N08/4/PHYSI/HP2/ENG/TZ0/XX/M+

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MARKSCHEME

November 2008

PHYSICS

Higher Level

Paper 2

14 pages

General Marking Instructions

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 **no**t 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. 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.

9. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper.

10. 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*

SECTION A

A1. (a) correct placing of both error bars; ***[1]***
Total error bar length 3 to 5 squares.
Be generous as the error bars are a bit difficult to place.

(b) (i) a straight line can be drawn;
that passes through the error bars; ***[2]***
Notice that first point may be implicit, for example, if they have drawn a straight-line of best fit.

(ii) slope $= -1.0$; *(accept answers in the range -0.95 to -1.1 and ignore any units)*
intercept $= 1.85$; *(accept answers in the range of 1.75 to 1.90)*
correct statement of equation *e.g.* $\frac{R}{R_S} = 1.85 - 1.0 \times \frac{M}{M_S}$; $\left\{ \begin{array}{l} \textit{accept e.g.} \\ R = 1.85 - 1.0 \times M \end{array} \right.$ ***[3]***

(iii) $1.85\ M_S$; $\left\{ \begin{array}{l} M_S \textit{ unit needed. Accept answers in the range } 1.6\ M_S \textit{ to } 2.0\ M_S, \\ \textit{i.e. consistent with a line of best-fit} \end{array} \right.$ ***[1]***

(c) the maximum mass corresponds to a star of zero radius/$R = 0$, so it is unphysical / radius is zero/too small; ***[1]***

(d) (i) <u>smooth</u> curve through data points; ***[1]***

(ii) $1.4\ M_S$ / consistent with any line of best-fit even if straight; ***[1]***
Do not penalize absence of unit M_S if already penalized earlier.

(iii) answers based on an extrapolation from a curve which is imprecise; ***[1]***
The idea is to see a comment about extrapolation outside the data range so plain references to uncertainties in general should not be accepted.

(e) (i) since $\ln R = \ln k + n \ln M$;
a plot of $\ln R$ against $\ln M$ would produce a <u>straight line</u>; ***[2]***
Accept log in place of ln.

(ii) with n being the gradient/slope of the graph; ***[1]***

A2. (a) (i) the rocket exerts a force on the gases and so the gases exert a force on the rocket / there is a reaction force on rocket from gases / *OWTTE*;
force on the rocket causes the rocket to accelerate; ***[2]***

(ii) the net external force on the rocket and gases/system is zero / system is closed/isolated, therefore the total momentum of the system stays the same;
change in momentum of the gases = (–) change in momentum of the rocket; ***[2]***

(iii) force on gases is rate of change of gas momentum = Rv;
so force on rocket is also Rv;
$a = \frac{F}{M}$;
$a = \frac{Rv}{M}$ ***[3]***

(b) the two-stage rocket will have a larger final speed;
because after the fuel in the first stage is used up the acceleration will be $a = \frac{Rv}{M}$ and M will be less than the corresponding single stage rocket mass; ***[2]***

A3. (a) satisfies $pV = nRT$ (at all *p*, *V* and *T*) / point molecules / no intermolecular forces; ***[1]***
Allow any other kinetic theory assumption.

(b) (i) the (total random) kinetic energy of the molecules (of the gas); ***[1]***

(ii) the (absolute kelvin) temperature is proportional to/is a measure of the average kinetic energy of the molecules of the gas;
and hence the internal energy is proportional to the temperature (and the total number of molecules in the gas) / $U \propto NT$; ***[2]***
*Do not accept T increases U increases. Award **[0]** for **any** reference to potential energy.*

(c) (i) correct substitution to get
$$T = \frac{pV}{nR} = \frac{2.0\times10^{5}\times8.0\times10^{-3}}{0.64\times8.31};$$
$\approx 300\,\text{K}$ ***[1]***

(ii) use of $\frac{V}{T} =$ constant/ratio idea;
to calculate new volume at $24\times10^{-3}\,\text{m}^3$; ***[2]***

(iii) $W = p\Delta V$
$\Delta V = 16\times10^{-3}\,\text{m}^3$;
so $W = 2.0\times10^{5}\times16\times10^{-3} = 3200\,\text{J}$; ***[2]***

(iv) $\Delta U = Q - W$;
$W = 0$ therefore increase in *U* greater (for constant volume);
therefore *T* is greater; (*T greater must be justified by correct arguments)* ***[3]***

SECTION B

B1. Part 1 Wave motion

(a) (i) 1.5 mm; ***[1]***

(ii) 8.0 cm; ***[1]***

(iii) distance travelled in 0.20 s is 3.2 cm;

so speed is $\left(\frac{3.2\times10^{-2}}{0.20}\right)=0.16\,\text{m s}^{-1}$; ***[2]***

