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# MARKSCHEME

## November 2012

## 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) smooth curve going through error bars and within half square of other points; ***[1]***

(b) not proportional because not straight/trend cannot go through origin; ***[1]***

(c) fractional error in $v = \frac{20}{250} (= 0.080)$;

fractional error in $v^{\frac{1}{3}} = \frac{0.080}{3} (= 0.027)$; *(allow ECF from first marking point)*

uncertainty in $v^{\frac{1}{3}} = (0.063 \times 0.027 =) 0.00169$; *(allow 0.00168 – 0.00170)*

*Allow expression of answer as 0.630 ± 0.002 if calculation above seen.*

*Award **[3]** for a bald correct answer.* ***[3]***

***or***

recognizes uncertainty in $v^{\frac{1}{3}} = \frac{\sqrt[3]{270} - \sqrt[3]{230}}{2}$ ***or*** $\sqrt[3]{250} - \sqrt[3]{230}$ ***or*** $\sqrt[3]{270} - \sqrt[3]{250}$;

$= 0.168$;

conversion to $0.00168\,\text{m}\,\text{s}^{-1}$;

(d) (i) large triangle > half line used;

read-offs and substitution correct; *(allow power of ten error here)*

$k^{\frac{1}{3}} = 0.012 \pm 0.001$; *(allow ECF)*

$k = 1.73 \times 10^{-6}\,\text{m}\,\text{N}^{-3}\,\text{s}^{-1}$; *(allow correct power of ten only)* ***[4]***

*Award **[0]** for use of a single data point.*

(ii) $\text{m}\,\text{N}^{-3}\,\text{s}^{-1}$ ***or*** $\text{kg}^{-3}\,\text{m}^{-2}\,\text{s}^{5}$; ***[1]***

**A2.** (a) if no external forces act / isolated system;
momentum is constant / (total) momentum before = (total) momentum after; ***[2]***

(b) (i) use of $v = \sqrt{2gh}$;
6.11 m s$^{-1}$; *(must show calculation to better than 1 sf)* ***[2]***

(ii) rate of change of vertical momentum = $13 \times 6.11$;
79 N; *(accept answers in the range of 78 N to 80 N)* ***[2]***

(iii) mass accrued = $5.0 \times 13 = 65$ kg;
weight of this mass ( = $65 \times 9.8$) = 637 N; *(650 from g = 10 m s$^{-2}$)*
total force = (637 + 79 =) 716N; ***[3]***

(c) (i) 14.6 J s$^{-1}$; ***[1]***

(ii) horizontal momentum gain per second = $13 \times 1.5$ ( = 19.5 kg m s$^{-1}$);
power required = 29.3 W; ***[2]***

(iii) additional energy/power required to accelerate gravel (through friction at the surface of the belt) / the gravel has to slip to gain horizontal speed / *OWTTE*; ***[1]***

**A3.** (a) $\theta = \frac{6.2\times10^{-7}}{4.5\times10^{-4}} (= 1.38\times10^{-3})$;
distance $(= 1.38\times10^{-3} \times 3.4 = 4.68) \approx 4.7\text{mm}$; ***[2]***

(b) (i) in order to be (just) resolved the first minimum of diffraction pattern (of one image) coincides with the central maximum of the other (image) / *OWTTE*; ***[1]***

(ii) criterion specifies $> 4.7\text{ mm}$ in this case / clear use of answer to (a) as distance;
$\left(\frac{4.7}{3.4}\times 6.0\right) = 8.3\text{ mm}$; ***[2]***
*Award **[1 max]** if factor of 1.22 used.*

(c) *for white light*:
central maximum white, laser central maximum is monochromatic;
white light fringes/lines will be coloured;
blue diffracted least / *OWTTE*; ***[2 max]***

**A4.** (a) providing the temperature/physical conditions are constant and pd $\propto$ current; ***[1]***

***or***

providing the temperature/physical conditions are constant and the resistance is constant;

(b) (i) current for one lamp $= 1.5\text{ A}$;
$\frac{13}{1.5} = 8.67$;
so 8; ***[3]***
*Must show working for full credit. Allow any suitable method.*

