M13/4/PHYSI/HP2/ENG/TZ2/XX/M

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MARKSCHEME

May 2013

PHYSICS

Higher Level

Paper 2

17 pages

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.

2. Each marking point has a separate line and the end is shown 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 ***OWTTE*** (or words to that effect).

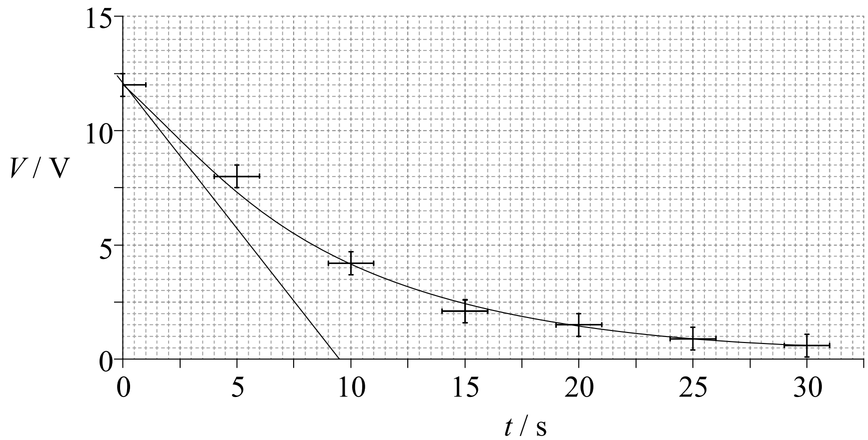
8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

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. When marking indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

SECTION A

A1. (a)



(i) smooth curve;
that passes through all error bars; ***[2]***

(ii) correctly identifies three points from own graph;
correctly processes these three points using exponential/half life/constant ratio/relationship;
to conclude that decay is exponential;
within uncertainty; ***[4]***

(b) (i) evaluates a gradient over a minimum of 5 s to give an initial rate for example, $\left(\frac{12}{9.5}=\right)1.3\ \text{V s}^{-1}$ for graph above; *(allow ECF from the graph)*

V s^{-1}; ***[2]***
Clear evidence of calculation of gradient must be seen.

(ii) obtains evidenced answer for *t* intercept; ***[1]***

(c) $C = \left(\frac{10}{10 \times 10^6} =\right) 1.0\ (\pm 0.2) \times 10^{-6}\ \Omega^{-1}\ \text{s/F}$; **[1]**

*Award **[0]** for absence of 10^6 unless unit is in terms of MΩ.*

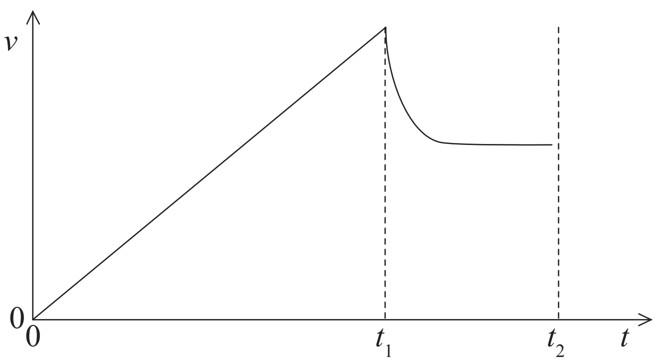
A2. (a) (i) $s = 12.5/12.6$ m; **[1]**

(ii) $v = \sqrt{2gs}$ ***or*** gt; *(allow any use of* suvat *equations)*

$= \left(\sqrt{2 \cdot 9.8 \cdot 12.5} =\right) 15.7\ \text{m s}^{-1}$; **[2]**

*Award **[2]** for a bald correct answer.*

(b)



straight line to water surface;

clear decrease after hitting surface;

constant non-zero speed reached *smaller* than maximum; *(speed must be less than maximum velocity)* **[3]**

A3. (a) *internal energy*:
the sum of the potential and the (random) kinetic energy of the molecules/particles of a substance;

thermal energy:
the (non-mechanical) transfer of energy between two different bodies as a result of a temperature difference between them; ***[2]***

(b) (i) $(\Delta U) = 0.25 \times 4.2 \times 10^3 \times 27 \ (= 2.835 \times 10^4 \text{ J})$;
$= 2.8 \times 10^4$ J ; ***[2]***

(ii) energy transfer $= [300 \times 120] - [2.8 \times 10^4] = 7.65 \times 10^3$ J ;
rate of transfer $= \dfrac{7.650 \times 10^3}{120} = 64$ W ; ***[2]***

Allow ECF from (b)(i).

