International Baccalaureate®
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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 <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.

**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) smooth curve through all the error bars; *[1]*

(b) (i) the graph is not linear/a straight line (going through the error bars) / does not go through origin; *[1]*

(ii) $7.7\ \text{m s}^{-1}$; *[1]*

*Accurate reading from* *<u>their</u>* *graph to within* $\frac{1}{2}$ *square. Allow ECF from (a).*

(c) (i) % uncertainty in $v = \left(\frac{0.3}{7.7} = \right) 3.9\%$;

doubles 3.9% *(allow ECF from (b)(ii))* to obtain % uncertainty in $v^2 (= 7.8\%)$;

absolute uncertainty $(= \pm[0.078 \times 59.3]) = 4.6$;

$(= \pm 5\ \text{m}^2\ \text{s}^{-2})$ *[3]*

***or***

calculates overall range of possible value as $7.4 - 8.0$; *(allow ECF)*

squares values to yield range for $v^2$ of 54.8 to 64; *(allow ECF)*

so error range becomes 9.2 hence $\pm 4.6$; *(must see this value to 2 sig fig or better to award this mark)*

(ii) correct error bars added to first point ($\pm\frac{1}{2}$ square) <u>and</u> last-but-one point ($\pm 2.5$ squares); *(judge by eye)* *[1]*

(iii) a straight-line/linear graph can be drawn that goes through origin; *[1]*

(iv) uses triangle to evaluate gradient; *(triangle need not be shown if read-offs clear, read-offs used must lie on candidate's drawn line)*

to arrive at gradient value of $1.5 \pm 0.2$; *(unit not required)*

recognizes that gradient of graph is $a^2$ <u>and</u> evaluates $a = 1.2 \pm 0.2\,(\text{m}^{\frac{1}{2}}\ \text{s}^{-1})$; *[3]*

***or***

candidate line drawn through origin <u>and</u> one data point read;

correct substitution into $v^2 = a^2\lambda$; *($a^2$ does not need to be evaluated for full credit)*

$a = 1.2 \pm 0.2\,(\text{m}^{\frac{1}{2}}\ \text{s}^{-1})$;

*Award **[2 max]** if line does not go through origin – allow* $\frac{1}{2}$ *square.*

*Award **[1 max]** if one or two data points used* *<u>and</u>* *no line drawn.*

(v) $k = 9.4\ \text{m s}^{-2}$; *(allow ECF from (c)(iv))* *[1]*

**A2.** (a) $h = \frac{v^2}{2g}$;

$= \left(\frac{225}{20} =\right) 11\,\text{m}$; ***[2]***

*Award **[1 max]** for 91 m or 91.25 m (candidate adds cliff height incorrectly).*

(b) time to reach maximum height $= 1.5\,\text{s}$;
time to fall $91\,\text{m} = 4.3\,\text{s}$;
total time $= 5.8\,\text{s}$; ***[3]***
*Answer can be alternatively expressed as 3.0 (to return to hand) + 2.8 (to fall 80 m).*

***or***

use of $s = ut + \frac{1}{2}at^2$;
$80 = -15t + 5t^2$ ***or*** $-80 = 15t - 5t^2$;
$t = 5.8\,\text{s}$;

**A3.** (a) internal energy is the total kinetic and potential energy <u>of the molecules</u> of a body;
thermal energy is a (net) amount of energy transferred between two bodies;
at different temperatures; ***[3]***

(b) (i) $60\times[\theta-45]$; ***[1]***
*Allow this correct expression to be equated to another (could be incorrect) expression. Award this mark (b)(i) if correct expression appears in (b)(iii).*

(ii) $\left(2.0\times10^{3}\times29\right)=5.8\times10^{4}\text{ J}$; ***[1]***

(iii) $60\times[\theta-45]=5.8\times10^{4}$;
$\theta=1000\,^{\circ}\text{C}$; *(allow 1010°C to 3 sig fig)* ***[2]***

