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Baccalauréat International
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MARKSCHEME

November 2013

PHYSICS

Higher Level

Paper 2

14 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 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 ***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. 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.

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

SECTION A

1. (a) smooth curve that goes through all error bars; ***[1]***

Do not allow thick or hairy or doubled lines, or lines where the curvature changes abruptly.
Do not allow lines that touch horizontal ends of error bars but miss the verticals.

(b) (i) (no)
reference to going through all the error bars;
the line is a curve/not straight / straight line would not pass through all the points / equal increments in *l* give rise to unequal increments in *d*; ***[2]***

(ii) mentions or shows clear extrapolation to *l* axis; } *(allow from curve or straight line)*
read-off to within a square ($0.50 \pm 0.05\,\text{m}$); ***[2]***
Award [1max] if no extrapolation seen on graph.
Answer must match read-off to 2+sig fig.

(c) two data points on line correctly read and more than 0.5 apart on *l*-axis;
$d^2 = kl$ ***or*** $d = k\sqrt{l}$;
two or more correct calculations of *k* from readings;
comment that two or more values are not equal (even with error bar consideration) therefore hypothesis is not valid; ***[4]***
*Award **[3 max]** if l-axis values differ by less than 0.5.*

2. (a) temperature is a measure of the (average) kinetic energy of the molecules;
at the boiling point, energy supplied (does not increase the kinetic energy) but (only) increases the potential energy of the molecules/goes into increasing the separation of the molecules/breaking one molecule from another / *OWTTE*; ***[2]***

(b) (energy gained by cold water is) $0.300 \times 4180 \times [34.6 - 15.2]$ / 24327;
(energy lost by cooling water is) $0.012 \times 4180 \times [100 - 34.6]$ / 3280;
(energy lost by condensing steam is) $0.012L$;
$1.75 \times 10^6 (\text{J kg}^{-1})$ /

$$\frac{[\text{their energy gained by cold water – their energy lost by cooling water}]}{0.012};$$ ***[4]***

*Award **[4]** for 1.75×10^6 (J kg^{-1}).*
*Award **[2 max]** for an answer that ignores cooling of condensed steam.*

(c) some of the energy (of the condensing steam) is lost to the surroundings;
so less energy available to be absorbed by water / rise in temperature of the water would be greater if no energy lost; ***[2]***

3. (a) *X*: graph is a straight line and through the origin / resistance is constant;
so because $V \propto I$ it is ohmic;

Y: not ohmic because graph is not straight/is curved / resistance is not constant; ***[3]***

*Award **[3]** for an answer where resistance values are calculated to show constancy or otherwise.*

(b) (i) read-off of intersection of lines X and Y $[4.0, 6.0]$ / reference to 4.0 V **and** 6.0 mA; *(allow power of 10 error)*

$R_X = R_Y = \dfrac{6.0}{4.0\times10^{-3}} = 1.5\times10^3\ \Omega$;

resistance of combination $= 750\ \Omega$; ***[3]***

(ii) use the idea of potential divider $\dfrac{R}{750} = \dfrac{2.0}{6.0}$;

$R = 250\ \Omega$; ***[2]***

or

current $= 8$ mA;

$R = \dfrac{2.0}{0.008} = 250\,(\Omega)$;

4. (a) defined from the equation of state of an ideal gas $PV = nRT$;
all symbols (*PVnT*) correctly identified; ***[2]***

(b) 390/391 K; ***[1]***

(c) work done $= \left(P\Delta V = 2.32\times10^5 \times 2.20\times10^{-3} =\right) 510\ \text{J}$;

thermal energy $= \left(760 + 510 =\right) 1.27\times10^3\ \text{J}$; ***[2]***

*Award **[1 max]** if volume is taken as 3.6×10^{-3}, giving an answer of 1600 J.*

(d) an adiabatic change is one in which no (thermal/heat) energy is transferred between system and surroundings / no energy enters/leaves system;
a rapid compression means that there is insufficient time (for energy transfer) / *OWTTE*; ***[2]***

5. (a) (i) *minimum*: zero / –*BA* *(minus sign required)* *maximum*: *BA* *(both needed)* ***[1]***

