N15/4/PHYSI/HP2/ENG/TZ0/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2015

Physics

Higher level

Paper 2

16 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 x 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 underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

Section A

1. (a) smooth curve line through all error bars; **[1]**
Do not allow kinked or thick lines or double/multiple lines.
Ignore any line beyond the range of plotted points.
Assume a broken line is due to scan and allow BOD.
Line must go through vertical part of error bar. Do not allow line to clip horizontal endcaps.

(b) (i) coordinates of two points on the line correctly read from the graph; *(check points read to within half a square)*

$\frac{T^2}{h}$ or $\frac{h}{T^2}$ calculated for both values;

consistent conclusion that values similar within the (typical) experimental error so sensible / differ outside (typical) experimental error so not sensible; *(must see reference to experimental error not just bald statement)* **[3]**

Award ***[2 max]*** *for a graph of h_{mean} versus T^2 and a conclusion that hypothesis is not valid.*
Do not award credit for "does not go through origin".

(ii) two points define a straight line / any arbitrary curve can pass through two points;
to confirm hypothesis third point (or more) must lie on the straight line; **[2]**

or

refers to experimental error in data (and therefore error in ratio) / depending on the two points chosen the hypothesis may be confirmed;
increasing the number of data points increases the strength of conclusion;

or

one of the two points chosen may be anomalous/erroneous/outlier;
third point needed to confirm hypothesis;

(c) (i) $(\pm)1^\circ$ C/K/deg; *(do not allow 2 or more sig figs in the answer)* **[1]**

(ii) same thermometer used;
same eyes used;
same reading method used;
this type of thermometer has (typically) equal graduations;
liquid in thermometer expands linearly; **[2 max]**

(d) $\frac{\Delta h}{h} = \frac{0.01}{0.72}$ ***or*** 0.014 ***or*** 1.4 % <u>and</u> $\frac{\Delta T}{T} = \frac{1}{50}$ ***or*** 0.02 ***or*** 2 %; *(allow ECF from (c)(i))*

$\frac{\Delta K}{K} = 3 \times \frac{1}{50} + \frac{0.01}{0.72}$ ***or*** $= 7.4 \times 10^{-2}$ ***or*** 7.4 %;

$K = 5.8/5.76/6 \times 10^{-6}$;

$\Delta K = 4 \times 10^{-7}\ \mathrm{m\,K^{-3}}$ ***or*** $\mathrm{m\ ^\circ C^{-3}}$; *(1 sig fig **and** correct unit required)* **[4]**

2. (a) gravitational provides centripetal force / gravitational provides force towards centre;
(because radius is implied constant) (centripetal) force is constant;

at 90° to velocity (vector)/orbit/direction / *OWTTE* / $\frac{GmM}{r^2} = \frac{mv^2}{r}$ (or re-arranged) and therefore speed is constant (and motion is uniform);
(do not allow "inwards/centripetal" for this mark. The right angle must be explicit) **[3]**

(b) $v = \omega r$ and $\omega = \frac{2\pi}{T}$ combined;

$v = \left(\frac{2\pi r}{T} =\right) \frac{2\pi \times 9.4 \times 10^6}{7.7 \times 3600}$ ***or*** $2.1(3) \times 10^3\ \text{m s}^{-1}$; **[2]**

Allow approach from speed $= \frac{s}{t}$, *do not allow approach from* $v^2 = ar$ *or* $f = \frac{1}{T}$.

(c) $m\frac{v^2}{r} = G\frac{mM}{r^2}$ ***or*** $F_c = F_G$;

$M = \frac{v^2 r}{G}$ ***or*** $\frac{(2.13 \times 10^3)^2 \times 9.4 \times 10^6}{6.67 \times 10^{-11}}$;

$M = 6.4 \times 10^{23}\ \text{kg}$ from 2.13 ***or*** $5.6 \times 10^{23}\ \text{kg}$ from 2; **[3]**

3. (a) force/acceleration proportional to the displacement/distance from a (fixed/equilibrium) point/mean position;
directed towards this (equilibrium) point / in opposite direction to displacement/ distance; **[2]**
Allow algebra only if symbols are fully explained.

