International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2008

PHYSICS

Standard Level

Paper 3

21 pages

General Marking Instructions

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.

10. Only consider units at the end of a calculation. Omission of units should only be penalized once in the paper.

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*

Option A — Mechanics Extension

A1. (a) (i) $\left(\sqrt{1800}\right) = 42\,\mathrm{m\,s^{-1}}$; ***[1]***

(ii) $\left(\sqrt{2600}\right) = 51\,\mathrm{m\,s^{-1}}$; ***[1]***

(b) $(V_V) = \sqrt{2600-1800}$;
$= 28\,\mathrm{m\,s^{-1}}$; ***[2]***

*Allow **[3 max]** for (a) and (b) if factor 2 missing. Allow **[1]** for $v^2 = 2gh$.*

A2. (a) $T^2 \propto R^3$ where T is the period of orbit and R is the radius of orbit; ***[1]***

(b) (i) gravity/gravitational; ***[1]***

(ii) $\dfrac{2\pi r}{T}$; ***[1]***

(c) centripetal force $= \dfrac{mv^2}{r} = G\dfrac{mM_\mathrm{E}}{r^2}$;

$\dfrac{4\pi^2 r}{T^2} = G\dfrac{M_\mathrm{E}}{r^2}$;

$T^2 = \dfrac{4\pi^2}{GM_\mathrm{E}} r^3$;

$\left(\text{so constant} = \dfrac{4\pi^2}{GM_\mathrm{E}}\right)$ ***[3]***

(d) $g = \dfrac{GM_\mathrm{E}}{{R_\mathrm{E}}^2}$; ***[1]***

Correct symbols for M_E and R_E needed to receive the mark.

(e) $GM_\mathrm{E} = g_0 {R_\mathrm{E}}^2$;

$T^2 = \dfrac{4\pi^2}{g_0 {R_\mathrm{E}}^2} r^3$;

$T^2 = \dfrac{4 \times \pi^2 \times \left(2R_\mathrm{E}\right)^3}{g_0 {R_\mathrm{E}}^2} = \dfrac{40 \times 8 \times 6.4 \times 10^6}{10}$;

to give $T = 1.4 \times 10^4\,\mathrm{s}$ ***[3]***

A3. (a) (i) $Mg\sin\theta$; ***[1]***

(ii) $Mg\cos\theta$; ***[1]***

(b) frictional force $= \mu_K Mg\cos\theta$;
net force $= Mg\sin\theta - \mu_K Mg\cos\theta$; ***[2]***

(c) $Mg\sin\theta - \mu_K Mg\cos\theta = 0.60\,Mg$;
$0.5 - 0.87\mu_K = 0.15$;
$\mu_K = 0.40$ ***[2]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) all particles/bodies have wave properties/an associated wavelength;
the wavelength is given by $\lambda = \dfrac{h}{p}$ where p is momentum and h the Planck constant; ***[2]***

(b) $\text{momentum} = 80 \times 5.0 = 400\,\text{N s}$;
$\lambda = \left(\dfrac{6.6 \times 10^{-34}}{400}\right) = 1.7 \times 10^{-36}\,\text{m}$; ***[2]***

B2. (a) (i) whenever a charged particle is accelerated it radiates e.m. radiation / *OWTTE*;
<u>due to collision with target atoms</u> accelerations of all different magnitudes result so many different wavelengths produced / *OWTTE*; ***[2]***

(ii) characteristic spectra results from accelerated electrons ejecting electrons from deep energy levels in the molybdenum atoms / *OWTTE*;
photons are emitted when electrons from higher levels move to the vacancies in these levels / *OWTTE*;
$20\,\text{kV}$ acceleration does not give electrons enough energy to cause excitation from deep energy levels / *OWTTE*; ***[3]***

(b) $\dfrac{hc}{\lambda} = Ve$;
$\lambda = \left(\dfrac{hc}{Ve}\right) = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{15 \times 10^{3} \times 1.6 \times 10^{-19}}$;
to give $\lambda = 8.3 \times 10^{-11}\,\text{m}$; ***[3]***