(iv) $f=\frac{0.16}{8.0\times10^{-2}}=2.0\,\text{Hz}$; ***[1]***

(b) travelling waves transfer energy (standing waves do not);
travelling waves have a constant amplitude (standing waves do not);
standing waves have points that always have zero displacement (travelling waves do not);
the phase of a travelling wave constantly changes (but in standing waves points in between consecutive nodes have constant phase); ***[2 max]***

(c) (i) it is the speed of energy transfer/rate/speed at which wavefronts move forward; ***[1]***

(ii) a standing wave is formed from the superposition of two travelling waves;
wave speed refers to the speed of the travelling waves; ***[2]***

(d) (i) the oscillating string collides with the air molecules surrounding it;
creating a pressure/longitudinal wave; ***[2]***

(ii) wavelength of wave on string is $2\times0.80=1.6\,\text{m}$;

frequency is then $\left(\frac{240}{1.6}\right)=150\,\text{Hz}$;

sound has the same frequency and so wavelength is $\left(\frac{340}{150}\right)=2.3\,\text{m}$; ***[3]***

*Award **[1 max]** for those using a wavelength of 0.80 m obtaining a wavelength of 1.1 m in air. Accept alternative derivations that use a ratio and do not calculate the frequency explicitly.*

Part 2 Electromagnetic induction

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

(b) (i) the flux is changing and therefore an (e.m.f.) and a clockwise current are induced (in the loop);
a magnetic force on the loop develops that opposes the motion;
the force decreases the speed; ***[3]***

(ii) when a length Δx of the loop has entered the region of magnetic field the flux changes by $\Delta\Phi = BL\Delta x$;
the rate of change of flux *i.e.* the e.m.f. is then
$V = \left(\frac{\Delta\Phi}{\Delta t}\right) = \frac{BL\Delta x}{\Delta t}$;
$= BLv$ ***[2]***

or

equating electric to magnetic force on electrons to get $eE = evB \Rightarrow E = vB$;
use of $E = \frac{V}{L}$ to get answer;

(iii) at $t = 0,\ V = BLv = 0.30 \times 0.54 \times 5.0$;
$V = 0.81\,\text{V}$;
at $t = 0.18\,\text{s},\ V = 0$ because the flux is not changing and there is no induced e.m.f.; ***[3]***

(c) (i) kinetic energy lost is $\frac{1}{2} \times 0.060 \times \left(5.0^2 - 3.0^2\right) = 0.48\,\text{J}$;
so power $= \left(\frac{0.48}{0.14}\right) = 3.4\,\text{W}$; ***[2]***

(ii) maximum current is at $t = 0$;
$I_{\text{max}} = \left(\frac{0.81}{0.12}\right) = 6.8\,\text{A}$; ***[2]***

(d) speed shown decreasing (along a curve);
and then remaining constant; ***[2]***

B2. Part 1 Nuclear fusion

(a) the minimum energy required to (completely) separate the nucleons in a nucleus / the energy released when a nucleus is assembled from its constituent nucleons; ***[1]***

(b) mass defect $= 1\times1.007276 + 2\times1.008665 - 3.016049 = 8.56\times10^{-3}$ u ;
binding energy $= 8.56\times10^{-3}\times931.5 = 7.97$ MeV ;
binding energy per nucleon $= \dfrac{7.97}{3}$ MeV ;
$= 2.66$ MeV ***[3]***

(c) calculation of binding energies as shown below;
deuterium $^{2}_{1}\mathrm{H}$ $1.11\times2 = 2.22$ MeV
tritium $^{3}_{1}\mathrm{H}$ $2.66\times3 = 7.97$ MeV
helium $^{4}_{2}\mathrm{He}$ $7.20\times4 = 28.8$ MeV
energy released is the difference of binding energies;
and so equals 18.6 MeV; ***[3]***
*Award **[2 max]** for an answer that uses binding energy per nucleon without multiplying by the number of nucleons.*

(d) (i) the electrostatic/Coulomb force; ***[1]***

(ii) total energy initially available is $2E_K$;
at closest point potential energy is $E_P = \dfrac{kq_Dq_T}{d}$;
reference to energy conservation to equate the two; ***[3]***

(iii) correct identification of charges involved $q_D = q_T = 1.6\times10^{-19}$ C;
substitution to get $E_K = \dfrac{9\times10^{9}\times(1.6\times10^{-19})^2}{2\times1.2\times10^{-14}}$;
$E_K = 9.6\times10^{-15}$ J ***[2]***

