1 - 0.8^2}} = \dfrac{5}{3} = 1.67$;

to get time $= \dfrac{7.5}{\gamma} = 4.5\text{ y}$;

or

calculation of gamma factor $\gamma = \dfrac{1}{\sqrt{1 - 0.8^2}} = \dfrac{5}{3} = 1.67$;

length contraction of 6.0ly to get $d = \dfrac{6.0}{\gamma} = 3.6$ ly and so time is $\dfrac{3.6}{0.80\,c} = 4.5\text{ y}$; ***[2]***

(b) (i) the length of an object in its rest frame / length measured by (inertial) observer with respect to whom object is at rest; ***[1]***

(ii) $L = \dfrac{40}{\gamma}$;

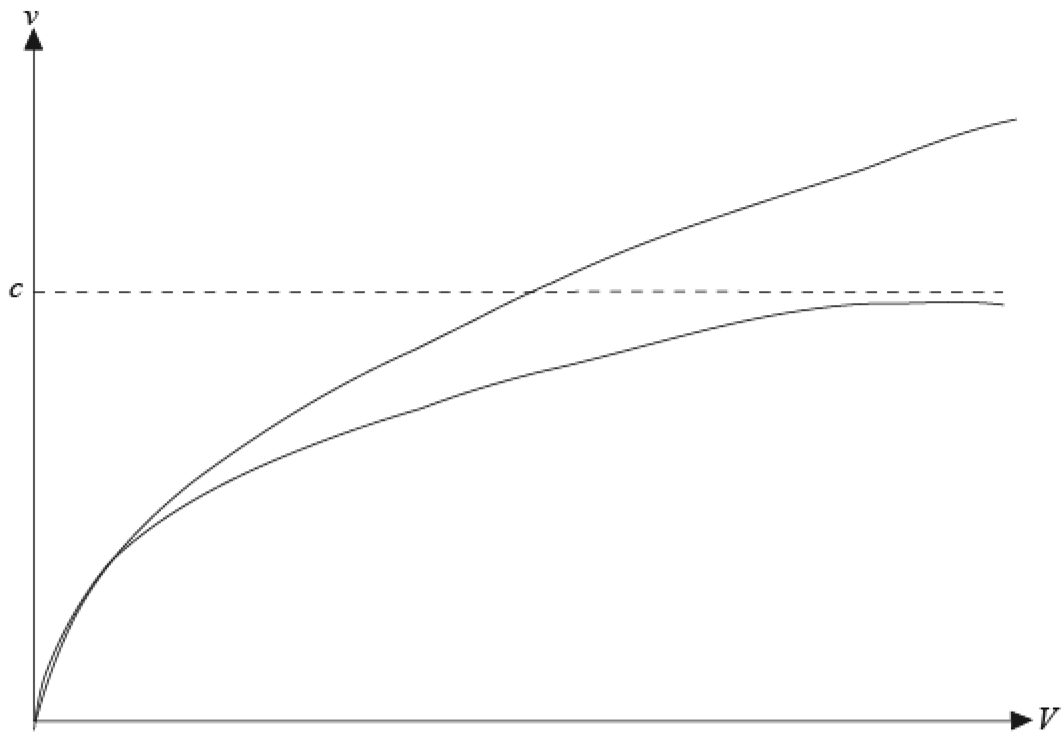
$= 24\text{ m}$; ***[2]***

(c) (i) from Tom's point of view both signals travel at the same speed (and have been emitted simultaneously);
so since the front of the station moves towards the signal, the front gets the signal first; ***[2]***
*Award **[1]** for the correct answer without explanation or incorrect explanation.*
Beware of the incorrect argument that Tom travels towards the front mirror.

