M11/4/PHYSI/HP2/ENG/TZ1/XX/M

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MARKSCHEME

May 2011

PHYSICS

Higher Level

Paper 2

16 pages

General Marking Instructions

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[45 marks]** and **TWO** questions in Section B **[2 × 25 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 underlined 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.

9. Only consider units at the end of a correct calculation.

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) line of best fit is not straight / line of best fit does not go through origin; *[1]*

(b) smooth curve;
that does not go outside the error bars; *[2]*
Ignore extrapolations below n=1.

(c) we can re-write the suggested relation as $\log D = \log c + p \log n$;
now we can plot a graph of log D versus log n;
the slope of the (straight line) graph is equal to p; *[3]*
Accept logs in any base.

(d) (i) absolute uncertainty in diameter D is $\pm 0.08\,\text{cm}$;
giving a relative uncertainty in D^2 of $2 \times \frac{0.08}{1.26} = 0.13$ ***or*** 13%; *[2]*
Award ***[2]*** *if uncertainty is calculated for a different ring number.*

(ii) it is possible to draw a straight line that passes through the origin (and lies within the error bars);

or

the ratio of $\frac{D^2}{n}$ is constant for all data points; *[1]*

(iii) gradient $= k$;
calculation of gradient to give 0.23 *(accept answers in range 0.21 to 0.25)*;
evidence for drawing or working with lines of maximum and minimum slope;
answers in the form $k = 0.23 \pm 0.03$; *[4]*
Accept an uncertainty in k in range 0.02 to 0.04. First marking point does not need to be explicit.

(iv) cm^2; *[1]*

A2. (a) because the force is always at right angles to the velocity / motion/orbit is an equipotential surface; ***[1]***
Do not accept answers based on the displacement being zero for a full revolution.

(b) (i) equating gravitational force $\frac{GMm}{r^2}$;
to centripetal force $\frac{mv^2}{r}$ to get result; ***[2]***

(ii) kinetic energy is $\frac{GMm}{2r}$;
addition to potential energy $-\frac{GMm}{r}$ to get result; ***[2]***

(c) the total energy (at the new orbit) will be greater than before/is less negative;
hence probe engines must be fired to produce force in the direction of motion / positive work must be done (on the probe); ***[2]***
*Award **[1]** for mention of only potential energy increasing.*

A3. (a) light for which the electric field is oscillating in (only) one plane; ***[1]***

(b) (i) at a particular angle of incidence the reflected light is horizontally polarized;
and will be blocked by an analyser/polarizer with a vertical transmission axis;

or

at a particular angle of incidence when the reflected and refracted rays are at right angles the reflected light/rays will be horizontally polarized;
and will be blocked by an analyser/polarizer with a vertical transmission axis; ***[2]***

(ii) realization that $n = \tan 50^{\circ}$;
to give $n = 1.19$; ***[2]***

(c) (i) mention of superposition/interference;
interference is destructive and so there will be no light at P; ***[2]***
*Award **[0]** for correct answer with no or wrong argument.*

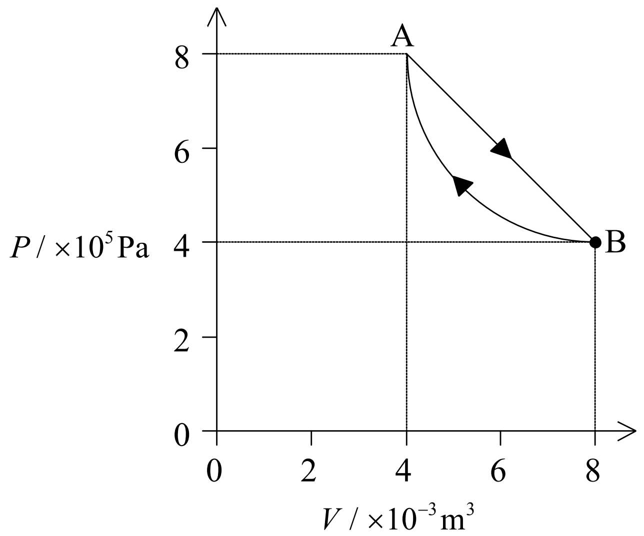
(ii) there will be light at P;
the two sources cannot interfere because their planes of polarization are at right angles; ***[2]***
*Award **[0]** for correct answer with no or wrong argument. Award **[0]** if answer mentions no light at P irrespective of anything else said.*