(e) (i) 4.6×10^{8} K ; ***[1]***

(ii) even at lower temperatures there are nuclei moving sufficiently fast for fusion to occur;
because the formula for energy only refers to the average energy; ***[2]***

(iii) the nuclei have to overcome a Coulomb barrier/the repulsive force between the nuclei;
and so high temperatures are required to make the nuclei come sufficiently close to each other (for the nuclear force to then make them fuse); ***[2]***

(iv) at short distances the dominant force is the strong nuclear force which is attractive;
at large separations the nuclear force is negligible because it has short range leaving the repulsive electric force as the dominant force; ***[2]***

Part 2 The Doppler effect

(a) the difference between the emitted and received frequency;
when there is relative motion between the source and the receiver; ***[2]***

(b) (i) $u+v$; ***[1]***

(ii) $f\left(1+\frac{u}{v}\right)$; ***[1]***

(c) $\lambda' = \dfrac{u+v}{f\left(1+\frac{u}{v}\right)}$;

$= \dfrac{v}{f} = \lambda$; ***[2]***

(d) frequency received by moving observer is $1200\left(1+\frac{u}{340}\right)$;
reflected wave appears to original source to be coming from a moving source;
and so the reflected wave back at the original source has a frequency

$$1400 = \frac{1200\left(1+\frac{u}{340}\right)}{\left(1-\frac{u}{340}\right)};$$

$u = 26\,\text{m s}^{-1}$; ***[4]***

Award ***[2 max]*** *for use of single Doppler 57 m s*$^{-1}$ *or 59 m s*$^{-1}$.

B3. Part 1 Mechanics

(a) (i) $\dfrac{350}{9.8} = 36\,\text{kg}$; *(accept 35 kg)* ***[1]***

(ii) girl took 0.5 s to fall;
so $v = gt = (9.8 \times 0.5) = 4.9\,\text{m s}^{-1}$; *(accept 5.0 m s^{-1})* ***[2]***

(iii) $h = \frac{1}{2}gt^2$
$= \frac{1}{2}(9.8 \times 0.50^2)$;
$= 1.2\,\text{m}$; *(accept 1.3 m)* ***[2]***

or

use of conservation of energy to get
$\frac{1}{2}mv^2 = mgh \Rightarrow h = \dfrac{v^2}{2g}$;
$h = \dfrac{4.9^2}{2 \times 9.8} = 1.2\,\text{m}$; *(accept 1.3 m)*

(iv) maximum force on girl $= 1400\,\text{N}$;
so maximum acceleration $= \dfrac{1400}{36} = 39\,\text{m s}^{-2}$; *(accept 40 m s^{-2})* ***[2]***

(b) (i) the net force is still in the downward direction / the trampoline force is less than the weight / the trampoline has not yet deflected enough to give rise to a force larger than the weight;
and so the girl keeps accelerating downwards; ***[2]***

(ii) the change in momentum = area under graph from point C to point D;
$= \frac{1}{2} \times 350 \times (0.53 - 0.50)$;
$\approx 5\,\text{N s}$ ***[2]***

(iii) $36 \times (v_{\text{max}} - 4.9) = 5\,\text{N s}$;
so $v_{\text{max}} = 5\,\text{m s}^{-1}$; ***[2]***

Part 2 Wave-particle duality

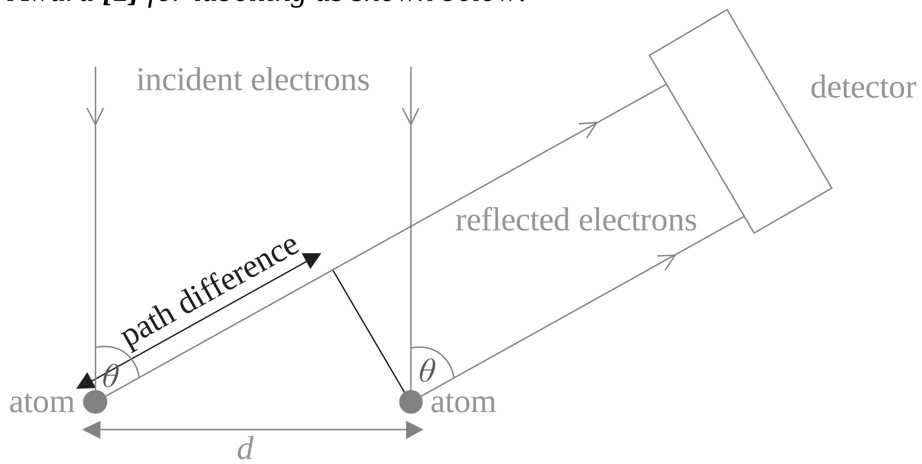
(a) there is a (probability) wave associated with all particles;
wavelength is given by Planck's constant divided by the particle's momentum; ***[2]***