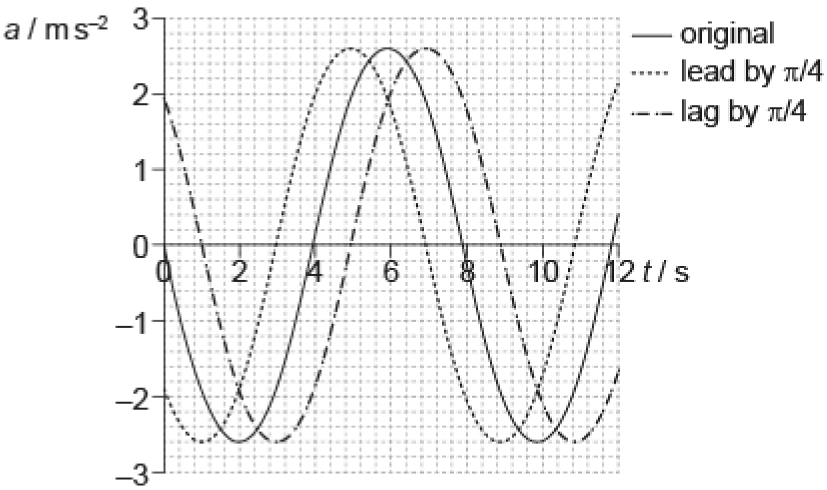
(b) 0.73 N; **[1]**

(c) use of $a_0 = -\omega^2 x_0$;

$T = 7.9$ s ***or*** $\omega = 0.795$ ***or*** $\frac{\pi}{4}$ rad s^{-1};

$x_0 = 4.1(1)$ m; *(allow answers in the range of 4.0 to 4.25 m)*
two significant figures in final answer whatever the value; **[4]**

(d) shape correct, constant amplitude for new curve, minimum of 10 s shown; *(there must be some consistent lead or lag and no change in T)*
lead/lag of 1 s (to within half a square by eye); **[2]**



4. (a) use of $\frac{PV}{T} = \text{constant}$ ***or*** use of $T \propto PV$ ***or*** via intermediate calculation of n in $PV = nRT$;

$\frac{1.95}{358} = \frac{8.55}{T_C}$ ***or*** $n = 6.55 \times 10^{-3}$ mol; } *(allow power of ten omission provided same omission on both sides)*

1570 K ***or*** 1300 °C ; **[3]**

*Omitting conversion to Kelvin yields answer of 373 – award **[2 max]** as one error.*

(b) same temperature change so same change in internal energy/ΔU;
work done along ABC is larger/ADB is smaller because area under ABC is greater than area under ADC/ΔV same in both, P greater for ABC so $P\Delta V$ also greater for ABC;
because $\Delta Q = \Delta U + W$ thermal energy transferred is greater for route ABC/smaller for route ADB; **[3]**

Must see reference to first law for MP3.

5. (a) electrons require energy for release;
electrons (are observed) to appear instantaneously;
wave model requires time delay (to build up enough energy); **[3]**

or

the kinetic energy of the (emitted) electrons depends on frequency (of incident light);
with no electron emission below a threshold frequency;
a wave model suggests emission at all frequencies;

(b) (i) (photon) energy $\frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{420 \times 10^{-9}} (= 4.74 \times 10^{-19}\text{ J})$;

$E_{max} = (hf - \phi =)\, 4.74 \times 10^{-19} - 2.60 \times 10^{-19}$;

1.33 ***or*** 1.34 eV; } *(this mark is for correct conversion to eV allow ECF from incorrect MP1 and MP2)* **[3]**

(ii) $5.1\,\mu\text{W m}^{-2} = 5.1 \times 10^{-12}\text{ J s}^{-1}\text{ mm}^{-2}$;

(number of incident photons per mm^2 per second) $= \frac{5.1 \times 10^{-12}}{4.74 \times 10^{-19}} (= 1.08 \times 10^{7})$;

(number of photoelectrons per mm^2 per second) $= \frac{1.08 \times 10^{7}}{800} (= 1.3 \times 10^{4})$; **[3]**

Accept 1.4×10^4 using rounded energy in (b)(i).