(ii) *Look for these main points*:

(Faraday's law states that the) induced emf equals/is proportional to the rate of change of flux/flux linkage; *(must see induced)*

speed greater so time for change shorter / flux (linkage) is unchanged;

greater rate of change (of flux *etc*) gives a greater (induced) emf; ***[3]***

Award ***[1 max]*** *if answer states flux (linkage) change is larger.*

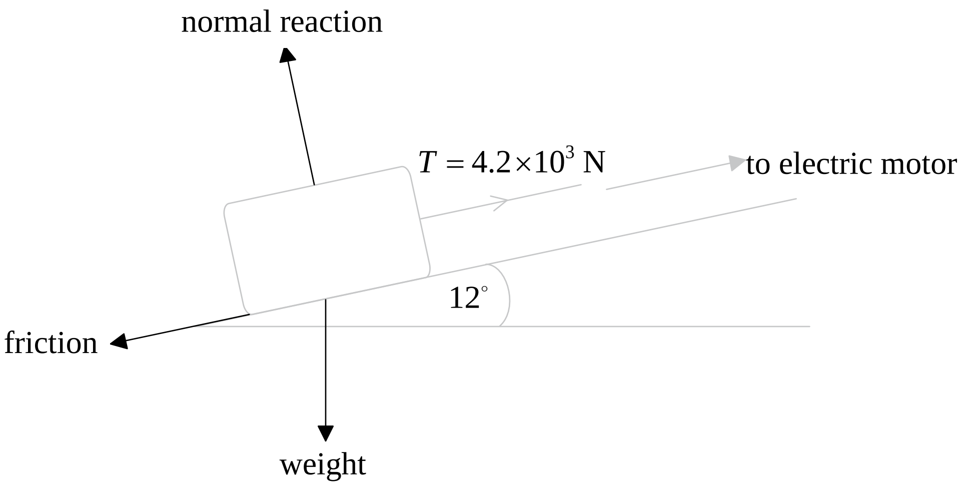
(b) (i) (equivalent) direct current;

dissipating same power in a (fixed) resistor (as the rms current); ***[2]***

(ii) maximum current $=\left(\sqrt{2}\times 2.3=\right)3.2/3.3\,\text{mA}$;

maximum power $=\left(3.3^2\times 15=\right)0.16\,\text{mW}$; ***[2]***

6. (a)



(normal) reaction/*N*/*R* and weight/force of gravity/gravity force/gravitational force/*mg*/*w*/*W* with correct directions;

friction/frictional force/*F*/F_f with arrow pointing down ramp along surface of ramp; ***[2]***

Do not allow "gravity" as label. Do not allow "drag" as label for friction.

(b) recognize that friction $= T - W\sin\theta$;

$W\sin\theta = 3.1\times 10^3$ N;

friction $= 1.1\times 10^3$ N; ***[3]***

SECTION B

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

(a) the force exerted per unit charge;
on a positive small/test charge; ***[2]***

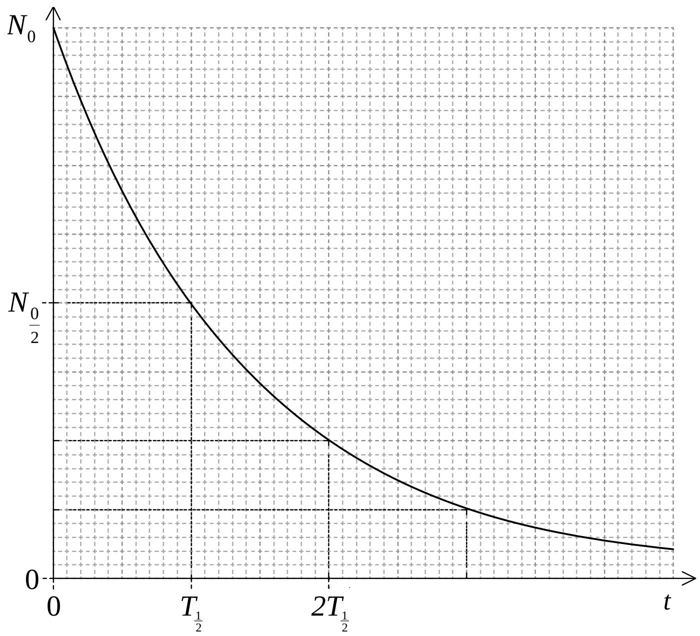
(b) (i) into the (plane of the) paper; ***[1]***