A4. (a) (i) nuclides/atom/element/nucleus/nuclei that have the same proton number/ same element but different nucleon/neutron numbers / *OWTTE*; ***[1]***

(ii) the time taken for the activity (of a radioactive sample) to decrease by half / the time taken for half the (initial) number of radioactive nuclei/atoms/mass to decay; ***[1]***

(b) (i) 2; ***[1]***

(ii) (mass difference $=$) $7.0160 - [3.0161 + 4.0026] = (-)2.7 \times 10^{-3}$ u ;
(energy required $=$) $(-)2.7 \times 10^{-3} \times 931.5$ ***or*** 2.5151 MeV ;
(≈ 2.5 MeV) ***[2]***
Allow unit conversions via mass and mc^2.

(c) ${}^{3}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + \beta^- + \bar{\nu}$
β^- ***or*** ${}^{0}_{-1}\text{e}$ ***or*** e^- ***or*** electron ***or*** beta particle;
$\bar{\nu}$ ***or*** ${}^{0}_{0}\bar{\nu}$ ***or*** antineutrino; ***[2]***
Allow answers in any order.

A5. (a) the work done per unit charge;
in bringing a positive test / positive point / positive small charge
from infinity to the point; } *(accept use of a "reference point where potential is zero")* ***[3]***

(b) (i) $Q = 4\pi\varepsilon_0 rV$ ***or*** krV ;

$= \frac{1}{9} \times 10^{-9} \times 0.080 \times 300$ ***or*** $2.67\,\text{nC}$;

$(\approx 2.7\,\text{nC})$ ***[2]***

(ii) $E = \frac{Q}{4\pi\varepsilon_0 r^2}$

$= \left(\frac{9\times10^9 \times 2.7\times10^{-9}}{0.16^2} =\right) 950$;

$940 / 950\ \text{N C}^{-1}$ ***or*** V m^{-1} ; ***[2]***

(iii) $950\,\text{V m}^{-1}$; ***[1]***
Allow ECF from (b)(ii).

A6. (a) (at constant speed) forces are balanced;
force is (electro) magnetic;
due to current in rod;
which arises from induced emf (from motion); ***[4]***

(b) (Lenz's law states) the direction of an induced emf/current is such as to oppose the change to which it is due;
in this situation the induced current (in the rod) is in such a direction that the magnetic force on the rod opposes the force *F*; ***[2]***

(c) $Bv = \left(\frac{E}{l} =\right) 0.015\,\text{Vm}^{-2}$;

$F = (Bev =)\ 2.4\times10^{-21}\,\text{N}$; ***[2]***

*Award **[2]** for a bald correct answer.*

SECTION B

B1. Part 1 Electric charge and electric circuits

(a) the force between two (point) charges;
is inversely proportional to the square of their separation and (directly) proportional to (the product of) their magnitudes; ***[2]***
*Allow **[2]** for equation with F, Q and, r defined.*

(b) (i) $F = \left(k\frac{q_1 q_2}{r^2} = \right) \frac{9\times10^{9}\times[1.6\times10^{-19}]^2}{4\times10^{-20}}$;
$= 5.8\times10^{-9}\,\text{N}$; ***[2]***

(ii) $\frac{(b)(i)}{1.6\times10^{-19}}$ ***or*** $3.6\times10^{10}\,\text{N}\,\text{C}^{-1}$ ***or*** $\text{V}\,\text{m}^{-1}$;
(directed) away from the proton; ***[2]***
Allow ECF from (b)(i).

(iii) $H = \left(G\frac{m}{r^2} = \right) \frac{6.67\times10^{-11}\times1.673\times10^{-27}}{4\times10^{-20}} = 2.8\times10^{-18}\,\text{N}\,\text{kg}^{-1}$;
$\frac{H}{E} = \frac{2.8\times10^{-18}}{3.6\times10^{10}}$ ***or*** $7.8\times10^{-29}\,\text{C}\,\text{kg}^{-1}$;
$(\approx 10^{-28}\,\text{C}\,\text{kg}^{-1})$ ***[2]***
Allow ECF from (b)(i).