Section B

6. **Part 1** Electric fields and radioactive decay

(a) minimum of three lines equally spaced and distributed, perpendicular to the plates and downwards;
edge effect shown; **[2]**

(b) (i) $4.3 \times 10^5\,\mathrm{N C^{-1}}$; **[1]**

(ii) $(F = Eq =)\, 4.3 \times 10^5 \times 2 \times 1.6 \times 10^{-19}$; *(allow ECF from (b)(i))*
$1.4 \times 10^{-13}\,\mathrm{N}$; **[2]**

(iii) $\Delta E_P = q\Delta V$ ***or*** $3.2 \times 10^{-19} \times 5.2 \times 10^3$;
$1.7 \times 10^{-15}\,\mathrm{J}$;
negative/loss; **[3]**

(c) (i) no mass / no charge; **[1]**

(ii) $\left({}^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He} + {}^{0}_{0}\gamma\right)$
${}^{222}_{86}\mathrm{Rn}$ ***or*** ${}^{4}_{2}\mathrm{He}$;
numbers balance top and bottom on right-hand side; **[2]**

(iii) $\lambda = \dfrac{\ln 2}{1600} = 4.33 \times 10^{-4}\,\mathrm{yr^{-1}}$;
$0.05 = e^{-\lambda t}$;
6900 years; **[3]**
Award ***[2 max]*** *for 2.18×10^{11} s.*
Award ***[3]*** *if number n of half-lives is calculated from $0.05 = 2^{-n}$ $(= 4.32$ usually from use of $\log_2$ working) and time shown.*

Part 2 Waves

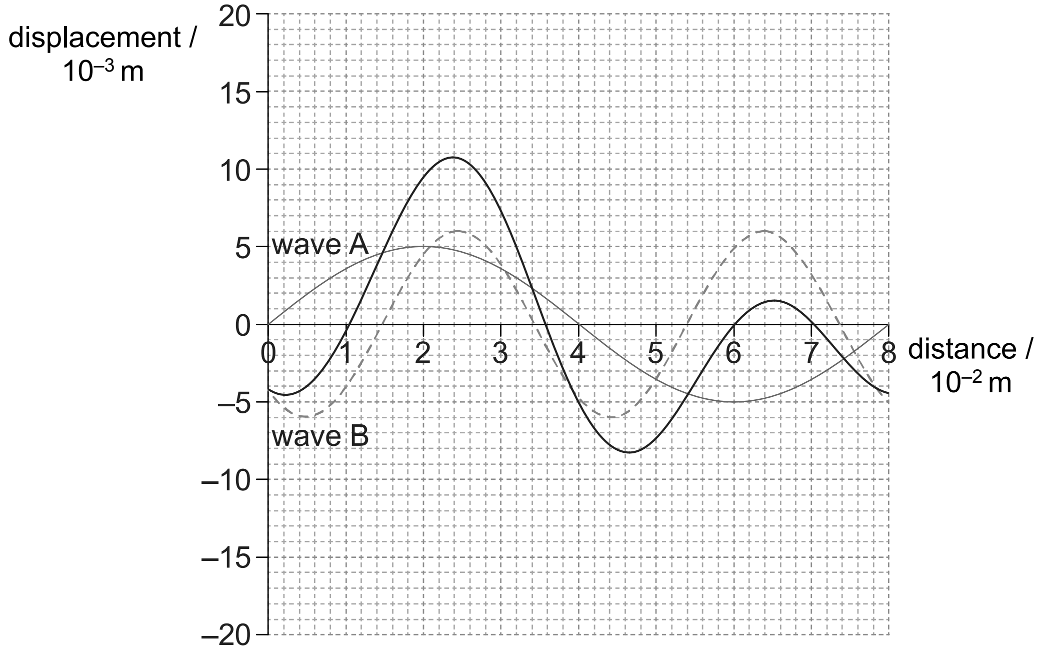
(d) 5 mm ***or*** 5.0 mm; *units are required* **[1]**
Allow other units, eg: $5/5.0\times10^{-3}$ *m.*

(e) (i) wavelength = 8.0 cm ***or*** 8 cm; *(accept clear substitution in MP2 for this mark)*
$v=(f\lambda=)\,9\times8=72\text{ cm s}^{-1}$; *(units are required)* **[2]**

(ii) wavelength = 3.9 cm; *(accept answers in the range of 3.8 to 4.0 cm)*
frequency $=\left(\frac{72}{3.9}=\right)18$;
Hz ***or*** s^{-1}; **[3]**

(f) (i) when two or more waves (of the same nature) meet/interfere / *OWTTE*;
the resultant displacement is the (vector) sum of their individual displacements; *(do not allow "constructive" or "destructive interference" as answer to this point)* **[2]**
Do not accept "amplitude" for "displacement" anywhere in answer.