B3. (a) (i) *proton number*: 55;
neutron number: 74; ***[2]***

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

(iii) weak (interaction); ***[1]***

(iv) uud (group) changes to ddu (group); ***[1]***

(b) $\lambda = \dfrac{0.69}{2.2} = 0.32\,\text{hr}^{-1}$;
$\dfrac{N}{N_0} = e^{-\lambda t} = e^{-0.31 \times 6.0} = 0.15$;

therefore reduction in activity = 85 % ; ***[3]***

Option C — Energy Extension

C1. (a) a change in the pressure, volume and temperature of the gas;
in which there is no energy exchange between the gas and its surroundings; ***[2]***

(b) (i) $B \rightarrow C$: isobaric;
$D \rightarrow A$: isochoric/isovolumetric; ***[2]***

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

(c) $eff = \dfrac{W}{Q_{\text{in}}}$;
$W = (0.4 \times 900) = 360\,\text{J}$;
area ABCD equals the work done $= 360\,\text{J}$; ***[3]***

(d) BC is an isothermal (change) / temperature at B is the same as temperature at C;
DA is an isothermal (change) / temperature at D is the same as temperature at A; ***[2]***

C2. (a) *photovoltaic cell*: converts light energy into electric energy;
active solar heater: converts light energy into thermal energy; ***[2]***

(b) energy lost per second by the water $= 4.0 \times 10^3 \times 4200 \times \dfrac{0.38}{3600}$;
$= 1.8 \times 10^3\,\text{W}$;
area needed $= \left(\dfrac{1.8 \times 10^3}{720}\right) = 2.5\,\text{m}^2$; ***[3]***

C3. (a) when neutrons collide with nuclei of U-235 they can cause fission / undergo capture by the nuclei;
low energy/slow neutrons are much more likely to produce fission;
so maintaining the nuclear fission; ***[2 max]***

(b) (i) kinetic (energy); ***[1]***

(ii) thermal (energy) in pile/moderator;
thermal energy in coolant; ***[2]***

Option D — Biomedical Physics

D1. (a) (i) 27; ***[1]***

(ii) 9; ***[1]***

(b) ratio of pressures $= 3$;
therefore mother exerts greater pressure and will sink further / some comment to justify conclusion; ***[2]***

D2. (a) (minimum) intensity (in $\mathrm{W\,m^{-2}}$) that can just be detected by the ear; ***[1]***

(b) recognize that change in intensity level $= 10\lg\left(\dfrac{3\times10^{-6}}{10^{-6}}\right)$;