A4. (a) realization that since $pV = \text{constant}$, the temperature must be the same *i.e.* 400 K / full calculation using gas law to get 400 K; ***[1]***

(b) (i) work done is area under curve;
and this is $\left(\frac{4.0+8.0}{2} \times 4 \times 10^2\right) = 2400\,\text{J}$; ***[2]***
*Award **[2]** for correct bald answer.*

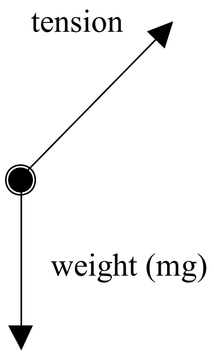
(ii) ($Q = \Delta U + W$ with) $\Delta U = 0$;
so $Q = 2400\,\text{J}$; ***[2]***
*Award **[0]** for correct answer with no or wrong argument.*

(c) (i) curve under given straight line starting at B and ending at A; ***[1]***



(ii) it would be less;
since the work done would be less / area under curve is less (and $\Delta U = 0$); ***[2]***

A5. (a) (i) ***[1]*** each for correct arrow <u>and</u> (any reasonable) labelling; ***[2]***



*Award **[1 max]** for arrows in correct direction but not starting at the ball.*

(ii) no;
because the two forces on the ball can never cancel out / there is a net force on the ball / the ball moves in a circle / the ball has acceleration/it is changing direction; ***[2]***
*Award **[0]** for correct answer with no or wrong argument.*

(b) $T\left(=\frac{mg}{\cos 30^{\circ}}\right)=2.83\,\text{N}$;

$\frac{mv^2}{r}=T\sin 30^{\circ}$;

$v=\left(\sqrt{\frac{Tr\sin 30^{\circ}}{m}}=\sqrt{\frac{2.83\times 0.33\times\sin 30^{\circ}}{0.25}}\right)=1.4\,\text{m}\,\text{s}^{-1}$;

or

$T\cos 30^{\circ}=mg$;

$T\sin 30^{\circ}=\frac{mv^2}{r}$;

$v=\left(\sqrt{gr\tan 30^{\circ}}=\sqrt{9.81\times 0.33\times\tan 30^{\circ}}\right)=1.4\text{ m s}^{-1}$; ***[3]***

SECTION B

B1. Part 1 CCDs and photons

(a) the number of pixels / distance between pixels; ***[1]***

(b) the image is digital so it can be manipulated;
it can show a bright object as well as a faint object accurately at the same time;
it requires shorter exposure times / has greater sensitivity;
responds to wider range of wavelengths;
responds linearly with intensity; ***[1 max]***

(c) (i) power deposited on one pixel is
$5.3\times10^{-3}\times4.2\times10^{-12}\left(=2.226\times10^{-14}\,\mathrm{W}\right)$;
power = $N\times6.63\times10^{-34}\times3.9\times10^{14}\left(=N\times2.5857\times10^{-19}\right)$;
$N=\frac{2.226\times10^{-14}}{2.5857\times10^{-19}}$;
$=8.6\times10^{4}$ ***[3]***

(ii) number of electrons emitted in 25 ms is
$\left(0.80\times8.6\times10^{4}\times25\times10^{-3}=1720\right)\approx1.7\times10^{3}$;
and so charge is $\left(1.7\times10^{3}\times1.6\times10^{-19}\right)=2.8\times10^{-16}\,\mathrm{C}$; ***[2]***

(iii) $V\left(=\frac{Q}{C}=\frac{2.8\times10^{-16}}{14\times10^{-12}}\right)=20\,\mu\mathrm{V}$; ***[1]***