(ii) $Ee = Bev$ ***or*** $E = Bv$;
$= \left(2.3\times10^{-4}\times3.9\times10^{6} =\right) 900/897$;
$\mathrm{N\,C^{-1}}$ ***or*** $\mathrm{V\,m^{-1}}$; ***[3]***

(c) $\left.\begin{array}{l}\textit{proton number}: 8\\ \textit{nucleon number}: 17\end{array}\right\}$ *(both needed)* ***[1]***

(d) $16.9991\mathrm{u} + 1.0073\mathrm{u} - [14.0031\mathrm{u} + 4.0026\mathrm{u}]$;
$= -7.00\times10^{-4}$;
$7.000\times10^{-4}\times931.5 = 0.6521\,\mathrm{MeV}$;
$(\sim0.7\,\mathrm{MeV})$ ***[3]***

(e) (i) time for the activity (of a radioactive sample) to fall by half its original value / time for half the radioactive/unstable nuclei/atoms (in a sample) to decay; ***[1]***

(ii)


(approximately) exponential shape;
minimum of three half lives shown;
graph correct at $\left[T_{\frac{1}{2}}, \frac{N_0}{2}\right]$, $\left[2T_{\frac{1}{2}}, \frac{N_0}{4}\right]$, $\left[3T_{\frac{1}{2}}, \frac{N_0}{8}\right]$; ***[3]***

Part 2 The Doppler effect and optical resolution

(f) the observed change in frequency/wavelength of a wave;
emitted by a source moving away from or towards/relative to the observer; ***[2]***

(g) (i) a blue-shift / towards the blue end of the spectrum / to a higher frequency / *OWTTE*; ***[1]***

(ii) $v = \left(\frac{c\Delta f}{f} =\right) \frac{3\times10^{8}\times1.3\times10^{12}}{4.6\times10^{16}}$;
$8.5\times10^{3}\ \mathrm{m\,s^{-1}}$;
assume that the speed is very much less than speed of light; ***[3]***

(h) (i) the two stars are (just) seen as separate images;
if the central maximum of the diffraction image of one star coincides with the first minimum of the diffraction image of the other star / *OWTTE*; ***[2]***
Accept an appropriate diagram for second marking point.

(ii) $\theta = \left(\frac{1.22\lambda}{b} =\right) \frac{1.22\times4.8\times10^{-7}}{5.0\times10^{-2}}$ ***or*** 1.17×10^{-5} rad;
$\theta = \frac{d}{1.0\times10^{18}}$;
$(d =)\,1.2\times10^{13}\ \mathrm{m}$; ***[3]***
*Award **[2 max]** if 1.22 is missing, giving an answer of 0.98×10^{13}.*

8. **Part 1** Energy sources and the greenhouse effect

(a) (i) methane/CH_4, water vapour/H_2O, carbon dioxide/CO_2, nitrous oxide/N_2O; ***[1]***
*Award **[1]** for two of the above.*

(ii) *Mechanism **[2]**:*
mention of resonance;
natural frequency of (resonating) greenhouse gas molecules is same as that of infrared radiation from Earth;

or

mention of energy level differences;
differences between energy levels of greenhouse gas molecules matches energy of infrared radiation from Earth;

*Explanation **[2]**:*
less infrared trapped if absorption is reduced;
so more infrared is transmitted through atmosphere;

or

more infrared is trapped if absorption is increased;
so more infrared is re-radiated back to Earth; ***[4 max]***
Allow only one variant for each alternative.