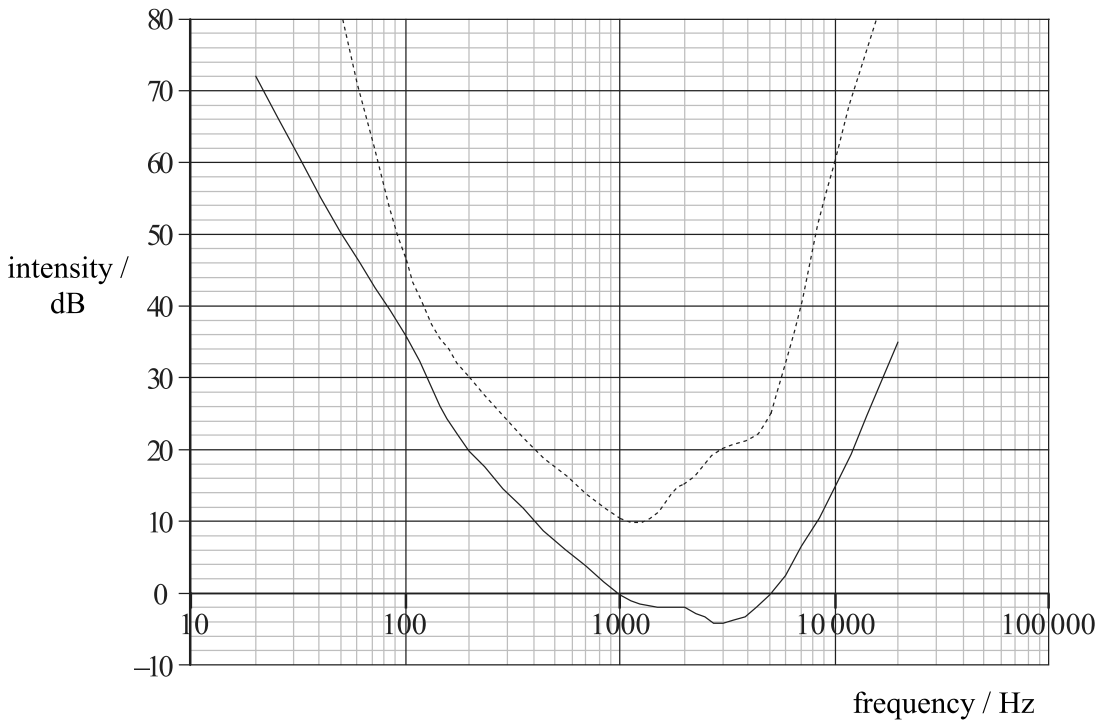
Accept also use of $I = 1\times10^{-6}$ to get 60 dB, then use of 3×10^{-6} to get 64.8 dB.

$= 4.8\,\mathrm{dB}$; ***[2]***

(c) $20 = 10\lg\left(\dfrac{I}{I_0}\right)$;

$\left(\dfrac{I}{I_0}\right) = 100$; ***[2]***

(d)



increased intensity at all frequencies;

frequency range is reduced;
overall shift as shown / larger difference in intensity for higher frequencies; ***[3]***

D3. (a) $3\,\text{MHz}\,(\pm 2\,\text{MHz}) \rightarrow 15\,\text{MHz}\,(\pm 5\,\text{MHz})$; ***[1]***

(b) *A-scan*: one dimensional;
B-scan: two dimensional; ***[1]***
Both needed to receive the mark.

(c) *advantage*: good resolution / produces sharp image;
disadvantage: poor depth penetration / not able to scan organs deep within the body / *OWTTE*; ***[2]***

(d) bone thickness $= 5 \times$ half-value thickness : muscle thickness $= 2 \times$ half-value thickness;
bone intensity reduced by $\frac{1}{32}$: muscle by $\frac{1}{4}$; $\left(\textit{accept use of } \frac{31}{32} : \frac{3}{4}\right)$
ratio $= \frac{1}{8}$; ***[3]***

(e) much greater reduction in intensity by bone, therefore image gives good contrast between muscle and bone; ***[1]***

Option E — The History and Development of Physics

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

(b) the stars are fixed to the surface of a sphere whose centre is at the Earth;
the surface rotates about the Earth; ***[2]***

(c) Kepler's laws are empirical laws;
Newton proposed a universal law of attraction between all bodies/particles;
this law applied to the planets and Sun;
Newton's law enabled Kepler's laws to be derived/explained/given theoretical backing; ***[3 max]***
Allow any other salient points.

E2. (a) the stone pushes aside the air in front of it;
which then fills the void created behind the stone as it moves through the air so pushing the stone along / *OWTTE*;
however, the stone eventually falls to Earth as this is its natural motion; ***[3]***

or

the stone's motion sets into motion a column of air alongside it;
this motion of this column of air drags the stone along with it / *OWTTE*;
however, the stone eventually falls to Earth as this is its natural motion;

(b) all objects will remain in a state of rest <u>or</u> motion in straight-line unless acted upon by an external force; ***[1]***

E3. (a) caloric theory of heat proposed that heat was a substance;
the mechanical equivalent of heat is the amount of mechanical work needed to produce a given temperature rise in a given mass of water / *OWTTE*;
its measurement showed that heat was energy and not a substance; ***[3]***