(iv) momentum of one photon
$\left(\frac{6.63\times10^{-34}\times3.9\times10^{14}}{3.0\times10^{8}}=\right)8.62\times10^{-28}\,\mathrm{N\,s}$; ***[1]***

(v) pressure = rate of change of momentum per unit area;
$P\left(=\frac{8.6\times10^{4}\times8.62\times10^{-28}}{4.2\times10^{-12}}\right)=1.8\times10^{-11}\,\mathrm{Pa}$; ***[2]***
Accept unit $\mathrm{N\,m^{-2}}$ *for Pa.*

Part 2 Simple harmonic oscillations

(a) (i) the amplitude is constant; ***[1]***

(ii) period is $0.20\,\text{s}$;

$a_{\max} = \left(\left[\frac{2\pi}{T}\right]^2 x_0 = 31.4^2 \times 2.0 \times 10^{-2}\right) = 19.7 \approx 20\,\text{m}\,\text{s}^{-2}$; ***[2]***

(iii) displacement at $t = 0.12\,\text{cm}$ is $(-)1.62\,\text{cm}$;

$v\left(= \frac{2\pi}{T}\sqrt{x_0{}^2 - x^2}\right) = 31.4\sqrt{(2.0\times10^{-2})^2 - (1.62\times10^{-2})^2} = 0.37\,\text{m}\,\text{s}^{-1}$;

Accept displacement in range 1.60 to 1.70 cm for an answer in range $0.33\,m\,s^{-1}$ to $0.38\,m\,s^{-1}$.

or

$v_0 = \frac{2\pi}{T}x_0 = 0.628\,\text{m}\,\text{s}^{-1}$;

$|v| = \left(\left|-v_0 \sin\left[\frac{2\pi}{T}t\right]\right| \Rightarrow |v| = |-0.628\sin[31.4\times0.12]| = |0.37|\right) = 0.37\,\text{m}\,\text{s}^{-1}$;

or

drawing a tangent at 0.12 s;
measurement of slope of tangent; ***[2]***
Accept answer in range $0.33\,m\,s^{-1}$ to $0.38\,m\,s^{-1}$.

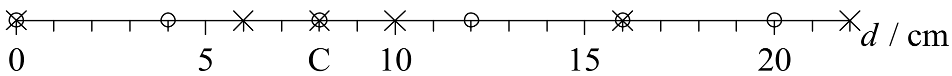
(iv) to the right; ***[1]***

(b) (i) use of $f = \frac{1}{T}$;

and so $f\left(= \frac{1}{0.20}\right) = 5.0\,\text{Hz}$; ***[2]***

(ii) wavelength is $16\,\text{cm}$;
and so speed is $v\left(= f\lambda = 5.0\times0.16\right) = 0.80\,\text{m}\,\text{s}^{-1}$; ***[2]***

(c) (i) points at 0, 8 and 16 cm stay in the same place;
points at 4 and 20 cm move 2 cm to the right;
point at 12 cm moves 2 cm to the left; ***[3]***

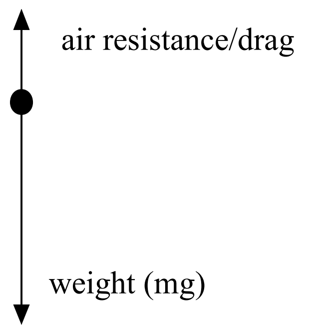


(ii) the point at 8 cm; ***[1]***

B2. Part 1 Mechanics and thermal physics

(a) the area under the curve; *[1]*

(b) (i) arrows as shown, with up arrow shorter; *[1]*



(ii) drawing of tangent to curve at $t = 2.0\,\text{s}$;
calculation of slope of tangent in range $3.5 - 4.5\,\text{m}\,\text{s}^{-2}$; *[2]*
*Award **[0]** for calculations without a tangent but do not be particular about size of triangle.*

