IBO

IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M07/4/PHYSI/HP2/ENG/TZ1/XX/M+

MARKSCHEME

May 2007

PHYSICS

Higher Level

Paper 2

15 pages

Subject Details: Physics HL Paper 2 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 markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalizing 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.

SECTION A

A1. (a) correct positioning of all 3 error bars;
correct length of error bars – at least 3 mm long, even if only two are shown; ***[2]***

(b) a smooth curve through the data points within 2 mm of each data point; ***[1]***
*Award **[0]** for points joined by straight-line segments.*

(c) line of best-fit must be a curve;
in order to pass through the error bars; ***[2]***
*Award **[0]** for plain "curve" without attempt at an explanation.*

(d) (i) $20(\pm 2)\ ^{\circ}\text{C}$; ***[1]***

(ii) large enough triangle-hypotenuse 6 cm, from which to get slope;
correct calculation of slope at $x = 50\,\text{cm}$ to give $(-)1.05 \pm 0.25\ ^{\circ}\text{C cm}^{-1}$;
for a more accurate calculation in the range $(-)1.05 \pm 0.15\ ^{\circ}\text{C cm}^{-1}$; ***[3]***

(e) realization that $\dfrac{R_{50}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{50}} = \dfrac{R_{10}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{10}}$ if rate is proportional to temperature gradient;

substitution to get $R_{50} = \left(\dfrac{R_{10}}{\left(\dfrac{\Delta\theta}{\Delta x}\right)_{10}}\left(\dfrac{\Delta\theta}{\Delta x}\right)_{50}\right) = \dfrac{43}{1.81} \times 1.05 = 25\ \text{W}$;

with a comment about the agreement of the result with the given value of R_{50}; ***[3]***

(f) a graph of $\ln\theta$ versus x would be a straight-line;
with $k =$(negative) slope; ***[2]***
Do not accept answers that use point(s) from the graph on page 4 and solve for k.

A2. (a) (i) initial momentum $= 500 \times 6 = 3000\ \text{N s}$;
final momentum $= 500 \times (-1) + 700 \times 5 = 3000\ \text{N s}$; ***[2]***
(working must be shown to award marks)
Allow approach that shows equal and opposite momentum changes.

(ii) initial kinetic energy $= \frac{1}{2} 500 \times 36 = 9000\ \text{J}$;
final kinetic energy $= \frac{1}{2} 500 \times 1 + \frac{1}{2} 700 \times 25 = 9000\ \text{J}$; ***[2]***
(working must be shown to award marks)

(b) impulse $=$ change of momentum $= 700 \times 5 = 3500\ \text{N s}$;
duration of collision $= 2.0\ \text{s}$;
to give $F = \dfrac{3500}{2.0} = 1800\ \text{N}$; ***[3]***
Accept force in the range 1700 N to 1800 N even with three significant figures.

A3. (a) (i) **two** arrows directed towards the centre of the circular path, within $\pm 0.5\,\text{cm}$ of the centre; *[1]*

(b) (i) negative by stating any rule for the direction of the magnetic force; *[1]*

(ii) the work done is zero;
since the force is at all times normal to the velocity; *[2]*

(c) a curved path starting at X and in the right direction i.e. counterclockwise;
circular path of radius $\frac{R}{2}$; *[2]*
Allow diameter 3-4 cm and be generous with how round the circle is.

A4. (a) the kinetic energy of 3.8 MeV gets converted to electrical potential energy;
equal therefore to $3.8\times10^{6}\times1.6\times10^{-19}=6.1\times10^{-13}\,\text{J}$; *[2]*

(b) correct identification of charges of alpha and palladium nucleus;
electrical potential energy $=9\times10^{9}\times\dfrac{2\times46\times(1.6\times10^{-19})^{2}}{d}$;
$d=3.5\times10^{-14}\,\text{m}$; *[3]*
*Award **[1 max]** for those who fail to square the elementary charge (answer* $2.2\times10^{3}\,\text{m}$*) or those who square the d in the denominator (answer* $1.9\times10^{-7}\,\text{m}$*).*

(c) it will be greater <u>since the gold nucleus has more protons/force of repulsion is greater</u>/<u>electrical potential energy between alpha and gold nucleus is larger at the same distance</u>; *[1]*

(d) (i) $m\approx Au$; *[1]*

(ii) $\rho=\dfrac{m}{V}$

$$=\frac{A\times1.66\times10^{-27}\,\text{kg}}{\frac{4\pi}{3}A(1.2\times10^{-15})^{3}\,\text{m}^{3}};$$

to give $\rho\approx2\times10^{17}\,\text{kg}\,\text{m}^{-3}$ *(no mark for answer)* *[1]*

