International Baccalaureate
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2008

PHYSICS

Higher Level

Paper 2

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[35 marks]** and **TWO** questions in Section B **[2 × 30 marks]**. Maximum total = **[95 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.

SECTION A

A1. (a) a straight line / linear graph cannot be drawn that lies within all the error bars; *[1]*

(b) smooth curve;
that does not go outside error bars; *[2]*

(c) recognize that D_λ is the gradient of the graph;
suitable triangle $\Delta\lambda \geq 100$ nm;
to give magnitude $1.15 - 1.40 \times 10^{-5}\,\text{nm}^{-1}$ / $10^{4}\,\text{m}^{-1}$;
negative sign; *[4]*

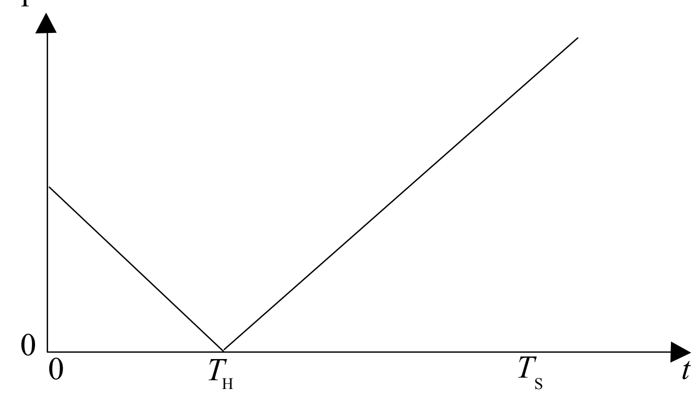
(d) $\lg n$ against $\lg\lambda$;
$\lg n = \lg k + p\lg\lambda$;
slope/gradient $= p$; *[3]*

(e) (i) recognize that A is the intercept on the n axis;
line shown extrapolated;
$A = 1.6020(\pm 0.0001)$; *[3]*
*Award full marks for correct answer with omission of first marking point award **[2 max]** if they find the gradient (B) and then use a data point to calculate A.*

(ii) it is the value of n / refractive index for an infinite wavelength / $\lambda =$ infinity / minimum value of n; *[1]*

A2. (a) initial KE of stone + loss in PE = gain in KE / or equivalent statement;
$\frac{14^2}{2} + 9.8 \times 28 = \frac{v^2}{2}$;
to give $v = 27\text{ m s}^{-1}$; *[3]*
*Must be some indication that an energy method used for max credit otherwise **[max 1]**.*

(b)



two lines going in the correct direction as shown;
speed greater at sea than initial speed;
(magnitude of) slopes the same; *(judge by eye)*
zero at T_H; ***[4]***
*Award **[2 max]** if lines do not go to zero.*
*Award **[1 max]** if initial speed zero and then going to zero at* T_H.

A3. (a) (i) an atom or nucleus that is characterized by the constituents of its nucleus / a particular type of atom or nucleus / *OWTTE*;
(in particular) by its proton (atomic) number and its nucleon number / number of protons and number of neutrons; ***[2]***

(ii) nuclides that have the same proton number but different nucleon number / same number of protons different number of neutrons; ***[1]***

(b) (i) ${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} + \beta^- + \bar{v}$
β^- / e^- / ${}^{0}_{-1}e$;
$\bar{v}$; ***[2]***

(ii) 5.00216 MeV is equivalent to 0.00537 u;
$23.99096 = 23.98504 + 0.00537 +$ rest mass of particle;
rest mass $= 0.00055\,u$; ***[3]***
No credit given for bald correct answer.

(c) sodium-24 has more nucleons;
and more nucleons (usually) means greater (magnitude of) binding energy;

or

sodium-23 has less nucleons;
and less nucleons (usually) means less (magnitude of) binding energy; ***[2]***

A4. (a) product of normal component of magnetic field strength and area that it links / *OWTTE*;
$\phi = BA\cos\theta$; ***[2]***

(b) rate of change of flux $= \left(1.8\times10^{-3}\times5.0\times10^{-2}\right) = 9.0\times10^{-5}\left(\text{Wb s}^{-1}\right)$;
recognize that e.m.f. $=$ rate of change of flux $= 9.0\times10^{-5}\,\text{V}$; ***[2]***
Ignore any sign.