(iv) 3.4 V; ***[1]***

(c) (i) power supplied per unit current / energy supplied per unit charge / work done per unit charge; ***[1]***

(ii) energy supplied per coulomb $= \frac{5.1\times10^{-19}}{1.6\times10^{-19}}$ ***or*** 3.19 V;

($\approx 3.2\text{ V}$) ***[1]***

(iii) pd across $5.0\,\Omega$ resistor $= \left(\frac{4.0\times10^{-19}}{1.6\times10^{-19}} =\right) 2.5\text{ V}$;

pd across $r = (3.2 - 2.5 =)\ 0.70\text{ V}$;

and

either

current in circuit $= \left(\frac{2.5}{5.0} =\right) 0.5\text{ A}$;

resistance of $r = \left(\frac{0.70}{0.50} =\right) 1.4\,\Omega$;

or

resistance of $r = \frac{0.70}{2.5}\times5.0$;

$= 1.4\,\Omega$;

or

$3.2 = 0.5(R + r)$;

resistance of $r = 1.4\,\Omega$; ***[4]***

*Award **[4]** for alternative working.*

Part 2 Thermodynamic cycle

(a) a real gas can be liquefied (whereas an ideal gas cannot);

a real gas does not always obey (the equation of state) $PV = nRT$ (whereas an ideal gas does); *(do not accept "obeys equation of state" without statement of equation)*

a real gas does not obey Boyle's law for all values of pressure;
a real gas does not obey Charles's law for all values of temperature; ***[2 max]***
Accept discussion only of macroscopic effects.

(b) (i) for an adiabatic change there is no (non-mechanical) transfer of (heat/thermal) energy (to or from the gas);
so the work done on or by the gas is equal to the (magnitude of the) change in internal energy of the gas; ***[2]***

(ii) for an isothermal change there is no change in internal energy;
so that the work done on or by the gas is equal to the energy (to or from the gas); ***[2]***

(c) CD;
(isothermal) compression / volume decreases;
in which work is done on the gas;
if there is to be no increase in internal energy the gas must lose energy to the surroundings / *OWTTE*; ***[4]***

B2. Part 1 Power production and the greenhouse effect

(a) energy output in a year $= \left(4.0\times10^{9}\times3.2\times10^{7}=\right)1.28\times10^{17}$ J

energy input $= \left(\frac{1.28\times10^{17}}{0.4}=\right)3.2\times10^{17}$ J ;

mass of coal $= \left(\frac{3.2\times10^{17}}{2.4\times10^{7}}=\right)1.3\times10^{10}$ kg ; *[3]*

Allow approach using power output.

or

power required from coal $= \frac{4.0}{0.4} = 10\,\text{GW}$;

mass of coal required each second $= \left(\frac{10\times10^{9}}{24\times10^{6}}=\right)417$ kg ;

mass of coal required each year $= (417\times3.2\times10^{7}=)\,1.33\times10^{10}$ kg

Allow alternative working leading to correct answer.

(b) *advantage*:
(nuclear power) does not produce carbon dioxide;
therefore it does not add to the greenhouse effect/global warming;

or

energy density of U-235 (fuel) is very high / small mass is required;
fuel is likely to last a long time/easier to transport / *OWTTE*;

disadvantage:
waste products (of U-235 fuel) are radioactive;
no safe method of disposal / long half-life; *(do not accept "lasts a long time")* *[4]*

or

allows development of nuclear weapons;
mention of plutonium/uranium enrichment/dirty bomb;

or

accidents are potentially catastrophic;
leading to widespread mutations/cancers/contamination/other named effect;

or

power plant is more expensive;
plausible reason for the expense for example safety/complex plant/ decommissioning / *OWTTE*;

(c) power output of a turbine $= 0.3 \times \frac{1}{2}\rho A v^3 = 0.3 \times 0.5 \times 1.2 \times 3.14 \times [42]^2 \times [12]^3$ $(= 1723\,\text{kW})$;

number of turbines needed $= \dfrac{4 \times 10^9}{1.723 \times 10^6}$ $(= 2322)$;

area needed $= 2322 \times 5.0 \times 10^4$;

$= 1.2 \times 10^8\ \text{m}^2$; ***[4]***

(d) *look for these main points*:

the surface of Earth re-radiates the Sun's radiation;

greenhouse gases (in atmosphere) readily absorb infrared;

mention of resonance;

the absorbed radiation is re-emitted (by atmosphere) in all directions;