(ii)



start and end points correct (equal B) and crossing points on distance axis correct (1, 3.6, 6, 7);
peaks and troughs at (2.4, 11) (4.6, –8) (6.5, 1.5);
general shape correct as in example; *(maximum and minimum must be alternating +/–)* **[3]**

7. **Part 1** Energy resources

(a) pump storage;
renewable as can be replaced in short time scale / storage water can be pumped back up to fall again / source will not run out; **[2]**

(b) (i) (allows coolant to) transfer thermal/heat (energy) from the reactor/(nuclear) reaction to the water/steam; **[1]**
Must see reference to transfer.

(ii) reduces speed/kinetic energy of neutrons; *(do not allow "particles")*
improves likelihood of fission occurring/U-235 capturing neutrons; **[2]**

(c) (i) (203 MeV is equivalent to) 3.25×10^{-11} J;
6.02×10^{23} nuclei have a mass of 235 g / evaluates number of nuclei;
(2.56×10^{21} nuclei produce) 8.32×10^{10} J / multiplies two previous answers; **[3]**

(ii) 2.97×10^{6} ***or*** 3.0×10^{6}; *(allow ECF from (c)(i))* **[1]**

(iii) *fossil fuel station*:
large transportation cost;

nuclear station:
needs to be isolated (from human settlement) for safety / needs to be near water source; **[2]**

(d) (i) water flows between water masses/reservoirs at different levels;
flow of water drives turbine/generator to produce electricity;
at off peak times the electricity produced is used to raise water from lower to higher reservoir; **[3]**

(ii) use of $\frac{mgh}{t}$;

$\frac{m}{t}=\frac{4.5\times10^{6}}{0.92\times9.81\times57}$;

$8.7\times10^{3}\ \text{kg s}^{-1}$; **[3]**

Part 2 Charge-coupled devices (CCDs)

(e) magnification $= \sqrt{\dfrac{1.9 \times 10^{-3}}{9.5 \times 10^{12}}}$ $(= 1.4 \times 10^{-8})$;

separation of crater images $(= 1.4 \times 10^{-8} \times 1.5 \times 10^{3} = 2.1 \times 10^{-5})$;

length of pixel $= \left(\sqrt{6.25 \times 10^{-10}} =\right) 2.5 \times 10^{-5}$ m;

(accept word or sensible letter for quantity in MP2 and MP3 but meaning must be clear)

as images separated by less than a pixel they cannot be resolved; **[4]**

(f) (i) ratio of number of electrons released to number of incident photons (in the same time); **[1]**

(ii) number of electrons emitted $= 0.8 \times 0.3 \times 4.7 \times 10^{2}$ $(= 113)$;

charge produced on pixel $= 113 \times 1.6 \times 10^{-19}$ C;

pd across pixel $= \left(\dfrac{1.81 \times 10^{-17}}{25 \times 10^{-12}} =\right) 0.72\ \mu\text{V}$; **[3]**

8. Part 1 Kinematics and Newton's laws of motion

(a) (i) distances itemized; *(meaning of numerical quantity must be clear)*
distances equated;
$t = \frac{2v}{a}$ / cancel and re-arrange;
substitution $\left(\frac{2 \times 45}{3.2}\right)$ shown / 28.1s seen; **[4]**

or

clear written statement that the average speed of B must be the same as constant speed of I;
as B starts from rest the final speed must be 2×45;
so $t = \frac{\Delta v}{a} = \frac{90}{3.2}$;
28.1 s seen; *(for this alternative the method must be clearly described)*

or

attempts to compare distance travelled by I and B for 28 s;
I distance $= (45 \times 28 =) 1260$ m;
B distance $= (\frac{1}{2} \times 3.2 \times 28^2 =) 1255$ m;
deduces that overtake must occur about $\left(\frac{5}{45} =\right) 0.1$ s later;

(ii) use of appropriate equation of motion;
$(1.26 \approx)$ 1.3 km; **[2]**

(b) driver I moves at constant speed so no net (extra) force according to Newton 1;
driver B decelerating so (extra) force (to rear of car) (according to Newton 1) / momentum/inertia change so (extra) force must be present;
(hence) greater tension in belt B than belt I; **[3]**
*Award **[0]** for stating that tension is less in the decelerating car (B).*

(c) (i) $930 \times v + 850 \times 45 = 1780 \times 52$ ***or*** statement that momentum is conserved;
$v = 58$ m s^{-1}; **[2]**

(ii) use of force $= \frac{\text{change of momentum}}{\text{time}}$ (or any variant, *eg*: $\frac{930 \times 6.4}{0.45}$);
13.2×10^3 N; } *(must see matched units and value ie: 13 200 without unit gains MP2, 13.2 does not)* **[2]**
Allow use of 58 m s^{-1} from (c)(i) to give 12 400 N.