SECTION B

B1. **Part 1** Motion of a ball

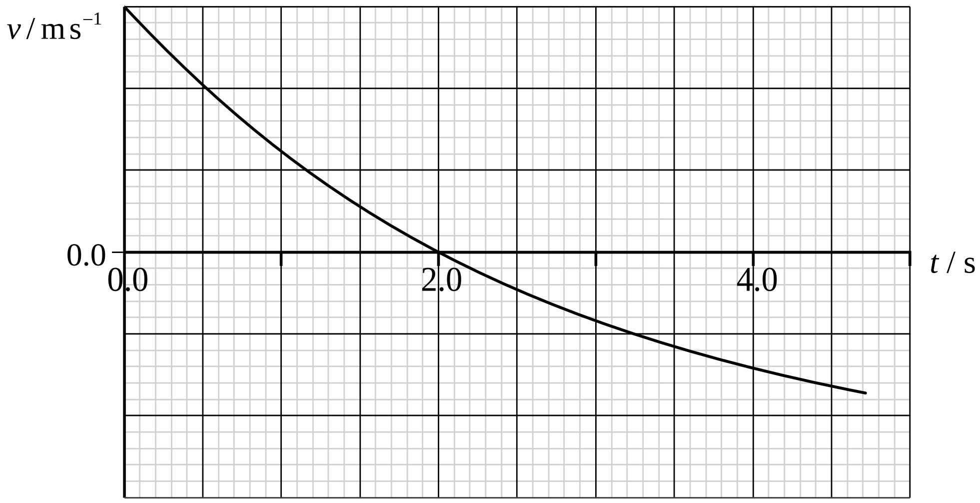
(a) the maximum height reached by the ball/the displacement in the first 2 s /the distance travelled; ***[1]***

(b) 30 m; ***[1]***
Accept answers in the range 25 m to 30 m.

(c) (i) drawing tangent at $t = 1.0\,\text{s}$;
using a sufficiently large triangle – at least 6 cm hypotenuse;
to get $a = 15\,\text{m s}^{-2}$; ***[3]***
Accept acceleration in the range $14.5 - 15.5\,\text{m s}^{-2}$.

(ii) $R + mg = ma$;
$R = 3.75 - 2.50 = 1.2\,\text{N}$; ***[2]***
(Watch ECF from (i))

(d) slope of the graph is decreasing;
the force of air resistance must decrease as well; ***[2]***

(e)


smooth curve at t = 2.0 s ;
terminating between 4.25 s and 4.50 s ; ***[2]***
(Award second marking point only if first is correct)

(f) it will be less;
because mechanical energy/kinetic energy is being transformed into thermal energy (in the particle and air); ***[2]***
*Award **[0]** for an answer without justification.*

(g) the areas under the graph for the upward and downward motion must be the same;
from the way the <u>curve slopes</u> it follows that the time must be longer than 2.0 s ; ***[2]***

or

the average speed on the way down is less;
and so the time taken is longer;

Part 2 Emission of electrons

(a) energy required to leave the metal is $1.8\times1.6\times10^{-19} = 2.88\times10^{-19}$ J ;
area from which energy is collected is $\pi(5.0\times10^{-11})^2 = 7.85\times10^{-21}$ m^2 ;
energy falling on area per second is $E = 1.6\times7.85\times10^{-21} = 1.26\times10^{-20}$ J ;
so time required is $\dfrac{2.88\times10^{-19}\ \text{J}}{1.25\times10^{-20}\ \text{J}}$;
$= 22.9$ s, approximately 23 s (*no mark for answer*) ***[4]***

(b) the energy of light is carried in bundles/quanta/photons;
so the electron will be ejected immediately after it absorbs one photon (of sufficient energy); ***[2]***

(c) (i) the <u>minimum</u> voltage for which the ammeter reads zero current;
the recorded voltage is the kinetic energy of the electrons in electron volts; ***[2]***

(ii) straight-line with positive slope;
with positive intercept on frequency axis; ***[2]***

(iii) <u>since</u> $E_K = hf - \phi$;
slope is Planck's constant; ***[2]***
*Award **[1]** for a statement without explanation.*

(d) energy falling on one square meter of the metal per second is 1.6 J ;
realization that $N\dfrac{hc}{\lambda} = 1.6$ J (where photon energy is $\dfrac{hc}{\lambda} = 3.83\times10^{-19}$ J and
N = number of photons per unit area per second is 4.18×10^{18} m^{-2} s^{-1}) ;
number of electrons is $0.05\times N = 2.1\times10^{17}$; ***[3]***

B2. Part 1 Waves on a string

(a) (i) wavelength $= 3.0\,\text{cm}$; ***[1]***

(ii) period $= 0.25\,\text{ms}$;
hence frequency $= 4000\,\text{Hz}$; ***[2]***
(Bald answer 4000 Hz scores ***[2]****)*

(iii) $c = \left(\dfrac{0.03}{0.25\times10^{-3}}\right) = 0.03\times4000 = 120\,\text{m s}^{-1}$; ***[1]***
Watch ECF from (i) and (ii).