(ii) arrivals of reflected signals are simultaneous for Jerry (because he is in the middle of the space station);
since arrivals occur at the same point in space they are simultaneous for all other observers as well, including Tom; ***[2]***
*Award **[1]** for the correct answer without explanation or incorrect explanation.*

G3. (a) calculation of gamma factor from $\gamma = \frac{1}{\sqrt{1-0.998^2}} = 15.8$;
total energy of proton is then $E = 15.8 \times 938 = 14.8\ \text{GeV}$;
hence electrical potential energy is $(14.8 - 0.938) = 13.9\ \text{GeV}$;
and so accelerating voltage is $V = 13.9\ \text{GV}$; ***[4]***

(b) curve that is identical to Newtonian curve for small velocities / curve that is below Newtonian curve;
and approaches speed of light asymptotically;
as in the following graph:



[2]

Option H — Optics

H1. (a) the ratio of the speed of light in vacuum to the speed of light in the medium / the ratio of the sine of the angle of incidence to the sine of the angle of refraction; *[1]*

(b) (i) $45°$; *[1]*

(ii) critical angle must be at most $45°$;
$n \sin 45° = 1$;
to give $n = 1.4$; *[3]*
Award full marks for correct answer even if work is not shown.

(c) blue light has a larger index of refraction;
and so the critical angle is less than $45°$ (so total internal reflection still occurs); *[2]*

or

blue light has a larger index of refraction so total internal reflection takes place;
all colours follow same path;

H2. (a) the point on the principal axis of the lens;
through which a ray parallel to the principal axis goes after refraction in the lens / *OWTTE*; *[2]*

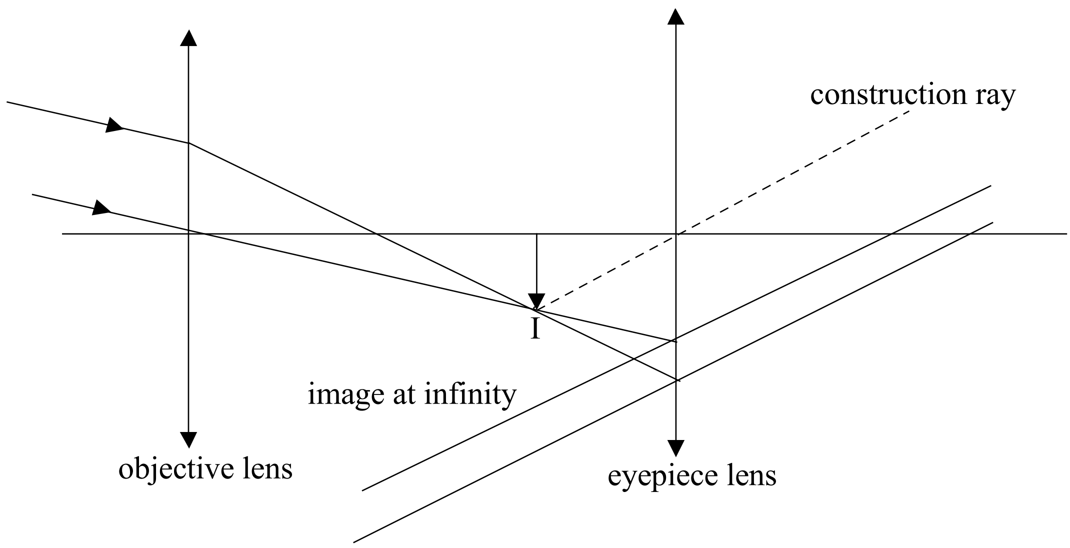
(b) for $u = 30$ cm, $v = 30$ cm;
for $u = 25$ cm, $v = 37.5$ cm;
distance moved $= 7.5$ cm;
away from lens;

or

for those using a scaled diagram:
choice of suitable scale;
correct construction of both images;
measurement of separation between 6.0 and 9.0 cm;
correct statement of direction of displacement; *[4]*

H3. (a) $f_0 + f_e$; *[1]*

(b) construction of ray from tip of image through pole of eyepiece / parallel to principal axis from tip of image and then through F to right eyepiece;
rays from image extended to eyepiece lens;
rays from eyepiece parallel to construction ray;
rays produced to show final image at infinity; *[4]*
Do not penalize if rays do not have arrows.



(c) (i) ratio of angle subtended by image at eye to angle subtended by object at eye; *[1]*

(ii) $\frac{f_0}{f_e}$; *[1]*