(iii) calculation of $F = ma = 0.50 \times 4 = 2\ \text{N}$;
$R(= mg - F = mg - ma = 0.50 \times 9.81 - 2) \approx 3\,\text{N}$; *[2]*

(iv) the acceleration is decreasing;
and so R is greater;

or

air resistance forces increase with speed;
since speed at 5.0 s is greater so is resistance force; *[2]*

(c) (i) loss of potential energy is $mg\Delta h = 0.50 \times 9.81 \times 190 = 932\,\text{J}$;
gain in kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2}0.50 \times 25^2 = 156\,\text{J}$;
loss of mechanical energy is 932–156;
$\approx 780\,\text{J}$ *[3]*

(ii) $mc\Delta\theta = 780\,\text{J}$;
$\Delta\theta = \left(\frac{780}{0.5 \times 480}\right) \approx 3\,\text{K} / 3^\circ\text{C}$; *[2]*

(iii) all the lost energy went into heating just the ball / no energy transferred to surroundings / the ball was heated uniformly; *[1]*

Part 2 Nuclear physics

(a) (i) the (minimum) energy required to completely separate the nucleons of a nucleus / the energy released when a nucleus is assembled; *[1]*

(ii) mass defect is $94 \times 1.007276 + 145 \times 1.008665 - 238.990396 = 1.95\,\text{u}$;
binding energy is $1.95 \times 931.5 = 1816$ MeV;
binding energy per nucleon is $\frac{1816}{239}$ MeV;
$= 7.6$ MeV *[3]*

(b) (i) $x = 3$; *[1]*

(ii) binding energy of plutonium is $7.6 \times 239 = 1816 \approx 1800\,\text{MeV}$
(known in (ii))
binding energy of products is $8.6 \times 91 + 8.2 \times 146 = 1980 \approx 2000\,\text{MeV}$;
energy released is $(2000 - 1800) = 200\,\text{MeV}$; *[2]*

(c) the electric force is repulsive/tends to split the nucleus;
the electric force acts on protons, the strong nuclear force acts on nucleons;
the nuclear force is attractive/binds the nucleons;
but the electric force is long range whereas the nuclear force is short range;
so adding more neutrons (compared to protons) contributes to binding and does not add to tendency to split the nucleus / a proton repels every other proton (in the nucleus) so extra neutrons are needed for binding; *[4 max]*

B3. Part 1 Quantum aspects of the electron

(a) a function whose (absolute squared) value may be used to calculate the probability of finding a particle near a given position / quantity related to the probability of finding an electron near a given position/at a given position; ***[1]***

(b) middle of the box / (near) $0.5\times10^{-10}\,\text{m}$; ***[1]***

(c) the de Broglie wavelength is $2.0\times10^{-10}\,\text{m}$;

$$p=\frac{h}{\lambda}=\frac{6.63\times10^{-34}}{2.0\times10^{-10}}=3.3\times10^{-24}\,\text{N s};$$ ***[2]***

(d) difference in energy is

$$\Delta E\left(=-\frac{2.18\times10^{-18}}{2^2}+\frac{2.18\times10^{-18}}{1^2}\right)=1.635\times10^{-18}\,\text{J};$$

$$\lambda=\frac{hc}{\Delta E};$$

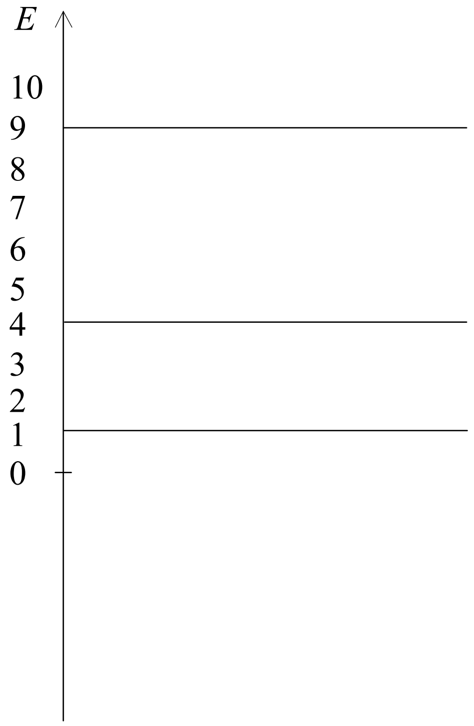
$$\lambda=\left(\frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.635\times10^{-18}}\right)=1.22\times10^{-7}\,\text{m};$$ ***[3]***

