MARKSCHEME

May 2007

PHYSICS

Higher Level

Paper 2

13 pages

General Marking Instructions

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.
- 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.
- Units should always be given where appropriate. Omission of units should only be penalized once. 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*

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) *1*: the lines do not go through the origin;
2: the lines are not straight (lines) / gradient is not constant; ***[2]***
Award full marks if the candidate combines the two statements.

(b) the petrol is stored in cans / initial volume of petrol not taken into account;
the radius at $t = 0$ is probably the size/radius of the can;

or

difficulty in measuring *R*;
some comment as to the whereabouts of the zero point in the experiment; ***[2]***

(c) $\lg(R) = n\lg(t) + \lg(k)$;
therefore, *n* is the gradient of the line;
suitable "triangle" to find the gradient; *(at least half the length of line)*
$n = \frac{0.20}{0.50} = 0.4$; ***[4]***
Accept an answer based on two data points.

(d) (i) by reading the value of *R* at $t = 20\,\text{ms}$ for each of the five lines / *OWTTE*; ***[1]***

(ii) smooth curve with an intercept of $R = 5.0\,(\pm 1.0)\,\text{m}$;
and does not go outside error bars; ***[2]***

(iii) no the line is not a straight-line;
even with the error bars it cannot be made to be a straight-line / *OWTTE*; ***[2]***
Award ***[0]*** *if "no" and incorrect explanation or if there is no explanation.*

(e) choice of suitable data point in the range $V = 5 \rightarrow 15$
e.g. $R = 10.5$ for $10 \times 10^{-3}\,\text{m}^3$;

$E = \frac{r^5}{t^2}$;

$= \frac{10.5^5}{(20 \times 10^{-3})^2} = 320 \times 10^6$;

divide by 10 / other chosen value of *V*;
$\approx 30\,\text{MJ}$ for $1.0 \times 10^{-3}\,\text{m}^3$ ***[4]***

A2. (a) *e.m.f.*:
the power supplied per unit current / the energy supplied per unit charge;

Ohm's law:
the resistance of a conductor is constant / current proportional to potential difference if its <u>temperature is constant</u>; ***[2]***

(b) (i) $(2.5 \times 0.10) = 0.25\,\text{W}$; ***[1]***

(ii) $0.23 = I^2 R$;
$R = \left(\frac{0.23}{0.10^2}\right) = 23\,\Omega$; ***[2]***

(iii) power dissipated in cell $= 0.02\,\text{W} = I^2 r$;
$r = \frac{0.02}{0.10^2} = 2.0\,\Omega$;

or

use $E = IR + Ir$
$2.5 = 0.10 \times 23 + 0.10r$;
$r = \frac{0.20}{0.10} = 2.0\,\Omega$; ***[2]***

(c) new internal resistance $= 4.0\,\Omega$ and new e.m.f. $= 5.0\,\text{V}$;
$5.0 = 0.15R + 0.15 \times 4.0$;
to give $R = 29\,\Omega$;
therefore, a non-ohmic device as resistance has changed/increased; ***[4]***
Allow calculation of what current should be (0.19A) if R were constant. Allow calculation based on power.

A3. (a) sensible shape of continuous spectrum;
<u>sharp</u> characteristic spectrum (only one need be shown);
correct labelling of characteristic spectrum; ***[3]***

(b) (i) $E(eV) = \frac{hc}{e\lambda}$;
$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 6.6 \times 10^{-11}}$;
$= 1.875 \times 10^{4}\,\text{eV} = 19\,\text{keV}$ ***[2]***

(ii) difference in energy levels $= 19\,\text{keV}$;
therefore, energy level $= 20 - 19 = 1.0\,\text{keV}$; *(accept -1.0 keV)* ***[2]***

SECTION B

B1. (a) before and after collision there are no forces acting on the objects;
from Newton 3 when the two bodies are in contact the forces that they exert on each other are equal and opposite / *OWTTE*;
therefore, the net force on the two balls is always zero;
therefore, there is no change in momentum (of the objects) / momentum is conserved;

or

Accept an argument based on change in momentum of each individual object.
e.g.

from Newton 3 $F_{12} = -F_{21}$; *(accept statement in words)*

$F_{12} = \dfrac{\Delta p_1}{\Delta t}$ and $F_{21} = \dfrac{\Delta p_2}{\Delta t}$;