**A4.** (a) $\frac{1}{12}$th mass of an <u>atom</u> of carbon-12/$^{12}\text{C}$; ***[1]***

(b) $(254.1001\times931.5=)\,236.7\left(\text{GeV c}^{-2}\right)$; *(only accept answer in GeV $c^{-2}$)* ***[1]***

(c) (i) proton / hydrogen nucleus / $\text{H}^{+}$ / $^{1}_{1}\text{H}$ / $^{1}_{1}\text{p}$; ***[1]***

(ii) $\Delta m=\left(16.8383-[3.7428+13.0942]=\right)0.0013\left(\text{GeV c}^{-2}\right)$;
energy required for reaction $=1.3$ (MeV);
KE of $^{17}_{8}\text{O}+\mathbf{X}=(7.68-1.3=)\;6.4\,(6.38)\text{ MeV}$; *(allow correct answer in any valid energy unit)* ***[3]***

**A5.** (a) (i) use of $R=\frac{pV}{nT}$; *(award mark if correct substitution seen)*
$\left(\frac{5.2\times10^{-3}\times1.0\times10^{5}}{0.23\times290}\right)=7.8\text{ J K}^{-1}\text{ mol}^{-1}$; *(accept Pa m$^{3}$ mol$^{-1}$ K$^{-1}$)* ***[2]***

(ii) the gas is ideal; ***[1]***

(b) constant temperature required; *(do not allow "isothermal")*
a slow compression allows time for (internal) energy to leave gas / *OWTTE*; ***[2]***

(c) (for adiabatic change) $Q=0$;
$W$ is positive / work is done by the gas;
$\Delta U=-W$ so $\Delta U$ is negative;
($T$ is a measure of $U$ therefore) $T$ less than 290 K. ***[4]***

**A6.** (a) the product of (the magnitude of) the normal component of magnetic field strength;
and area through which it passes/with which it is associated; ***[2]***

***or***

$\phi = BA\cos\theta$;
all terms defined/shown on a diagram;

(b) (i) letter T clearly marked at 5.0 ms ***or*** 15 ms; ***[1]***

(ii) 2.0 V / $\text{Wb s}^{-1}$;

emf equals rate of change of flux; *(clear statement or equation must be present to award this mark)* ***[2]***

*Use of slope to obtain answer is incorrect – this yields a value of 1.8.*

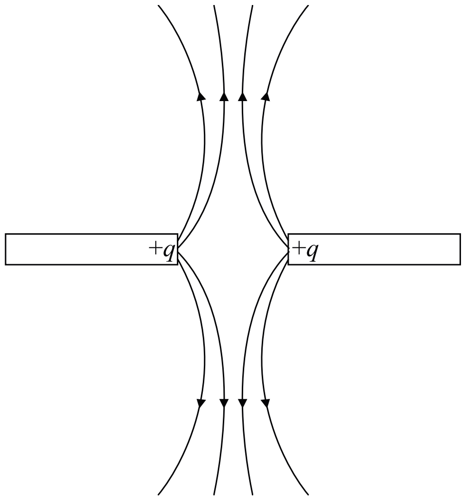
(iii) 4.2 V; ***[1]***

**SECTION B**

**B1. Part 1** Electric charge and resistance

(a) in the plastic there are no free electrons;
(but) electrons can be transferred to/from the cloth (by friction) leaving an imbalance of charge on the rod / *OWTTE*;
electrons can move freely in copper;
electrons transferred from/to the cloth from/to the rod;
because the body is a conductor;
will flow to/from Earth leaving the rod neutral; ***[5 max]***

(b) (i)




at least four field lines (minimum two per rod) to show overall shape of pattern;
direction of lines all away from poles; ***[2]***
*Ignore all working outside region.*
*Any field lines crossing loses first mark even if accidental.*

(ii) any line labelled V perpendicular to the field lines it traverses; *(judge by eye)* ***[1]***
*Ignore unlabelled lines as they could be field lines.*

(c) use of $l = \frac{RA}{\rho}$; { *(allow if correct substitution seen – watch for use of circumference in place of area)*