Part 2 Power transmissions

(d) (alternating) pd/voltage across primary coil leads to (alternating) current (in primary coil);
hence there is a changing/alternating magnetic field in primary;
leading to a changing magnetic flux linked to/appearing in secondary;
according to Faraday's law, an alternating emf is induced in the secondary coil; **[3 max]**

(e) rms secondary voltage $= 38.4$ V;
peak voltage $= (38\sqrt{2} =)\,54$ V; *(allow ECF from MP1)* **[2]**

(f) (i) $\left(I_s = \dfrac{120}{60 \times 10^{-3}}\right) = 2.0$ kA; *(30 A is a common and incorrect answer)* **[1]**

(ii) power (supplied to town) $= 2.0 \times 10^3 \times 120$ ***or*** 2.4×10^5; *(allow ECF from (f)(i))*

power (supplied to transformer) $= \left(\dfrac{2.4 \times 10^5}{0.9} =\right) 2.67 \times 10^5$ W; *(30 A in (f)(i) leads to 4 kW)* **[2]**

(iii) $I_p = \sqrt{\dfrac{2 \times 10^3}{4.0}} = 22.4$ A;

$V = \dfrac{P}{I} = \dfrac{2.67 \times 10^5}{22.4} = 12$ kV; **[2]**

Allow ECF from (f)(i) and (f)(ii).

(g) laminations increase resistance / reduce current in core material/metal / reduce eddy currents;
thus reducing I^2R /power/(thermal) energy/heat losses in the core; **[2]**

9. Part 1 Electrical circuits

(a) power (loss in resistor) $= 0.36$ W;
$I^2 \times 0.80 = 0.36$;
$I = 0.67$ (A) ***or*** $\sqrt{\left(\frac{0.36}{0.8}\right)}$; **[3]**

(b) (i) resistance of the components/chemicals/materials within the cell itself; *(not "resistance of cell")*
leading to energy/power loss in the cell; **[2]**

(ii) power (in cell with 0.7 A) $= 0.58$ W;
$0.7^2 \times r = 0.58$;
$r = 1.2\,\Omega$; **[3]**

or

when powers are equal;
$I^2R = I^2r$;
so $r = R$ which occurs at 1.2(5) Ω;
*Award **[1 max]** for bald 1.2(5) Ω.*

(c) $(E = I(R + r)) = 0.7\,(0.8 + 1.2)$;
1.4 V; **[2]**
Allow ECF from (a) or (b)(ii).

or

when $R = 0$, power loss $= 1.55$;
$E = (\sqrt{1.55 \times 1.2} =)\,1.4$ V;

(d) in this case $R = 0$ / total resistance is internal resistance;
power dissipated is greater than 1.2 W / power dissipated is 1.56 W which is larger than limit; *(must be quantitative)* **[2]**

Part 2 Magnetic fields

(e) minimum of two concentric circles;
three circles, centered on wire with separation increasing with distance from the wire;
minimum of one arrow showing anticlockwise; **[2 max]**

(f) magnetic field due to upper wire on lower wire horizontal and into page;
shows force is downwards by any valid rule;
reading of balance increases; **[3]**

or

currents are antiparallel / in opposite directions;
so wires repelled (by any argument giving force direction);
reading of balance increases;

(g) (i) $2.6\times10^{-5}\,\text{N m}^{-1}$; **[1]**

(ii) volume of wire $=\pi\times\frac{(2.5\times10^{-3})^2}{4}\times0.15\,(=7.36\times10^{-7}\,\text{m}^3)$;

charge in wire $=8.5\times10^{28}\times7.36\times10^{-7}\times1.6\times10^{-19}\,(=10\times10^{3}\,\text{C})$;

$v=\frac{F}{Bq}=\frac{3.9\times10^{-6}}{1.3\times10^{-4}\times10^{4}}$;

$3.0\,\mu\text{m s}^{-1}$; *(allow ECF from (g)(i))* **[4]**

Confusing diameter with radius award ***[3 max]***.

(h) parts of the wire will experience a smaller magnetic field;
and hence a smaller force;
so the reading of the balance will decrease / *OWTTE*; **[3]**