$\dfrac{\Delta p_1}{\Delta t} = -\dfrac{\Delta p_2}{\Delta t}$;

therefore, $\Delta p_1 + \Delta p_2 = 0$; ***[4]***

(b) the blades exert a force on the air and by Newton's third law the air exerts an equal and opposite force on the blades / air has change in momentum downwards giving rise to a force and from Newton 3 there will a force upwards;
if this force equals the weight of the helicopter;
the net vertical force on the helicopter will be zero / *OWTTE*; ***[3]***

(c) $\text{area} = \pi 0.7^2$;
$= 1.5\,\text{m}^2$ ***[1]***

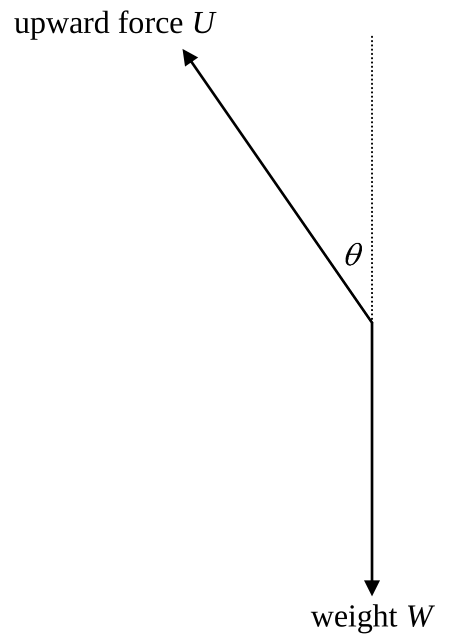
(d) (i) volume of air per second $= 1.5 \times 4.0\,(\text{m}^3\,\text{s}^{-1})$;
mass $=$ volume $\times$ density $= (1.2 \times 1.5 \times 4.0) = 7.2\,\text{kg}\,\text{s}^{-1}$; ***[2]***
No unit error for 7.2 kg.

(ii) momentum per second $= (7.2 \times 4.0) = 29\,\text{N}$; ***[1]***

(e) 29 N; ***[1]***

(f) recognise that the force on the blades $= Mg$;
to give $3.0\,\text{kg}$; ***[2]***

(g)



correct relative directions of forces;
upward force length greater than weight by eye;
appropriate labelling of forces;
angle θ as shown above; ***[4]***
Award ***[2 max]*** *if extra force(s) drawn.*

(h) the forward force is the horizontal component of U;
resolve vertically $U\cos\theta = W$;
horizontal component $F = U\sin\theta$;
divide to get $\frac{F}{W} = \tan\theta$;
$F = (W\tan\theta) = Mg\tan\theta = Ma$;
to give $a = g\tan\theta$ ***[5]***
Award ***[5 max]*** *for a correctly labelled force diagram incorporating mass with a justifying statement. Award* ***[1 max]*** *for triangle mixing accelerations and force.*

(i) work done in one cycle $= \frac{900}{300}$;
$= 3.0\text{ J}$ ***[1]***

(j) (i) isochoric / isovolumetric; ***[1]***

(ii) $\text{B} \rightarrow \text{C}$ absorbed;
$\text{D} \rightarrow \text{A}$ ejected; ***[2]***
Accept parallel arrows.

(iii) $Q_1 - Q_2 = 3.0$;
$1 - \frac{Q_2}{Q_1} = 0.6$;
$Q_1 = 5.0\text{ J}$ and $Q_2 = 2.0\text{ J}$; ***[3]***

B2. Part 1 Waves

(a) no energy is transferred;
variable amplitude / variable maximum displacement of particles / *OWTTE*;
points along the wave where amplitude is always zero / reference to phase / *OWTTE*; ***[2 max]***

(b) if two or more waves overlap / *OWTTE*;
the resultant displacement at any point is found by adding the displacements produced by each individual wave / *e.g.* peak/trough meets peak/trough to give maximum/minimum / *OWTTE*; ***[2]***

(c) (i) $t=\dfrac{T}{4}$: straight-line; *(a line must be drawn on the diagram)*

$t=\dfrac{T}{2}$: negative sine; ***[2]***

(ii) the points of no displacement/nodes (at middle and ends) do not change with time;
therefore, the wave cannot be moving forward / does not progress; ***[2]***