SECTION B

B1. Part 1 Momentum and energy

(a) (impulse =) force × time for which force acts;
impulse $(F\Delta t)$ = change in momentum (Δp); *[2]*

(b) *The following points are needed for maximum marks.*
from Newton 3;
when objects are in contact, the forces exerted by the objects on each other are equal and opposite;
from Newton 2 / collision time is the same;
impulses are equal and opposite;
therefore changes in momentum are equal and opposite / total change in momentum is zero;

or

Accept algebraic solution.
from Newton 3;
$F_{AB} = -F_{BA}$;
from Newton 2;
$F_{AB}\Delta t = m_{\mathrm{A}}\Delta v_{\mathrm{A}}$;
$= -m_B \Delta v_B$; *[5]*

(c) (i) $v = \sqrt{2gh}$;
to give $v = 2.2\ \mathrm{m\ s^{-1}}$; *[2]*
Award full marks for bald correct answer.

(ii) from conservation of momentum / $V \times 5.2 \times 10^{-3} = 0.38 \times 2.2$;
$V = \frac{0.38 \times 2.2}{5.2 \times 10^{-3}}$;
to give $V = 160\ \mathrm{m\ s^{-1}}$ *[2]*

(iii) KE before $= \left(\frac{1}{2} \times 5.2 \times 10^{-3} \times 1.6^2 \times 10^4\right) = 67\ \mathrm{J}$;
KE after $= \left(\frac{1}{2} \times 0.38 \times 4.8\right) = 0.91\ \mathrm{J}$ / $(0.38 \times 9.8 \times 0.24) = 0.91\ \mathrm{J}$;
lost energy $= 66\ \mathrm{J}$; *[3]*

(d) energy to increase from $20\,^{\circ}\mathrm{C}$ to $330\,^{\circ}\mathrm{C} = (5.2 \times 10^{-3} \times 130 \times 300) = 200\ (\mathrm{J})$;
energy to melt pellet $= (5.2 \times 10^{-3} \times 870) = 4.5\ (\mathrm{J})$;
total KE $= 210\ \mathrm{J}$;
$\frac{1}{2}mv^2 = 210$;
to give $v = 280\ \mathrm{m\ s^{-1}}$; *[5]*

B1. Part 2 Gravitation

(a) force between two point / small masses;
is proportional to the product of the masses;
and inversely proportional to the square of their separation; ***[3]***

Accept formula $F \propto \frac{m_1 m_2}{r^2}$ *but full marks only if all terms are defined e.g.* m_1 *and* m_2 *are point masses, r is their separation, F is the force between the point masses (and G is a constant if "F=" used).*

(b) recognize that $g = \frac{GM}{R^2}$;

$M = \frac{gR^2}{G} = \left(\frac{6.0\times10^{-3}\times1.5^2\times10^{22}}{6.7\times10^{-11}}\right)$;

$= 2.0\times10^{30}$ kg; ***[3]***

*Award **[1 max]** for use of* $G\frac{M}{R}$ $\left(=1.4\times10^{19}\right)$.

(c) $\frac{v^2}{R} = \frac{GM}{R^2}$;

$v = \frac{2\pi R}{T}$;

$\frac{4\pi^2 R^2}{T^2} = \frac{GM}{R}$;

hence $T^2 = \frac{4\pi^2 R^3}{GM}$;

recognize $\frac{4\pi^2}{GM}$ is a constant; ***[5]***

B2. Part 1 Waves

(a) Transverse

the particles (of the medium) vibrate at right angles;
to the direction of energy transfer;

Longitudinal

the particles (of the medium) vibrate in the same direction as the direction of energy transfer; ***[3]***

(b) (i) time period = 0.13 s;

$\left(f = \frac{1}{T} = \frac{1}{0.13}\right) = 7.7\ (\pm 0.3)\ \text{Hz}$; ***[2]***

Award full marks for bald correct answer.