$= \left( \frac{1.5 \times \pi \times [1.8]^2 \times 10^{-8}}{1.7 \times 10^{-8}} = \right) 9.0\,\text{m}$; ***[2]***

(d) (i) the resistance of a conductor/copper/metal increases with increasing temperature; increased power (dissipation) leads to higher temperature in the resistor/ resistor heating up; ***[2]***

(ii) $I = \left(\sqrt{\frac{P}{R}} =\right) \sqrt{\frac{1.0}{1.5}}$;

$(= 0.82\,\text{A})$ ***[1]***

*Allow working using 0.82 A to show that power is 1.0086 W, in this case final answer must be to 2 sig fig or better.*

(iii) total resistance $= [R + 3.3]$;

$6.0 = 0.82[R + 3.3]$;

to give $R = 4.0\,\Omega$; *(allow use of 1.65 Ω leading to 3.9 Ω)* ***[3]***

***or***

total resistance in circuit $= \frac{6.0}{0.82} = (7.3\,\Omega)$;

internal resistance + fixed resistance $= 3.3\,\Omega$;

to give $R = 4.0\,\Omega$;

**Part 2** Orbital motion

(a) $\frac{mv^2}{r} = \frac{GMm}{r^2}$;

$E_K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$;

$E_P = -\frac{GMm}{r}$ (hence magnitude of $E_K = \frac{1}{2}$ magnitude of $E_P$); ***[3]***

(b) (i) total energy $= (\text{KE} + \text{PE} =) -\frac{Vm}{2}$;

$= \left(-\frac{4.0\times10^7 \times 8.2\times10^2}{2} =\right) -1.6\times10^{10}$ J; ***[2]***

(ii) $v = \sqrt{V}$; *(or use of* $E_k = \frac{1}{2}mv^2$*)*

$= 6.3\times10^3\ \text{m s}^{-1}$; ***[2]***

(iii) total energy in new orbit $= \left(-\frac{2.0\times10^7 \times 8.2\times10^2}{2} =\right) -0.82\times10^{10}$ (J);

energy required $= \left(1.6\times10^{10} - 0.82\times10^{10} =\right)\ 7.8\times10^9$ J; ***[2]***

***or***

total energy is proportional to $E_P$;

so energy required $= -$(b)(i) $\div 2$ = 8 ***or*** $8.2\times10^9$ J; *(allow ECF from (b)(i))*

**B2. Part 1** Power production and global warming

(a) energy transferred to surroundings/from system; *(do not allow bald "energy lost")*
energy no longer available for use/cannot be used again; ***[2]***

(b) (i) U-235 fissions / neutrons are produced;
nuclei/neutrons have high energy/are fast moving;
nuclei transfer (kinetic) energy to (reactor) core / neutrons transfer (kinetic) energy to moderator;
names energy of moving nuclei/neutrons as <u>kinetic</u>;
core/moderator energy transferred to coolant/named coolant/surroundings; ***[4 max]***

(ii) heat exchanger allows transfer of (thermal) energy between reactor and coolant;
coolant transfers (thermal) energy to steam/other named fluid;
steam/fluid allows turbine to drive generator/dynamo; ***[3]***

(c) *Award any **one** of the following.*
heating the working fluid in the exchanger;
the working fluid passing through the turbine;
cooling the working fluid having passed through the turbine;
named dissipative/friction process in power station machinery; *(do not allow "air resistance/friction" unless seat of loss is clear)* ***[1 max]***

(d) energy output of Drax $=\left(4.0\times10^{9}\times3.2\times10^{7}=\right)1.28\times10^{5}$ TJ ;

mass of U-235 needed $=\left(\dfrac{1.28\times10^{5}}{82}=\right)1.6\times10^{3}$ kg ; ***[2]***

(e) $\Delta T=\dfrac{\Delta V}{\gamma V}$ ; *(award mark if correct substitution seen)*