(e) (i) attempt at using the energy – time uncertainty relation;

$$\Delta E\left(=\frac{h}{4\pi\Delta t}=\frac{6.63\times10^{-34}}{4\pi\times1.0\times10^{-10}}\right)=5.3\times10^{-25}\,\text{J};$$ ***[2]***

(ii) the wavelength of the photons is determined by the difference in energy between the two levels;
and that energy difference is not well defined/definite/not always the same (because of the uncertainty principle); ***[2]***

(f) energy levels all with strictly positive energy;
difference between levels increasing with increasing *n*; ***[2]***



Judge separation of levels by eye – there will not be numbers on the candidates' graphs.

Part 2 Electric circuits

(a) (i) the work done per unit charge in moving a quantity of charge completely around a circuit / the power delivered per unit current / work done per unit charge made available by a source; *[1]*

(ii) the ratio of the voltage across to the current in the conductor; *[1]*

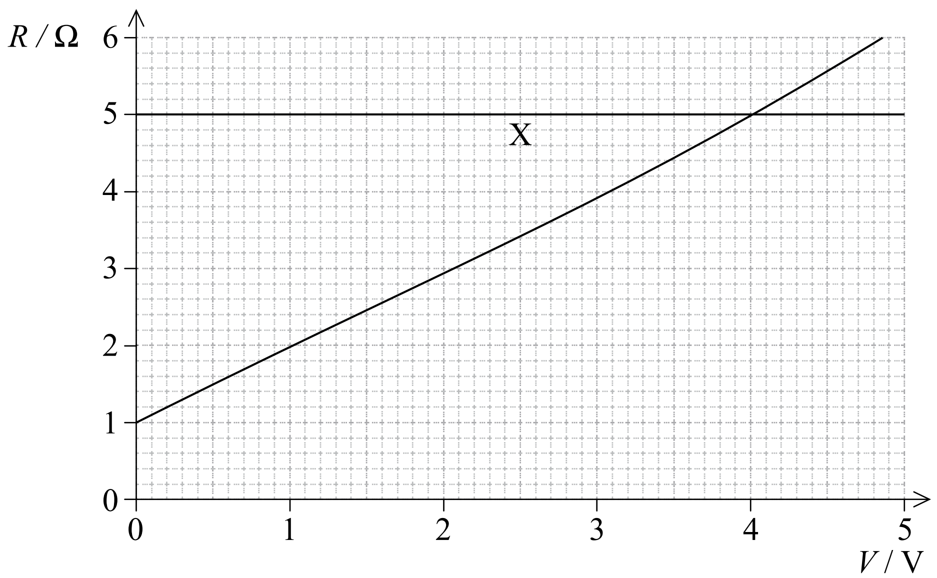
(b) (i) emf × current; *[1]*

(ii) total power is V_1I+V_2I;
equating with EI to get result;

or

total energy delivered by battery is EQ;
equate with energy in each resistor V_1Q+V_2Q; *[2]*

(c) graph X: horizontal straight line;
graph Y: starts lower than graph X;
rises (as straight line or curve) and intersects at 4.0 V; *[3]*



Do not pay attention to numbers on the vertical axis.