(b) the de Broglie wavelength of the ball is $\lambda = \dfrac{6.63\times10^{-34}}{0.06\times20} \approx 6\times10^{-34}\ \text{m}$;
and this is much smaller than the 1 m gap;
wave properties will not be observed; ***[3]***

(c) $\dfrac{p^2}{2m} = eV$ ***or*** $\frac{1}{2}mv^2 = eV$;
$p = \sqrt{2meV}$;
shown substitution into $\lambda = \dfrac{h}{p}$; ***[3]***

(d) $1.7\times10^{-10}\ \text{m}$; ***[1]***

(e) (i) *Award **[1]** for labelling as shown below.*



[1]

(ii) the path difference is an integral number of wavelengths;
so the waves will <u>interfere constructively</u>; ***[2]***

(f) use of $d\sin\theta = \lambda$ to find the electron wavelength;
$\lambda = d\sin\theta = 2.15\times10^{-10}\times\sin 51^\circ = 1.7\times10^{-10}\ \text{m}$;
comment that this is the same as the de Broglie wavelength for electrons of this energy which is what is expected if de Broglie were correct; ***[3]***

(g) atoms are regularly arranged in a crystal;
with a small separation between them; ***[2]***

B4. Part 1 Gravitation

(a) (i) $F = \dfrac{GM^2}{4R^2}$; *(**n.b.** the factor of 4 is crucial here)*

$= \dfrac{Mv^2}{R}$;

to give $v = \sqrt{\dfrac{GM}{4R}}$ ***[2]***

Need to see clear setting of gravitational force equal to centripetal force.

(ii) $v = \dfrac{2\pi R}{T}$;

substitution into formula for v; ***[2]***

Do not accept use of Kepler's third law $T^2 = kR^3$ *as a starting point.*

(b) correct substitution to get $T = \sqrt{\dfrac{16\pi^2 \times \left(6.5\times10^8\right)^3}{6.67\times10^{-11}\times3.0\times10^{30}}}$;

$T = 1.47\times10^4\,\text{s}\,(=4.1\,\text{hrs})$; ***[2]***

(c) (i) decreasing energy means that R has to <u>decrease</u>;

and hence the period decreases as well <u>by reference to the formula relating period to separation</u>; ***[2]***

(ii) $\dfrac{1.47\times10^4}{\Delta t} = 7\times10^{-5}$;

$\Delta t \approx 2\times10^8$ (years); ***[2]***

Part 2 Electricity

(a) greater;
negative charges at top (and an equal amount of positive at the bottom);
(the negative charges are closer to the particle) and so there is an attractive force between the particle and the sphere; ***[3]***

(b) (i) *diagram A*: excess negative charge at top;
diagram B: same as diagram A;
diagram C: negative charge uniformly distributed on sphere; ***[3]***

(ii) there is an attractive force between the positive particle and the (negative charged) sphere;
therefore work has to be done on the charged particle; ***[2]***

or

the positively charged particle has negative potential energy because the sphere is negatively charged;
hence positive work must be done to remove the particle far away;

(c) work done per unit charge in moving charge completely around the circuit / power supplied per unit current; ***[1]***

(d) (i) two sets of series resistors at $90\,\Omega$ each;
and these are in parallel for a total of $45\,\Omega$;
plus the internal resistance in series for a grand total of $50\,\Omega$; ***[3]***

(ii) total current is $I = \left(\frac{12}{50}\right) = 0.24\,\text{A}$; ***[1]***

Watch for ECF if answer for resistance is wrong.

(iii) $P_{\text{total}} = EI$;
$= (12 \times 0.24) = 2.9\,\text{W}$; ***[2]***

Watch for ECF if answer for current is wrong.

(iv) across $30\,\Omega$ voltage drops by $3.60\,\text{V}$ (so potential at X is $3.60\,\text{V}$);
across $60\,\Omega$ voltage drops by $7.20\,\text{V}$ (so potential at Y is $7.20\,\text{V}$);
so potential difference between X and Y is (negative) $3.6\,\text{V}$; ***[3]***

(e) in the original circuit there is no current between X and Y / the resistance between X and Y is infinite;
introducing a real voltmeter changes the total resistance of the circuit / allows current between X and Y / the resistance between X and Y is no longer infinite; ***[2]***