(some of) which reaches the Earth and further heats the surface; ***[3 max]***

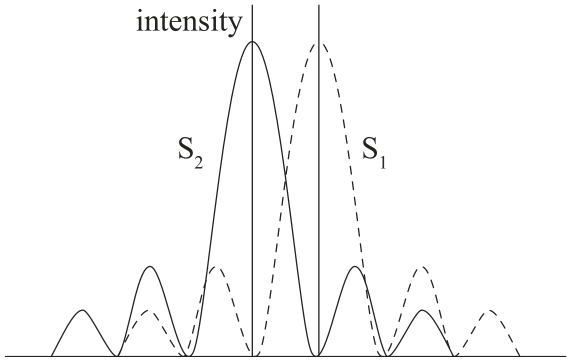
Award ***[1 max]*** *for responses along the lines that greenhouse gases trap infrared radiation.*

(e) total absorbed radiation $=$ total emitted radiation $= 238\,\text{W m}^{-2}$;

temperature of Earth $= \left[\dfrac{238}{5.67 \times 10^{-8}}\right]^{\frac{1}{4}} = 255\,\text{K}$; ***[2]***

Part 2 Optical resolution and polarization

(a)



S_1 / S_2 shows a central maximum flanked by at least one subsidiary maximum on each side;
intensity of first maximum is less than one-third of the intensity of the central maximum; *(judge by eye)*
first minimum of S_1 / S_2 coincides with central maximum of S_2 / S_1;

(b) angle (subtended at eye for Moon to be resolved) $= \frac{3.5\times10^6}{d}$;

$= \left(1.22\frac{\lambda}{b} =\right) \frac{1.22\times4.2\times10^{-7}}{4.0\times10^{-3}}$;

$d = \frac{3.5\times10^6 \times 4.0\times10^{-3}}{1.22\times4.2\times10^{-7}}$ ***or*** 2.7×10^{10} m;
$(\approx 3\times10^{10}$ m) ***[3]***

(c) (i) the (electric/magnetic) vector/direction of electric field (of the light) vibrates only in one plane; ***[1]***
Accept a labelled diagram.

(ii) $\phi = \tan^{-1} n = 54^\circ$ ***or*** 55° ***or*** 0.95 rad;
angle to surface $= (90 - 55 =)\ 36^\circ$ ***or*** 35° ***or*** 0.62 rad; ***[2]***
Award ***[2]*** *for a bald correct answer.*

B3. Part 1 Simple harmonic motion (SHM) and waves

(a) the acceleration of piston/P is proportional to its displacement from equilibrium;
and directed towards equilibrium; ***[2]***
There must be a clear indication what is accelerating otherwise award ***[1 max]****.*

(b) (i) 12 cm; ***[1]***

(ii) any maximum or minimum of the graph; ***[1]***

(iii) period = 0.04 s;
$\omega = \left(\frac{2\pi}{T} =\right) \frac{2 \times 3.14}{0.04} = 157 \text{ rad s}^{-1}$;
maximum acceleration $= (A\omega^2 =)\ 0.12 \times 157^2 = 3.0 \times 10^3 \text{ m s}^{-2}$; ***[3]***

(iv) at $t = 0.052$ s $x = (-)4\,(\pm 1)$ cm;
$\text{KE} = \left(\frac{1}{2} m\omega^2 [A^2 - x^2] =\right) 0.5 \times 0.32 \times 157^2\, [0.12^2 - 0.04^2] = 50\,(\pm 7)$ J; ***[2]***
Allow ECF from (b)(iii).

(c) (i) the direction of the oscillations/vibrations/movements of the particles (in the medium/gas);
for a longitudinal wave are parallel to the direction of the propagation of the energy of the wave;
for a transverse wave they are at right angles to the direction of the propagation of the energy of the wave; ***[3]***

(ii) $f = \frac{1}{T} = \frac{1}{0.04} = 25\text{ Hz}$;

$= \frac{v}{f} = \frac{340}{25} = 14\text{ m}$; ***[2]***

Award ***[1 max]*** *if frequency is not clearly stated.*
Allow ECF from calculations in (b)(iii).

Part 2 Charge-coupled device (CCD)

(a) (i) ratio of charge to potential difference; *[1]*
Must see symbols defined.