(d) (i) realization that the voltage must be 4.0 V across each resistor;
and so emf is 8.0 V; *[2]*

(ii) power in each resistor $=3.2\,\text{W}$;
and so total power is 6.4 W;

or

current is 0.80 A;
so total power is $8.0\times0.80=6.4\,\text{W}$; *[2]*

B4. Part 1 Energy balance of the Earth

(a) the solar radiation is captured by a disc of area πR^2 where R is the radius of the Earth;
but is distributed (when averaged) over the entire Earth's surface which has an area four times as large;

*Award **[1]** for reference to absorption/reflection.* ***[2]***

(b) (i) 0.700; ***[1]***

(ii) $I\left(=e\sigma T_{\mathrm{a}}^4\right)=0.70\times5.67\times10^{-8}\times242^4$;
$=136\,\mathrm{W\,m^{-2}}$ ***[1]***

(iii) $\sigma T_{\mathrm{e}}^4=136+245\,\mathrm{W\,m^{-2}}$;
hence $T_{\mathrm{e}}\left(=\sqrt[4]{\dfrac{381}{5.67\times10^{-8}}}\right)=286\,\mathrm{K}$; ***[2]***

(c) (i) the Earth radiates radiation in the infrared region of the spectrum;
the greenhouse gases have energy level differences (in their molecular energy levels) corresponding to infrared energies;
and so the infrared photons are absorbed;

or

the Earth radiates photons of infrared frequency;
the greenhouse gas molecules oscillate/vibrate with frequencies in the infrared region;
and so because of resonance the photons are absorbed; ***[3]***

(ii) most incoming radiation consists of photons in the visible/ultraviolet region / photons of much shorter wavelength than those radiated by the Earth / photons of different wavelength of that radiated by Earth;
and so these cannot be absorbed; ***[2]***

(iii) *Source*: emissions from volcanoes / burning of fossil fuels in power plants/cars / breathing;
Sink: oceans / rivers / lakes / seas / trees; ***[2]***

Part 2 Motion in a magnetic field and electromagnetic induction

(a) (i) $v=\sqrt{\dfrac{2eV}{m}}$;

$v=\sqrt{\dfrac{2\times1.6\times10^{-19}\times250}{9.1\times10^{-31}}}$;

$=9.4\times10^{6}\,\mathrm{m\,s^{-1}}$ ***[2]***

(ii) $evB=m\dfrac{v^2}{r}$;

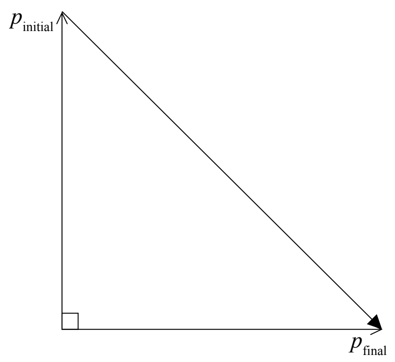
$r=\dfrac{9.1\times10^{-31}\times9.4\times10^{6}}{1.6\times10^{-19}\times0.12}$;

$=4.5\times10^{-4}\,\mathrm{m}$ ***[2]***

(iii) $t=\dfrac{1}{4}\dfrac{2\pi\times4.5\times10^{-4}}{9.4\times10^{6}}$;

$=7.5\times10^{-11}\,\mathrm{s}$ ***[1]***

(b) (i) vector as shown; ***[1]***



(ii) $\Delta p=\left(\sqrt{\left[8.6\times10^{-24}\right]^2+\left[8.6\times10^{-24}\right]^2}\right)$;

$=1.2\times10^{-23}\,\mathrm{N\,s}$ ***[1]***

(iii) $F\left(=\dfrac{\Delta p}{\Delta t}=\dfrac{1.2\times10^{-23}}{7.5\times10^{-11}}\right)=1.6\times10^{-13}\,\mathrm{N}$; ***[1]***

(c) (i) the flux in the loop is changing and so (by Faraday's law) an emf will be induced in the loop;
(by Lenz's law) the induced current will be (counter-clockwise) and so there will be a magnetic force opposing the motion;
requiring work to be done on the loop; ***[3]***

(ii) it is dissipated as thermal energy (due to the resistance) in the loop / radiation; ***[1]***