(b) energy in 1 litre $= (6.0 \times 10^4 \times 500) = 3.0 \times 10^7$;

equivalence $= \dfrac{3.0 \times 10^7}{7.1 \times 10^6} = 4.2$ (J per unit of caloric); ***[2]***

E4. (a) to accelerate and collimate/*OWTTE* the electrons; ***[1]***

(b) a potential difference is applied to the plates P_1 and P_2;
with P_1 + ve; ***[2]***

(c) (i) between P_1 and P_2; ***[1]***

(ii) to measure the speed of the electrons / return electrons to un-deflected path; ***[1]***

Option F — Astrophysics

F1. (a) *stellar cluster*: a group of stars (with gas and dust) held together by gravity/ forming a globular/open arrangement;

galaxy: a large-scale collection/large number of stars/star clusters, gas, and dust; ***[2]***

(b) 10^{-6}; ***[1]***
Accept interval within 10^{-5} and 10^{-7}.

F2. (a) *apparent brightness*: power incident per square metre of surface of Earth;
apparent magnitude: a measure of how bright a star appears (to the eye) viewed from Earth; ***[2]***

(b) measure the blackbody spectrum (of the star) / analysis of intensity-wavelength graph;
to find the wavelength at which the emitted energy is a maximum; *Accept statements in terms of peak wavelength.*
use Wien's displacement law ***or*** $\lambda_{\max} = \frac{2.90 \times 10^{-3}}{T}$ to find temperature; ***[3]***

(c) (i) $4.93 \times 10^{5}\ \text{AU} = 2.39\ \text{pc}$ ***or*** distance less than $100\ \text{pc}$;
(which is easily) measured by (stellar) parallax; ***[2]***

(ii) lower temperature than the Sun and further away from the Sun;
therefore less bright so apparent magnitude is greater; ***[2]***

(iii) $L = 4\pi d^{2} b$;
$d = (4.93 \times 10^{5} \times 1.50 \times 10^{11}) = 7.40 \times 10^{16}\ \text{m}$;
$L = 4 \times 3.14 \times 7.40^{2} \times 10^{32} \times 1.97 \times 10^{-12}$;
$= 1.35 \times 10^{23}\ \text{W}$ ***[3]***
Carefully verify the correct use of numerical values to reach the answer.

(d) $A = \frac{L}{\sigma T^{4}}$;
$= \left(\frac{1.35 \times 10^{23}}{5.67 \times 10^{-8} \times (4.00 \times 10^{3})^{4}} \right) = 9.30 \times 10^{15}\ \text{m}^{2}$; ***[2]***

F3. (a) that it is uniform / stars are uniformly distributed; ***[1]***
Accept also homogenous or isotropic.

(b) in every direction that one looked one would see a star;
hence the sky should never be dark; ***[2]***
Accept reasoning based on intensity $\propto r^{-2}$ *but number* $\propto r^{2}$.

Option G — Relativity

G1. (a) a system of coordinates;
that enables the position of various objects to be specified / that enables measurements to be made / *OWTTE*; ***[2]***

(b) (i) Myron: $L' = x_2' - x_1'$;

Linda: $L = x_2 - x_1 = (x_2' + vt) - (x_1' + vt)$

$L = x_2' - x_1' = L'$; ***[2]***

(ii) $\gamma(x_1 - x_2) = x_1' - x_2'$;

where $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ with c being the free space speed of light / speed of light in a <u>vacuum</u>; ***[2]***

(iii) Linda and Myron are inertial observers;
if not measured simultaneously the distance between the ends of the rod can have different values;
(because one of the postulates of relativity states) the speed of light in a vacuum is the same for all inertial observers; ***[3]***

(iv) Michelson and Morley could detect no difference in the time it takes light to travel equal path lengths that are perpendicular to each other / *OWTTE*;
this indicates that the speed of light is constant for all inertial observers; ***[2]***

(c) (i) Myron
(since this is) the time interval between two events measured in the reference frame;
in which the events occur at the same place; ***[2]***

(ii) $\gamma = \dfrac{1.20}{0.800} = 1.5$;

$1.5 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$;

to give $v = 0.75$c; ***[3]***

G2. (a) same up to about 0.3;
then curve asymptotic to 1.0; ***[2]***

(b) calculation of $\gamma = 2.3$;
$E = (\gamma m_0 c^2) = 1.2\,\text{MeV}$; ***[2]***

Option H — Optics

H1.