(ii) $4.0\,\Omega$; ***[1]***

(iii) resistance of incorrect lamp $= 16\,\Omega$;
total resistance of "correct" lamps in parallel $= 1.3\,\Omega$ ***or*** $\frac{1}{R} = \frac{1}{16} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4}$;
total resistance $= 1.2\,\Omega$; ***[3]***

**A5.** (a) at least two concentric circles;
with clockwise direction indicated; ***[2]***

(b) (i) each turn subject to the magnetic field of the other / field patterns for individual turns combine;
force shown to be attractive by use of direction rule/ by consideration of field pattern / *OWTTE*; *(can be shown diagrammatically)* ***[2]***

(ii) $F = (0.280 \times 10^{-3} \times 9.81 =) 2.75 \times 10^{-3}$ N;

$B = \frac{F}{Il}$ ***or*** correct substitution $2.75 \times 10^{-3} = B \times (15) \times 0.48$;

$B = \left( \frac{2.75 \times 10^{-3}}{15 \times 0.48} = \right) 3.8 \times 10^{-4}$ T; ***[3]***

**SECTION B**

**B1. Part 1** Processes in a gas

(a) $n = \left(\frac{pV}{RT} = \right) \frac{1.1 \times 10^5 \times 6.0 \times 10^{-4}}{8.31 \times 290}$;
0.027; ***[2]***

(b) (i) calculate $pV$ correctly for both states: 66 and 76; } *(do not penalize 66 k/K and 76 k/K as k may be a constant)*
isothermal change would mean that $p_1V_1 = p_2V_2$;
so not isothermal ***[2]***

(ii) no heat/thermal energy transferred;
(because change/compression) occurs (too) quickly/fast; ***[2]***

(iii) $Q = 0$;
$W = -15$; *(minus sign is required)*
so $\Delta U = (+)\, 15$ J; } *(symbols must be defined)* *(allow ECF from second marking point)* ***[3]***

(iv) number of air molecules $= 0.0274 \times 6.0 \times 10^{23} \left(= 1.64 \times 10^{22}\right)$;
$9.13 \times 10^{-22}$ J; ***[2]***

(c) entropy is a property that indicates degree of disorder in the system / *OWTTE*;
gas occupies a smaller volume; *(do not allow "compressed")*
entropy of gas/air in toy decreases because more ordered;
energy reaches surroundings/cylinder / entropy cannot decrease;
so entropy of surroundings/cylinder increases; } *(do not allow ECF from "entropy of gas increases")* ***[4 max]***

**Part 2** Rocket motion

(a) (i) attempt at area under graph;
appropriate triangle 175 m;
a comment about missing area making answer a little less / *OWTTE*; ***[3]***

(ii) $t=\sqrt{\frac{2\times 170}{9.81}}$ $(=5.89\,\text{s})$;
$u=57.8\,(\text{m}\,\text{s}^{-1})$ ***or*** $u^2=3340\,\text{m}^2\,\text{s}^{-2}$;
speed $(=\sqrt{(57.8^2+56^2)}=80.4\,\text{m}\,\text{s}^{-1}$;
$46^{\circ}$ to horizontal; ***[4]***

(b) $\frac{GMm}{r^2}=\frac{mv^2}{r}$;
$v=\sqrt{\frac{GM}{r}}$;
$7.75\times 10^3\,\text{m}\,\text{s}^{-1}$; ***[3]***

**B2.** (a) meltdown risks; *(do not accept "explosion")*
nuclear weapon production;
radiation leaks;
radioactive waste processing/handling/storage; } *(do not allow a general reference to "radioactive waste")* ***[2 max]***
*Award any other sensible associated safety problem.*

(b) U-238 is much more common than U-235 in ore;
U-235 is more likely to undergo fission / critical amount of U-235 required to ensure fission / *OWTTE*;
U-238 absorbs neutrons;
U-238 reduces reaction rate in reactor; ***[3 max]***

(c) (i) $^{137}_{56}\text{Ba}$;
$^{0}_{-1}\beta^{-}$;
anti-neutrino / $\bar{v}$; ***[3]***

(ii) $\lambda = \left(\frac{\ln 2}{30} =\right) 0.0231\ \text{year}^{-1}$;
$(N = N_0)\,e^{-0.0231\times100}$;
0.099 ***or*** 9.9%; ***[3]***