(b) (i) correct labelling of amplitude of 2.0 mm; ***[1]***
Any line from equilibrium to crest or trough.

(ii) cosine wave <u>from $x = 0$</u> ;
period constant throughout ; ***[2]***

(c) (i) pulse of similar shape and size;
and inverted; ***[2]***
Accept pulse that is of similar width but smaller amplitude.

(ii) the string pulls on the wall and so the wall pulls in the opposite direction on the string by Newton's third law;
the wall pushes on the string creating an inverted pulse; ***[2]***

(d) (i) the oscillating left end creates a travelling wave to the right;
which gets reflected by the fixed end;
at any one time there are two waves on the string travelling in opposite directions whose displacements/amplitudes are added (creating the standing wave); ***[3]***

(ii) $c = f\lambda$

$\lambda = \dfrac{4L}{3} = 4.0\,\text{m}$;

hence $f = \dfrac{120}{4.0} = 30\,\text{Hz}$; ***[2]***

Use ECF for wave speed from (a)(iii).

(e) (i) sources whose phase difference is constant; ***[1]***

(ii) the waves from the transmitters interfere;
the path difference varies as the satellite moves and so the amplitude of the detected (superposed) signal varies as well; ***[2]***
Accept references to path difference changing form being an integral or half integral multiple of the wavelength as the satellite moves.

(iii) three fringe separations in $7.7\,\text{km}$;

hence $s = \frac{7.7}{3} = 2.57\text{ km}$;

using $s = \frac{\lambda D}{s} \Rightarrow D = \frac{2.57 \times 160}{1.2} = 342\text{ km} = 340\text{ km}$ (2 s.d.); ***[3]***

Part 2 Electromagnetic induction

(a) the induced e.m.f. (in a loop) is proportional to the rate of change of the magnetic flux linkage (in the loop); ***[1]***

(b) (i) as the loop is moved away the magnetic field through the loop is getting smaller;
hence the magnetic flux through it is changing with time;

Accept also answers based on considerations of induced e.m.f. in each section of loop e.g.
e.m.f. is induced in upper and lower section of loop;
no e.m.f. induced in sides/e.m.f. of same sign;
e.m.f. in upper section larger hence current in loop; ***[2 max]***

(ii) the direction of the current is clockwise;
because in this way the magnetic field created by the induced current is in the same direction as the external magnetic field thus opposing the change in flux; ***[2]***
Accept any other reasonable formulation based on Lenz's law but not bald answer without explanation or incorrect explanation.

(iii) work is being performed on the loop by the agent pushing the loop;
against the attractive magnetic force between the loop and the wire;
so that the loop moves at constant speed; ***[3]***

B3. Part 1 Electrical conduction

(a) (delocalized/valence/free) electrons that are not bound to any one particular atom of the metal/electrons loosely bound to atoms; ***[1]***

(b) (i) the mass of $1.0\,\text{m}^3$ is $8.93\times10^3\,\text{kg}$;

and therefore number of moles is $\dfrac{8.93\times10^6}{64}$;

$=1.4\times10^5\,\text{mol}$ (*no marks for answer*) ***[2]***

(ii) $1.4\times10^5\times6.02\times10^{23}=8.4\times10^{28}$; ***[1]***

(c) there is no net transfer of electric charge to the right or left;
because on the average as much charge moves to the right as to the left;

or

random velocities means no net motion in any direction ;
hence no transfer of charge ; ***[2]***

(d) arrow to the right; ***[1]***

(e) (i) $\dfrac{0.50}{10^{-3}}=5\times10^2\,\text{s}$ ***or*** $\approx 8\,\text{min}$; ***[1]***

Accept answer in seconds or minutes up to 2 significant figures.