(d) (i) maximum amplitude of oscillation;
when a periodic force is applied to it and the frequency of the force is equal to the natural frequency of vibration of the system / *OWTTE*; ***[2]***

(ii) frequency of wave $f=\dfrac{c}{\lambda}=\left(\dfrac{6.0\times10^{3}}{1.2\times10^{4}}\right)=0.50\,\text{Hz}$;

natural frequency of oscillation of building $=\dfrac{1}{\underline{2.0}}=0.50\,\text{Hz}$;

the waves therefore, cause the building to resonate/vibrate violently / *OWTTE*; ***[3]***

(e) (i) the sound (heard) goes through a series of maximum and minimum intensities;
the frequency with which these occur is the beat frequency / with a regular frequency / *OWTTE*; ***[2]***

(ii) *beat frequency*:
time between two successive maxima $=0.05\,\text{s}$;

therefore, $f=\left(\dfrac{1}{0.05}\right)=20\,\text{Hz}$;

f_x:
time for one complete oscillation $=0.01\,\text{s}$;

therefore, $f_x=\left(\dfrac{1}{0.01}\right)=100\,\text{Hz}$; *(accept $100\rightarrow125$ Hz)* ***[4]***

(f) 120 Hz/80 Hz; ***[1]***
Answer to be consistent with (e)(ii).

Part 2 Neutron star

(a) the force per unit mass;
exerted on a point/small mass; ***[2]***

(b) (i) energy required to move an object of mass *m* from the surface of the star to infinity $= m\,g_0 R$;
if objects KE is equal to this it will escape the gravitational influence of the star / *OWTTE*;
therefore, $\frac{1}{2} m v_e^{\,2} = m\,g_0 R$;
to give $v_e = \sqrt{2 g_0 R}$ ***[3]***

(ii) $g_0 = \dfrac{v_e^{\,2}}{2R}$;
$\left(\dfrac{3.6^2 \times 10^{14}}{2 \times 1.6 \times 10^4}\right) = 4.1 \times 10^{10}\ \mathrm{N\,kg^{-1}}$; ***[2]***

(c) centripetal acceleration $= \dfrac{v^2}{R} = \dfrac{4\pi^2 R}{T^2}$;
$= \left(\dfrac{40 \times 1.6 \times 10^4}{4 \times 10^{-4}}\right) = 1.6 \times 10^9\ \mathrm{m\,s^{-2}}$;
a comment to the effect that this is less than the gravitational field strength so that gravity will stop matter being torn away; ***[3]***
*Award **[1 max]** for calculation of linear speed ($5.0 \times 10^6\ \mathrm{m\,s^{-1}}$) and a comment that this is less than the escape speed.*

B3. Part 1 Gases and liquids

(a) forces between gas molecules (except during collisions) are much smaller than between liquid molecules;
speed of gas molecules much greater than speed of liquid molecules;
motion/movement of gas molecules is less restricted than that for liquid molecules;
<u>average</u> separation of molecules much greater in a gas than in a liquid; ***[2 max]***

(b) the molecules do not have the same speed / the molecules have different speeds;
the speed of the molecules change each time they collide / the speed of individual molecules is always changing / *OWTTE*; ***[2]***
Accept use of words "kinetic energy" in place of speed.

(c) the energy/heat required to raise/change the temperature of a substance by $1\,\mathrm{K}/^{\circ}\mathrm{C}$; ***[1]***

(d) (i) the water is changing phase/boiling / KE of molecules is constant, (PE is changing); ***[1]***

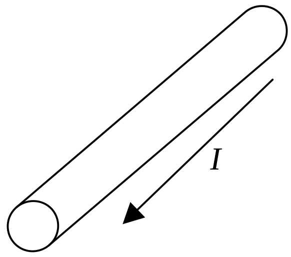
(ii) $\text{time} = 420\,(\text{s})$;
$\text{energy supplied} = 300 \times 420$;
$= 4.2 \times 10^3 \times 0.40 \times \Delta\theta$;
to give $\Delta\theta = 75$;
therefore, boiling temperature $\theta = 95\,^{\circ}\mathrm{C}$; ***[5]***

(e) $300 \times 3.0 \times 10^3 = 0.40\,L$;
to give $L = 2.3 \times 10^6\ \mathrm{J\,kg^{-1}}$; ***[2]***