(ii) 8 mm; ***[1]***

(c) $\lambda = \frac{v}{f}$;

$\frac{15}{7.7}$;

$\lambda = 1.95\ \text{cm} \approx 2.0\ \text{cm}$ ***[2]***

(d) start at $(-1.2 \rightarrow -2.0)$ on y-axis;
sine curve of amplitude 8 mm;
wavelength 2 cm; ***[3]***

(e) use of $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$

$\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$;

$= \frac{20}{15}\sin 30$ to give $\theta_2 = 42^{\circ}$;

angle $= 48^{\circ}$; ***[3]***

(f) (i) each slit acts as a point source of waves;
waves from these sources interfere;
because of the principle of superposition;
where a trough of one wave meets a crest of another the resultant displacement will be minimum / waves arrives with opposite phase/<u>completely</u> out of phase /
so destructive interference occurs; ***[4]***

(ii) $D = \frac{ds}{\lambda}$;
$= \frac{18 \times 9.4}{2.0}$;
= 85 / 90 cm; ***[3]***
Award full marks for bald correct answer.

(g) (i) the phase difference between them is constant; ***[1]***

(ii) fringes of equal intensity / intensity reducing from centre fringe;
and equal width; ***[2]***
[max 1] *if fringes do not touch axis.*

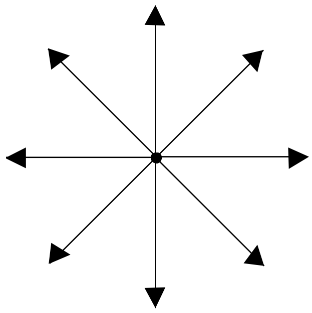
B2. Part 2 Magnetic fields

(a) effective current in each side of coil = 20I;
each wire needs to produce $\frac{1}{4}B$;
$I = \frac{2\pi r B}{\mu_0}$;
$= \frac{2\pi \times 0.6 \times 7.0 \times 10^{-5}}{4\pi \times 10^{-7} \times 80}$;
$= 2.6\text{A}$ ***[4]***
Accept correct substitution for I into $B = \frac{\mu_0 I}{2\pi r}$ *to show that* $B = 7.0 \times 10^{-5}\, T$

(b) plane vertical;
plane normal to Earth field; ***[2]***

B3. Part 1 Fields and electric charge associated with atoms

(a) (i)



at least 6 symmetric radial lines as shown <u>touching the proton</u>;
correct direction; ***[2]***

(ii) use of $E = k\frac{q}{r^2}$

$E = \frac{9.0\times10^{9}\times1.6\times10^{-19}}{25\times10^{-22}}$;

$= 5.8\times10^{11}\,\text{N C}^{-1}$; ***[2]***

Award full marks for bald correct answer.

(b) (i) use of $F = qE$

$F = 1.6\times10^{-19}\times5.8\times10^{11}$;

$= 9.3\times10^{-8}\,\text{N}$ ***[1]***

Allow use of force law.

(ii) recognize that $F = \frac{mv^2}{r}$;

$\frac{1}{2}mv^2 = \frac{1}{2}Fr$;

$= \frac{1}{2}\times9.3\times10^{-8}\times5.0\times10^{-11}$;

$= 2.3\times10^{-18}\ \text{J}$ ***[3]***

(c) (i) the work required per unit charge;
to bring a small positive charge / positive test charge / positive point charge from infinity to the point; ***[2]***

(ii) PE of electron $= -\frac{e^2}{4\pi\varepsilon_0 r}$;

$= -4.6\times10^{-18}\,\text{J}$; ***[2]***

Award full marks for bald correct answer.

(d) total energy required $= -4.6\times10^{-18} + 2.3\times10^{-18}$ J;
$= -\dfrac{2.3\times10^{-18}}{1.6\times10^{-19}} = 14\ (\text{eV})$; ***[2]***

(e) the power supplied per unit current / the energy supplied per unit charge; ***[1]***