(ii) all electrons in the wire start drifting at the same time/the electric field is established in the wire almost instantaneously;
the lamp will light as soon as the electrons already in the lamp filament begin to move; ***[2]***

(iii) the electrons gain kinetic energy as they are accelerated by the potential difference across the filament;
they collide with the filament atoms transferring energy to them;
the average kinetic energy of the filament atoms thus increases;
which implies that the temperature of the filament increases (since temperature is a measure of the average kinetic energy of the molecules); ***[4]***

(f) ammeter in series with battery;
voltmeter in parallel with lamp; ***[2]***

(g) (i) from zero up to a maximum of 0.15 A ; ***[1]***

(ii) correct identification of current;

to get $R=\dfrac{V}{I}=\dfrac{0.80}{0.32}=2.5\,\Omega$; ***[2]***

Part 2 Thermodynamics

(a) change in which the temperature stays constant; ***[1]***

(b) state X is at a lower temperature;
<u>because</u> $p_X V_X < p_Y V_Y$ /other argument *e.g.* comparing two points on the two curves that have the same volume or pressure ; ***[2]***
Do not award first point if explanation is missing or incorrect.

(c) (i) work is done <u>on</u> the gas and hence $W < 0$;
using $Q = \Delta U + W$ and $Q = 0$ it follows that $\Delta U > 0$;
thus the temperature increases; ***[3]***

(ii) curve starting at point p_Y, V_Y in direction of decreasing volume ;
steeper than the isothermal through point p_Y, V_Y ;
ending at a pressure equal to p_X ; ***[3]***

(d) the area under the isothermal curve of gas X;
from the initial to the final volume; ***[2]***

B4. **Part 1** Plutonium as a power source

(a) ${}^{238}_{94}\text{Pu} \rightarrow {}^{234}_{92}\text{U} + {}^{4}_{2}\alpha$ ***[2]***

*Award **[1]** for correct numbers on alpha, and **[1]** for correct numbers on uranium. No ECF on uranium if alpha wrong and other way around.*

(b) (i) mass difference is $237.9979539-(233.9904441+4.0015050)=6.00\times10^{-3}$ u ;
so energy released is $6.00\times10^{-3}\times931.5=5.59\,\text{MeV}$;
conversion to Joules through $5.59\times10^{6}\times1.6\times10^{-19}$ J ;
to get 8.9×10^{-13} J ***[3]***
Accept alternative paths for example converting masses into kg etc. Notice that using $E=mc^2$ gives
$E=6.00\times10^{-3}\times1.661\times10^{-27}\times9\times10^{16}=8.96\times10^{-13}\approx9\times10^{-13}$ J .

(ii) the alpha and the uranium nucleus have the same momentum;
and hence the alpha being of smaller mass than uranium carries most of the energy; ***[2]***

(c) (i) six months is short compared to the half-life and so the number of plutonium nuclei does not change appreciably ;
activity is proportional to the number of plutonium nuclei present/OWTTE ; ***[2]***

(ii) rate of energy released = $8.9\times10^{-13}\times4.1\times10^{13}$;
= $37\,\text{W}$; ***[2]***

(iii) $37=0.065\times150\times\dfrac{\Delta\theta}{\Delta t}$;
to get $\dfrac{\Delta\theta}{\Delta t}=3.8\,\text{K}\,\text{s}^{-1}$; ***[2]***

(d) (i) the alpha particles transfer kinetic energy to the plutonium atoms;
thus increasing the average kinetic/vibrational energy of the atoms;
and hence the temperature since temperature is a measure of the average kinetic energy of the atoms; ***[3]***

(ii) the transfer of energy increases the (interatomic) potential energy of the plutonium atoms;
at constant temperature;
while keeping the kinetic energy of the atoms constant; ***[3]***

Part 2 Motion of a satellite

(a) the work done per unit mass;
in bringing a small/point mass from infinity to a point (in the gravitational field); ***[2]***
Ratio idea essential for first mark.

(b) (i) equating gravitational force to centripetal $\frac{GMm}{r^2} = \frac{mv^2}{r}$;

to get the speed $v^2 = \frac{GM}{r}$;

and hence $E_K = \frac{1}{2}\frac{GMm}{r} = \frac{1}{2}\frac{GMm}{2R} = \frac{GMm}{4R}$; ***[3]***

(ii) potential energy in orbit is $E_P = -\frac{GMm}{r} = -\frac{GMm}{2R}$;

total energy is then $E = \frac{GMm}{4R} - \frac{GMm}{2R} = -\frac{GMm}{4R}$;

i.e. $E = -1.5 \times 10^{10}$ J; ***[3]***

*Award **[1 max]** for bare answer without explanation.*

(iii) at infinity the potential energy is zero and hence if satellite gets there its total energy will be $E \geq 0$;
but the satellite has <u>negative</u> energy and hence it cannot escape to infinity/the satellite is bound to the Earth forever;
the minimum energy that must be supplied is $E = 1.5 \times 10^{10}$ J; *(or ECF from (b) (ii))* } *the value must agree with the candidate's answer to (b) (ii).* ***[3]***