(ii) mention of photons;
the photons liberate electrons (within the silicon) / mention of photoelectric effect;
electrons migrate to an electrode / pixel acts as a capacitor (storing charge); *[3]*

(iii) the potential difference between the electrodes (of each pixel) is measured;
the pixel position is also stored/recorded; *[2]*

(b) energy of each photon $= \left(hf = 6.6\times10^{-34}\times5.8\times10^{14} =\right)3.83\times10^{-19}\text{ J}$;

number of photons incident in $3.0\text{ ms} = \left(\dfrac{400\times1.5\times10^{-10}\times3.0\times10^{-3}}{3.83\times10^{-19}} =\right)4.7\times10^{8}$;

charge produced $= \left(4.7\times10^{8}\times1.6\times10^{-19}\times0.7 =\right)5.26\times10^{-11}\text{ C}$;

$V = \dfrac{Q}{C} = \dfrac{5.26\times10^{-11}}{1.2\times10^{-9}}$;
$= 44\text{ mV}$; *[5]*

B4. Part 1 Momentum and energy

(a) product of mass and velocity; *[1]*
Accept symbols if defined correctly.

(b) if the net external force acting on a system is zero;
the momentum of the system remains constant/unchanged/the same; *[2]*

or

for a closed system;
the momentum remains constant/unchanged/the same;

(c) identifies the system as rocket + exhaust gases / total momentum of rocket and gas is equal before and after ;
no external forces act on this system;
increase/change in momentum of the gases is equal and opposite to the increase/change of momentum of the rocket; *[3]*

(d) (i) attempts to use conservation of momentum, *eg.* $8.0\times1.3 = 52\times v$;
$v = 0.20\text{ m s}^{-1}$; *[2]*

(ii) identifies new mass as 75.3 kg;
$V = 0.14\text{ m s}^{-1}$; *[2]*

(e) initial KE of Jane $= \frac{1}{2}52 \times 0.2^2 = 1.04\,\text{J}$;
use of $Fs = \frac{1}{2}mv^2$;
$s = \dfrac{1.04}{0.12} = 8.7\,\text{m}$;
repeat calculation for Joe + ball $s = \dfrac{0.5 \times 75.3 \times 0.14^2}{0.12} = 6.1\,\text{m}$;
new separation $= 4.0 + 8.7 + 6.1 = 18.8\,\text{m}$;
$(\approx 20\,\text{m})$ ***[5]***

or

acceleration of Jane $= \left(\dfrac{0.12}{52} =\right) 0.0023\,\text{m}\,\text{s}^{-2}$;
distance travelled by Jane $= \left(\dfrac{0.20^2}{2 \times 0.0023} =\right) 8.7\,\text{m}$;
acceleration of Joe $= \left(\dfrac{0.12}{75.3} =\right) 0.0016\,\text{m}\,\text{s}^{-2}$;
distance travelled by Joe $= \left(\dfrac{0.14^2}{2 \times 0.0016} =\right) 6.1\,\text{m}$;
total distance $= 4.0 + 8.7 + 6.1 = 18.8\,\text{m}$;

Part 2 The de Broglie hypothesis and radioactive decay

(a) all particles have an associated wavelength/exhibit wave properties;
the wavelength is given by the Planck constant divided by their momentum / $\lambda = \frac{h}{p}$; *(with symbols defined)* ***[2]***

(b) combine $p = \frac{h}{\lambda}$ and $E = \frac{p^2}{2m}$ to give $E = \frac{h^2}{2m\lambda^2}$;

$E = \left(\frac{[6.6 \times 10^{-34}]^2}{2 \times 9.1 \times 10^{-31} \times [1.8 \times 10^{-10}]^2} = \right) 7.39 \times 10^{-18}$ J;

$f = \left(\frac{E}{h} = \frac{7.39 \times 10^{-18}}{6.6 \times 10^{-34}} = \right) 1.1 \times 10^{16}$ Hz; ***[3]***

(c) (i) the gamma photon originates from the argon nucleus;
the (argon) nucleus relaxes from an excited state / to its ground state / making it stable; ***[2]***

(ii) $\lambda = \left(\frac{\ln 2}{1.3 \times 10^9} = \right) 5.33 \times 10^{-10}$ yr^{-1};

$0.10 = e^{-5.33 \times 10^{-10} t}$ ***or*** $\ln\left(\frac{N}{N_0}\right) = -5.33 \times 10^{-10} t$;

$t = 4.3 \times 10^9$ yr; ***[3]***