(d) proportion of waste builds up in fuel rod as uranium is consumed;
increasing numbers of neutrons will be absorbed;
this reduces the number available to sustain the chain reaction;
build up of waste deforms fuel rod (which can then be difficult to remove); ***[2 max]***

(e) (i) (alternating) current produces (alternating) field in the primary;
leading to alternating flux in core;
(changing) flux linked to the secondary;
Faraday's law relates induced emf to rate of change of flux linkage; *(do not allow "induced current" for "induced emf")*
if coil is part of a complete circuit a current flows; ***[4 max]***

(ii) $\frac{n_p}{n_s} = \frac{23}{33}$;
0.69 ***or*** 1:1.4; ***[2]***

(iii) power loss in cable is proportional to $(\text{current})^2$;
if pd is increased by transformer then current is decreased (by same ratio);
so power loss falls as cable resistance is constant; *(resistance point is vital for this mark)*
smaller current means lower temperature in metal cable so resistance lower;
lower genetic damage risk with lower currents/fields; ***[3 max]***

(iv) pd dropped across cables $= (290 \times 16 =)\ 4640\ \text{V}$;
fractional power lost $= \frac{4640}{33000}$;
0.14 ***or*** 14 %; ***[3]***

**B3. Part 1** Wave motion

(a) *ray*: direction of wave travel / energy propagation;
*wavefront*: line that joins points with same phase/of same crest/trough;
ray normal/at right angles/perpendicular to wavefront; ***[3]***

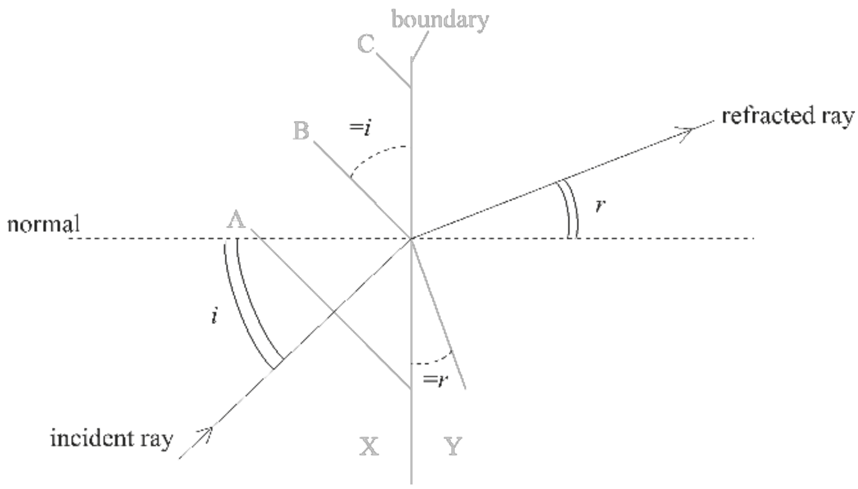
(b) (i) line parallel to existing line in Y and continuous at boundary; *(both needed)* ***[1]***

(ii) measures "wavelength" correctly in media X and Y; *(by eye)* *(look for ratio of 0.5 : 1 in responses)*

$\frac{n_X}{n_Y} = \frac{\lambda_Y}{\lambda_X}$;

$0.5:1$; *(accept answers in the range of 0.47 to 0.53)* ***[3]***

***or***




justification that angles needed for calculation are either pair of *i* and *r* as shown and angles measured correctly;

$\frac{n_X}{n_Y} = \frac{\sin r}{\sin i}$;

$0.5:1$;

(c) mention of perpendicular/right angle/$90^\circ$angle for transverse and parallel for longitudinal;
clear comparison between direction of energy propagation and direction of vibration/oscillation of particles for both waves; ***[2]***

(d) (i) time period $= 6.0$ ms;
167 Hz; ***[2]***

(ii) M where line crosses $x$-axis; ***[1]***

(iii) counts rectangles ($14 \pm 2$) to first peak;
one rectangle equivalent to 0.5 mm;
7.2 mm; ***[3]***

***or***

$\omega = (2\pi f =) 330\pi$;

$a = \left(\frac{v}{\omega} =\right) \frac{7.5}{330\pi}$;

7.2 mm;

*Allow any valid algebraic method, eg* $v = \omega\sqrt{(x_0^{\,2} - x^2)}$.