(iii) no radioactive waste;
no radiation risks to users;
lower expense of decommissioning / easier to decommission / easier to install / lower set-up cost;
transportation and storage less hazardous/safer;
simpler technology;
cannot be used for military purposes;
fossil fuels can be extracted/found more easily;
no chance of catastrophic accident/meltdown/Chernobyl; ***[1 max]***

(b) U-235 is (much) more fissionable that U-238 / U-238 is a good absorber of neutrons / U-238 removes neutrons from the reaction / U-238 cannot produce a chain/sustainable reaction;
(naturally occurring) uranium (ore) contains more U-238 (atoms) than U-235 (atoms) / very little U-235 in ore;
in fuel enrichment, U-238 is removed / the percentage of U-235 is increased / the ratio of U-235 to U-238 is increased / amount of U-235 increases; ***[3]***

(c) (i) energy required $= \left(620 \times 25 \times 4.2 \times 10^3 =\right) 6.51 \times 10^7$ J ;

mass of U-235 required $= \left(\frac{6.51 \times 10^7}{2.0 \times 10^{13}} =\right) 3.3 \times 10^{-6}$ kg ; ***[2]***

(ii) energy supplied $= 23 \times 740 \times 3600 \times$ time ;

time $= \left(\frac{6.51 \times 10^7}{23 \times 740 \times 3600} =\right) 1.1$ hr / 1 hour 4 minutes; ***[2]***

*Award **[1 max]** for correct answer expressed in seconds (3825 s).*

(d) kinetic energy of fission fragments into thermal energy / nuclear energy into thermal energy of the coolant/water/steam;
thermal energy into kinetic energy of (rotating) magnets/coils/turbines/generators (then to electrical energy); ***[2]***
Do not accept "heat energy" or "mechanical energy".

Part 2 Gravitational potential

(e) work done per unit mass;
in bringing (test) mass from infinity to point;
reference to small/point (test) mass; ***[3]***

(f) (i) tangent construction attempted at $R = 4.0 \times 10^8$ m ;
triangle/pair of coordinates used in calculation;
attempt to calculate gradient;
2.5×10^{-3} ms^{-2} ; *(accept answers in the range of 2.2 to 2.7)* ***[4]***

*Award **[1 max]** for $\frac{V}{R}$ to give (–)2.1 × 10^{-3}.*

(ii) change in $V = 0.45 \times 10^6 - 0.50 \times 10^6$ J kg^{-1} ;
change in PE $= \left(0.5 \times 10^6 \times 7.4 \times 10^{22} =\right) 3.3 - 3.7 \times 10^{28}$ J ; ***[2]***

(g) work is done against the gravitational field of Earth / Moon is now closer to infinity/further from Earth / $\frac{-GMm}{R}$ means that as R increases potential increases/becomes less negative; ***[1]***

9. **Part 1** Newton's laws and momentum

(a) the net (external) force acting on the system is zero / no force acting on system / system is isolated; ***[1]***

(b) (i) no external force/system is isolated so change in momentum is zero; (*do not accept momentum is conserved/constant)*
force on ball must be equal and opposite to force on the person;
so ball and person/Earth/pond move in opposite directions; ***[3]***

(ii) Newton's second law states that the rate of change of momentum is equal/proportional/directly proportional to the force acting;
the horizontal force acting on the ball is zero therefore the momentum must be constant/the rate of change of momentum is zero; ***[2]***

or

Newton's second law can be expressed as the force acting is equal to the product of mass and acceleration;
the horizontal force acting on the ball is zero therefore the acceleration is zero so velocity is constant (and therefore momentum is constant);

(c) $F=\frac{P}{v}$ ***or*** $\frac{0.75\times10^{6}}{44}$;
$17\,\text{kN}$; ***[2]***

(d) (i) $3.7\times4.0=10\times v$;
$v=1.5\,\text{m}\,\text{s}^{-1}$; ***[2]***

(ii) KE lost $=\frac{1}{2}\left[3.7\times10^{3}\times4.0^{2}\right]-\frac{1}{2}\left[10\times10^{3}\times1.5^{2}\right]$;
$=18\,\text{kJ}$; ***[2]***

(e) initial KE $=\left(\frac{1}{2}\left[10\times10^{3}\times1.5^{2}\right]=\right)11250\,\text{J}$;
friction $=\frac{11250}{40}$;
$=280\,\text{N}$; ***[3]***

or

use of kinematic equation to give a = $0.274\,\text{m}\,\text{s}^{-1}$;
use of $F(=ma)=10\times10^{3}a$;
$270/280\,\text{N}$;

Part 2 Data storage

(f) faster retrieval speed / portability / takes less space/higher storage density / data more easily manipulated/reproduced; ***[1]***

(g) depth must be $\frac{\lambda}{4}$ / $\frac{640}{4}(=160\text{ nm})$;

corresponds to $\frac{\lambda}{2}$ / π / 2*d* path difference between light (reflected) from pit and land;

results in destructive interference/cancellation; ***[3]***

Allow marking points to be shown on a clear labeled diagram.