(f) (i) $R = \left(\dfrac{6.0}{0.2}\right) = 30\,\Omega$; ***[1]***

(ii) $P = (6.0\times0.2) = 1.2$ W; ***[1]***

(g) (i) $I = \left(\dfrac{6.0}{15}\right) = 0.40$ A; ***[1]***

(ii) total current in the circuit 0.60 A;
resistance of parallel circuit $= 10\,\Omega$ / lost volts $= 5.0\times0.6$;
total resistance in circuit $= 15\,\Omega$ / lost volts $= 3$ V;
e.m.f. $= (0.60\times15) = 9$ V;

or

total current $= 0.60$ A;
pd across $\mathrm{R} = 6.0$ V;
e.m.f. $= 6.0 + 0.60\times5.0$;
$= 9.0$ V; ***[4]***

B3. Part 2 Thermodynamics

(a) heat pump uses work to transfer thermal energy / heat from a cold to a hot reservoir;
heat engine transfers thermal energy into work; ***[2]***

(b) (i) work done $=(P\Delta V)=1.2\times10^{6}\times0.3=3.6\times10^{5}\,(\text{J})$;
recognize that since $\Delta U=0$ then work done $=\Delta Q$;
$\Delta Q=3.6\times10^{5}\,\text{J}$ ***[2]***

(ii) $eff=1-\dfrac{Q_{\text{out}}}{Q_{\text{in}}}$;
$0.32=1-\dfrac{3.6\times10^{5}/10^{6}}{Q_{\text{in}}}$;
to give $Q_{\text{in}}=5.3\times10^{5}$ / 10^{6} J; ***[3]***

(iii) work done $=1.8/1.7\times10^{5}$/ 10^{6} J; ***[1]***

B4. Part 1 Power and an ideal gas

(a) the rate of working / $\dfrac{\text{work}}{\text{time}}$; ***[1]***
Ratio or rate must be clear.

(b) let $\Delta s=$ distance moved in time Δt such that $v=\dfrac{\Delta s}{\Delta t}$;
$P=\dfrac{\text{work}}{\text{time}}=\dfrac{F\Delta s}{\Delta t}$;
$=Fv$ ***[2]***

All symbols must be defined for full marks.

(c) (i) friction; ***[1]***

(ii) recognize that F= rate of change of momentum;

$\left(=\frac{\Delta m}{\Delta t}v\right)=(60\times 2.0)=120$ N; ***[2]***

(iii) $(P=120\times 2.0)=240$ W; ***[1]***

(iv) $K=\frac{1}{2}\frac{\Delta m}{\Delta t}v^2$;

$=\left(\frac{1}{2}\times 60\times 4.0\right)=120$ W; ***[2]***

Award full marks for bald correct answer.

(v) the sand on the conveyor belt must slip to be accelerated;
in slipping kinetic energy is dissipated / lost as internal energy / heat in the sand and conveyor belt;

or

there is friction between the sand and conveyor belt;
therefore kinetic energy is dissipated / lost as internal energy / heat in the sand and conveyor belt; ***[2]***
Award zero for bald statement "energy is lost as heat".

(d) temperature:
the molecules gain energy by collision with the moving piston;
therefore average KE of the molecules increases;
temperature is a measure of average KE of the molecules (so temperature increases);

pressure:
pressure is caused by the force that the molecules exert on collision with the walls of the cylinder;
the volume is decreased so there are more molecules per unit volume / more collisions per unit time;
increased temperature means greater speed;
rate of change of momentum per unit area is greater; ***[7]***

B4. Part 2 The photoelectric effect

(a) negative;
the electrons emitted from P have a certain maximum energy;
they will be repelled by plate Q / *OWTTE*;
if the maximum KE is less than the energy required for an electron to move between P and Q / less than the pd per unit charge it will not reach Q; ***[4]***

(b) light consists of photons each of energy $E = hf$;
where h is the Planck constant and f is the frequency (of the light);
the greater the frequency (of the incident light) the greater the energy of the emitted electrons / electrons now have sufficient energy to overcome the potential barrier / *OWTTE*; ***[3]***

(c) the energy of each photon is increased;
therefore for same intensity there are less photons; ***[2]***

(d) $h = \dfrac{E_{\mathrm{K_{max}}} + \phi}{f}$;

$= \dfrac{(8.0 + 4.4) \times 1.6 \times 10^{-19}}{3.0 \times 10^{15}}$;

$= 6.6 \times 10^{-34}$ J s; ***[3]***

Must show working for full credit.