**Part 2** Electrons

(a) (i) mention of photons;
of quantized energy / energy is $hf$;
one to one correspondence with electrons and photons / *OWTTE*;
(so arrival of light causes emission straightaway) ***[3]***

(ii) intensity is a measure of the number of photons not the individual photon energy; ***[1]***

(b) (i) $E = \frac{hc}{4.2 \times 10^{-7}}$;
$4.7 \times 10^{-19}$ J;
so maximum energy $= (4.7 \times 10^{-19} - 3.4 \times 10^{-19} =) 1.3 \times 10^{-19}$ J; ***[3]***

(ii) energy arriving per second $= 3 \times 10^{-6} \times 4.5 \times 10^{-6}$ ($= 1.35 \times 10^{-11}$ W);
so arrival rate of photons $= \frac{1.35 \times 10^{-11}}{4.7 \times 10^{-19}}$ ($= 2.9 \times 10^{7}$ photons $s^{-1}$); *(allow ECF from (b)(i))*
and a current of $\left(\frac{2.9 \times 10^{7} \times 1.6 \times 10^{-19}}{300} =\right) 1.5 \times 10^{-14}$ A; ***[3]***

**B4. Part 1** Oscillating water column (OWC) energy converter

(a) (i) mention of wave (as source of energy); *(do not allow reference to tide)*
water compresses air (already inside chamber);
air moves through a turbine;
turbine turns dynamo/generator; *(do not award this mark for discussion of energy, must see a clear idea that one turns the other)* ***[3 max]***

(ii) kinetic and (gravitational) potential energy of wave transferred to potential energy/kinetic energy of air; *(must see both energies for wave)*
(energy of air) transferred to kinetic energy of turbine;
kinetic energy of turbine transferred to electrical energy of dynamo/generator; ***[2 max]***

(b) (i) required wave power per unit width $= \frac{0.10 \div 0.24}{4.5} (= 0.093\text{ MW})$;
wave speed $= \frac{95}{8} \left(= 11.9\text{ m s}^{-1}\right)$;
use of $\frac{1}{2} A^2 \rho g v$ to give 1.3 m amplitude; ***[3]***

(ii) greater risk of damage to OWC (from wave energy) / greater cost of installation; ***[1]***
*Accept any other sensible suggestions.*
*Do not accept "it will break more easily" or similar.*

**Part 2** Melting of the Pobeda ice island

(a) (i) mass of ice $= 70000 \times 35000 \times 240 \times 920\ (= 5.4 \times 10^{14}\ \text{kg})$;
energy to raise ice temperature to 0 °C $= 5.4 \times 10^{14} \times 2.1 \times 10^{3} \times 35\ (= 3.98 \times 10^{19}\ \text{J})$;
energy to melt ice $= 5.4 \times 10^{14} \times 3.3 \times 10^{5}\ (= 1.8 \times 10^{20}\ \text{J})$;
total $= 2.2 \times 10^{20}$ J *[3]*

(ii) energy incident $= 450 \times 70000 \times 35000\ (= 1.1 \times 10^{12}\ \text{J s}^{-1}\ \text{m}^{-2})$;
energy available for melting $= 1.1 \times 10^{12} \times 0.2\ (= 2.2 \times 10^{11}\ \text{J})$;
time $= \left(\dfrac{2.2 \times 10^{20}}{2.2 \times 10^{11}} =\right) 9.9 \times 10^{8}$ s ***or*** 32 years; *[3]*

(b) (i) light consists of photons that deliver energy to pixel;
(energy) releases electrons from pixel;
so (negative) charge is lost from pixel and this leads to change in potential; *[3]*

(ii) number arriving during exposure $= (5.2 \times 10^{9} \times 0.75 \times 0.033 =)\ 1.3 \times 10^{8}$;
$1.3 \times 10^{8} \times 1.6 \times 10^{-19}\ (= 2.1 \times 10^{-11}\ \text{C})$;
$V = \dfrac{2.1 \times 10^{-11}}{2.7 \times 10^{-9}}$;
7.6 mV; *[4]*

(iii) object must be $\dfrac{1}{120}$ mm ( = 0.0083 mm) across on CCD;
length of object just resolved $= \dfrac{0.0083}{1.7 \times 10^{-5}}$ mm;
= 0.49 m; *[3]*