Name of associated region	*Frequency / Hz*	*Possible source*	
gamma radiation	*10^{18}*	*radioactive decay*	
infra red;	*10^{13}*	hot objects / laser / remote control device;	
radio waves;	*10^{6}*	(accelerated) motion of electrons in conductors/aerials/electric currents;	***[4]***

Do not apply ECF from region to possible source.

H2. (a) (i) when the (transmitted) ray/light in medium 2 is along the boundary/refracted at 90°;
the angle of incidence in medium 1 is the critical angle; ***[2]***

or

when a ray/light is incident on the boundary at an angle greater than the critical angle;
the ray is not transmitted / no light is transmitted but is totally reflected at the boundary / is totally internally reflected;

(ii) reflected ray with angle of reflection = angle of incidence;
transmitted ray with angle of refraction greater than angle of incidence; ***[2]***
Judge both by eye.

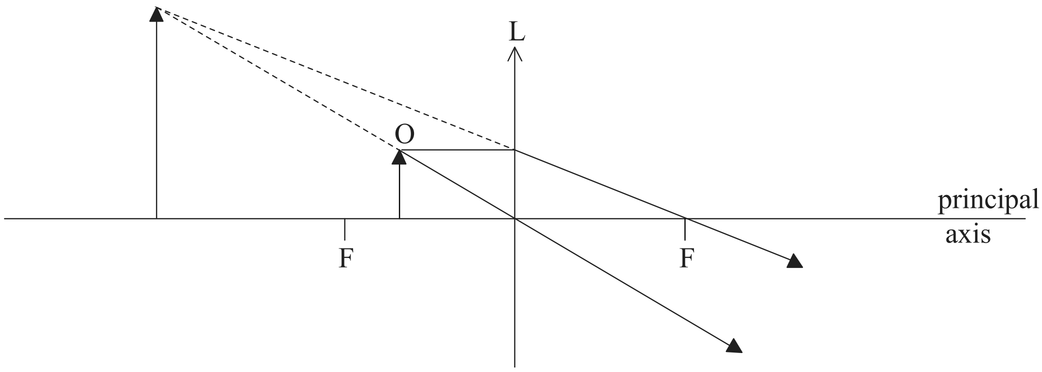
(b) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\theta_1 = \phi_c$ and $\theta_2 = 90^{\circ}$;

$n_1 \sin\phi_c = n_2$; ***[2]***

H3. (a) (i) *principal axis*: a line at right angles to the plane of the lens and that passes through the (optical) centre of the lens / *OWTTE*;
principal focus: a point on the principal axis to which rays parallel to the principal axis pass after refraction (through the lens) / *OWTTE*; ***[2]***

(ii)



two rays as shown;
extrapolated back to locate image;
Do not penalise if rays do not have arrows. ***[2]***

(iii) virtual
the rays diverge after passing through the lens;
cannot be focused onto a screen / appear to come from a point / *OWTTE*; ***[2]***
*Award **[1 max]** for an explanation based on the image on the same side of the lens.*

(b) (i) $M = \left(\frac{\theta_i}{\theta_o}\right) = \frac{h_i}{h_o}$;

$6 = \left(\frac{h_i}{h_o} = \frac{v}{u}\right) = \frac{25}{u}$;

$u = \left(\frac{25}{6.0}\right) = 4.2\,\text{cm}$; ***[3]***

(ii) maximum magnification; ***[1]***