$\dfrac{\Delta V}{V}=\dfrac{6.4\times10^{-2}\times\text{area}}{4.0\times10^{2}\times\text{area}}=1.6\times10^{-4}$ ;

$\Delta T=\left(\dfrac{1.6\times10^{-4}}{5.1\times10^{-5}}=\right)3.1\text{K}$ ; ***[3]***

**Part 2** Charge-coupled device (CCD)

(a) more easily reproduced;
more accurately reproduced;
noise can be removed; *(do not accept just noise)*
higher retrieval speed;
smaller space required for same amount of data;
any other sensible storage-related advantage; ***[2 max]***

(b) photons cause the creation/produce/give rise to electron-hole pairs (in the pixel);
the electrons/holes migrate to the relevant electrode;
leads to the build-up of charge on the electrodes (producing a change in voltage across the pixel); ***[3]***

(c) (i) energy of one photon $= 6.6\times10^{-34}\times7.2\times10^{14} = 4.75\times10^{-19}$ (J);

max number in 18 ms $= \dfrac{1.6\times10^{-3}\times2.0\times10^{-10}\times1.8\times10^{-2}}{4.75\times10^{-19}}$;

$(=1.2\times10^{4})$ ***[2]***

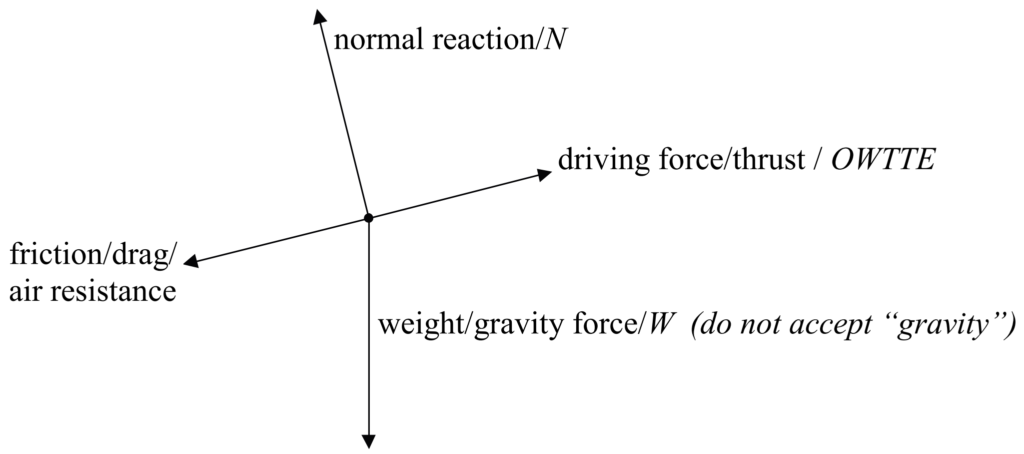
(ii) change in charge $= \left(1.0\times10^{-5}\times1.2\times10^{-11}=\right)\ 1.2\times10^{-16}$ (C);

number of photons needed $= \left(\dfrac{1.2\times10^{-16}}{1.6\times10^{-19}}=\right)\ 0.75\times10^{3}$;

quantum efficiency $= \left(\dfrac{0.75\times10^{3}}{1.2\times10^{4}}=\right)\ 0.063$ ***or*** $6.3\%$; ***[3]***

**B3. Part 1** Power and efficiency

(a) (i)




identification of normal reaction/*N* and weight/*W*;
identification of friction and driving force;
correct directions of all four forces;
correct relative lengths; *(friction ≅ driving force and N ≅ W but N must not be longer than W) (judge by eye)* **[4]**

(ii) zero; **[1]**

(b) $\text{input power} = \frac{\text{output power}}{\text{efficiency}} = \frac{70}{0.35}$;
$= 200\,\text{kW}$; **[2]**

(c) height gained in $1\,\text{s} = (6.2\sin 6 =)\ 0.648\,(\text{m})$;
rate of change of $\text{PE} = 8.5\times10^3 \times 9.81 \times 0.648$;
$= 5.4\times10^4\ \text{W}$; **[3]**