Part 2 Electrical conduction and induced currents

(a) the force on the electrons produced by the electric field causes them to accelerate along the direction of the rod;
however, they will (soon) collide with a lattice ion but after collision will again be accelerated (along the rod) before making another collision / *OWTTE*;
hence the electrons gain a drift/net velocity in the direction of the wire / in the (opposite) direction to the field even though they still have random velocities / *OWTTE*; ***[3]***

(b) (i)



; ***[1]***

(ii) Lenz's law says that the direction of the induced current is such as to oppose change;
therefore, to produce a (magnetic) force that opposes F the current must be in direction shown / reference to left/right hand rule / *OWTTE*; ***[2]***

(iii) the force on the electrons is given by Bev;
as v increases so does this force and therefore, so does the induced current;
therefore, net force on rod decreases / *OWTTE*; ***[3]***

(c) (i) the induced <u>e.m.f.</u> is equal/proportional to the rate of change/cutting of (magnetic) flux; ***[1]***

(ii) if the rod moves a distance Δx in time Δt then area swept out by rod $= l\Delta x$;
flux $= Bl\Delta x$;
rate of change of flux $= \dfrac{Bl\Delta x}{\Delta t} = Blv = \mathcal{E}$; ***[3]***

(iii) *induced current*:
$I = \dfrac{F}{Bl}$;
substitute to give $I = 3.1\,\text{A}$;

speed v:
$\mathcal{E} = IR = 0.47$;
$\mathcal{E} = Bvl$ substitute to give $v = 4.5\,(4.4)\,\text{m s}^{-1}$; ***[4]***

B4. Part 1 Radioactive decay

(a) (i) proton or neutron; *[1]*

(ii) proton $\rightarrow$ U U D / up, up down;
neutron $\rightarrow$ U D D / up down down; *[2]*
Award ***[1 max]*** *if transposed.*

(iii) both have the same number of protons but different number of neutrons;
strong force and Coulomb force between nucleons;
in Ar-36 strong force attraction and Coulomb repulsion balanced therefore nucleus stable;
in Ar-39 excess neutrons lead to an imbalance in forces hence nucleus unstable; *[4]*
Accept answer in terms of energy i.e. excess neutrons raises the PE of the nucleus.

(b) (i) $Z = 19$;
$N = 39$;
$x \rightarrow$ anti-neutrino / $\tilde{v}$; *[3]*

(ii) (in beta decay) beta energy spectra are continuous;
this implies energy is not conserved (in beta decay);
the particle x/the anti-neutrino was postulated to account for the missing energy / *OWTTE*; *[3]*

(iii) $\Delta m = 0.00061\,\text{u}$;
$\Delta E (= 0.00061 \times 932) = 0.568\,\text{MeV}$;
$(= 0.568 \times 1.6 \times 10^{-13}) = 9.1 \times 10^{-14}\,\text{J}$; *[3]*

(c) (i) the mass/amount of a sample;
activity *A* of the sample; *[2]*

(ii) calculate the number of atoms *N* in the sample from the mass and the Avagadro constant;
use the relation $\frac{dN}{dt} = A = -\lambda N$ to find the decay constant;
calculate half-life from $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$; *[3]*
Award ***[1]*** *for (c)(i) and* ***[2]*** *for (c)(ii) if mass or activity of argon at two separate times measured in (c)(i) and used to find* $T_{\frac{1}{2}}$ *from correct equation.*

Part 2 Friction

(a) nature of the surfaces;
normal reaction;
relative motion of the surfaces; ***[2 max]***

(b) friction is the frictional force between an object and a surface / two surfaces;
static friction is (the frictional force) when the object/surfaces are at rest;
dynamic friction is(the frictional force) when the object is sliding / one of the surfaces is sliding / moving with respect to the other;
some additional comment *e.g.* friction varies from zero to maximum / maximum value of static friction always greater than kinetic friction; ***[3 max]***
Award ***[1 max]*** *for an answer such as "friction force on an object at rest and friction force on a moving object". Some appreciation that it is friction between two surfaces is required.*

(c) $\mu_s = \left(\frac{7.2}{12}\right) = 0.60$; ***[1]***

(d) it will accelerate;
since the coefficient of dynamic friction is less than coefficient of static friction;
therefore, frictional force acting is less than 7.2 N / a net force greater than zero acting on the block; ***[3]***
Award ***[0]*** *for a bald statement or incorrect reasoning.*