(h) (i) CCD is (a silicon chip) divided into small/large number of areas/pixels;
each pixel behaves as/is a capacitor;
light incident on pixel releases electrons / produces a photoelectric effect; ***[3]***

(ii) length of pixel $= 8.8\times10^{-6}$ m;
distance between spots on image $= 2.4\times10^{-6}$ m;
less than two pixels apart / $= 2.4\times10^{-6}$ m $= 2.4\times10^{-6}$ m $< 8.8/17.6\times10^{-6}$ m therefore not resolved; ***[3]***

10. **Part 1** Simple harmonic motion (SHM) and waves

(a) (i) the acceleration (of a particle/P) is (directly) proportional to displacement;
and is directed towards equilibrium/in the opposite direction to displacement; ***[2]***
Do not accept "directed towards the centre".

(ii) $\frac{\pi}{2}$ / 90° /quarter of a period; ***[1]***

(b) (i) $0.30\,\text{s}$; ***[1]***

(ii) max velocity $= 0.74\ (\pm 0.02)\ \text{m s}^{-1}$;
recognize max velocity $= \omega x_0$;
$\omega = \left(\frac{2\pi}{T} = \frac{2\pi}{0.30} =\right) 20.9\,\text{rad s}^{-1}$;
$x_0 = \left(\frac{0.74}{20.9} =\right) 3.5\left(\pm 0.2\right) \times 10^{-2}\ \text{m}$; ***[4]***

or

identifies displacement with area;
uses one quarter of a cycle;
answer in the range of 30 to 40 mm;
answer in the range of 33 to 37 mm;

(iii) $v = 0.64\,(\pm 0.2)\,\text{m s}^{-1}$;
use $v = \omega\sqrt{(x_0^{\ 2} - x^2)}$ to get $x = 1.7\left(\pm 0.2\right) \times 10^{-2}\ \text{m}$; ***[2]***

or

recognition that $x = x_0 \cos \omega t$;
$x\left(= 35\cos\left[\frac{2\pi}{0.3} \times 0.2\right]\right) = 17.5\,\text{mm}$;

(c) (i) the direction of energy propagation is at right angles to the motion of the particles/atoms/molecules in the medium; ***[1]***

(ii) $\lambda = \frac{v}{f} = vT$;
$= (0.40 \times 0.3 =)\, 0.12\,\text{m}$; ***[2]***

Part 2 Atomic and nuclear energy levels

(d) (i) light from a hydrogen discharge tube/hot hydrogen gas/ hydrogen tube with potential difference across it;
is passed onto a prism/diffraction grating;
and then is observed on a screen/through a telescope; ***[3]***
Accept good labelled diagram for explanation of any marking point.

(ii) each wavelength corresponds to the energy of the photon emitted;
when an electron makes a transition from a higher to lower energy level;
since only discrete wavelengths/finite number of wavelengths are present, then only discrete energy levels are present / *OWTTE*; ***[3]***

(e) (i) $-3.40\,\text{eV}$; ***[1]***
*Award **[0]** for omitted negative sign.*

(ii) energy difference between levels $= \dfrac{hc}{\lambda e} = \dfrac{6.63\times10^{-34}\times3\times10^{8}}{4.85\times10^{-7}\times1.6\times10^{-19}}$;
$=2.55\,\text{eV}$;
$\left[3.40-2.55\right]=0.85=\dfrac{13.6}{n^2}$ to give $n^2=16$;
$n=4$; ***[3]***
*Award **[3]** for reversed argument.*

(f) the total emitted energy is shared between the electron and the antineutrino;
the energy/velocity can be shared/distributed in an infinite number of ways / *OWTTE*; ***[2]***