(d) power used to overcome friction $= \left(7\times10^4 - 5.4\times10^4 =\right) 1.6\times10^4\ (\text{W})$; *(allow ECF from (c))*

$F = \left(\frac{p}{v} =\right) \frac{1.6\times10^4}{6.2}$;
$= 2.6\,\text{kN}$; **[3]**

**Part 2** Photoelectric effect and de Broglie wavelength

(a) *Look for these main points.*
light consists of photons whose energy depends on the frequency/*hf*;
hence the energy available to the (photo)electrons will depend on *f*;
the potentials $V_A$ and $V_B$ correspond to/are a measure of the maximum kinetic of the emitted electrons;
the work function (of metal)/energy to emit electron is same for both light sources;
as electrons in A have more kinetic energy available, this frequency must be higher;
(so A) ***[4 max]***

(b) (i) 1.6 eV; *(answer must be expressed in eV)* ***[1]***

(ii) energy of photons $= \left( \frac{6.6 \times 10^{-34} \times 8.8 \times 10^{14}}{1.6 \times 10^{-19}} = \right) 3.6\,(\text{eV})$;

work function $= (3.6 - 1.6 =)\ 2.0\,\text{eV}$; ***[2]***

*Allow answer in J if (b)(i) expressed in joule (ECF), otherwise award **[1 max]**.*

(c) photon energy increases (because frequency increases);
so for same intensity fewer photons per second;
so current reduced / fewer electrons emitted per second; ***[3]***

(d) all particles/electrons exhibit wave properties/have an associated wavelength (called the de Broglie wavelength);
the wavelength is equal to the Planck constant divided by the momentum of the particle/electron/ $\lambda = \frac{h}{p}$ with terms defined; *(terms **must** be defined for mark)* ***[2]***

**B4.** (a) the maximum displacement of the system from equilibrium/from centre of motion / *OWTTE*; ***[1]***

(b) (i) the amplitude of the oscillations/(total) energy decreases (with time);
because a force always opposes direction of motion/there is a resistive force/ there is a friction force; ***[2]***
*Do not allow bald "friction".*

(ii) the displacement and acceleration/force acting on (the surface);
are in opposite directions; ***[2]***

(iii) $\omega = \sqrt{\frac{2g}{l}}$;
$T = 2\pi\sqrt{\frac{0.32}{2\times 9.81}}$;
$= 0.80\,\text{s}$; ***[3]***

(c) (i) upwards; ***[1]***

(ii) $y_0 = 0.050\,(\text{m})$ and $y = 0.030\,(\text{m})$;
$\omega = \left(\frac{2\pi}{0.80} =\right) 7.85\left(\text{rad s}^{-1}\right)$;
$v = 7.85\sqrt{[0.05]^2 - [0.03]^2}$;
$= 0.31\,\text{m s}^{-1}$; *(allow working in cm to give $31\,cm\,s^{-1}$)* ***[4]***

(iii) $\lambda = 4.0\,\text{m}$;
recognition that $f = \frac{1}{0.80}(=1.25)$;
$(f\lambda =)\, v = 1.25\times 4.0$;
$(= 5.0\,\text{m s}^{-1})$ ***[3]***

(iv) $y = -3.0\,\text{cm},\ d = 0.6\,\text{m}$; ***[1]***

(d) (i) wave <u>reflects</u> at ends (of string);
interference/superposition occurs (between waves);
regions of maximum displacement/zero displacement form (that do not move);
one region of max displacement/antinode forms at centre with zero displacement/node at each end;
*(allow these marking points from a clear diagram)* ***[3 max]***

(ii) the waves (in a string) are transverse and vibrate only in one plane;
light waves are transverse electromagnetic waves;
(and) for polarized light the electric field vector vibrates only in one plane; ***[3]***

(e) Brewster angle $= \tan^{-1}[1.3] = 52^{\circ}$ ;
$\theta = (90 - 52 =)\ 38^{\circ}$ ; ***[2]***