M14/4/PHYSI/HP2/ENG/TZ1/XX/M

International Baccalaureate®
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MARKSCHEME

May 2014

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

1. (a) (i) (±) 1 (°C); ***[1]***

(ii) absolute uncertainty is the same for the two points;
since T is higher at $B = 90$ (*stated or shown*), relative uncertainty is smaller; ***[2]***

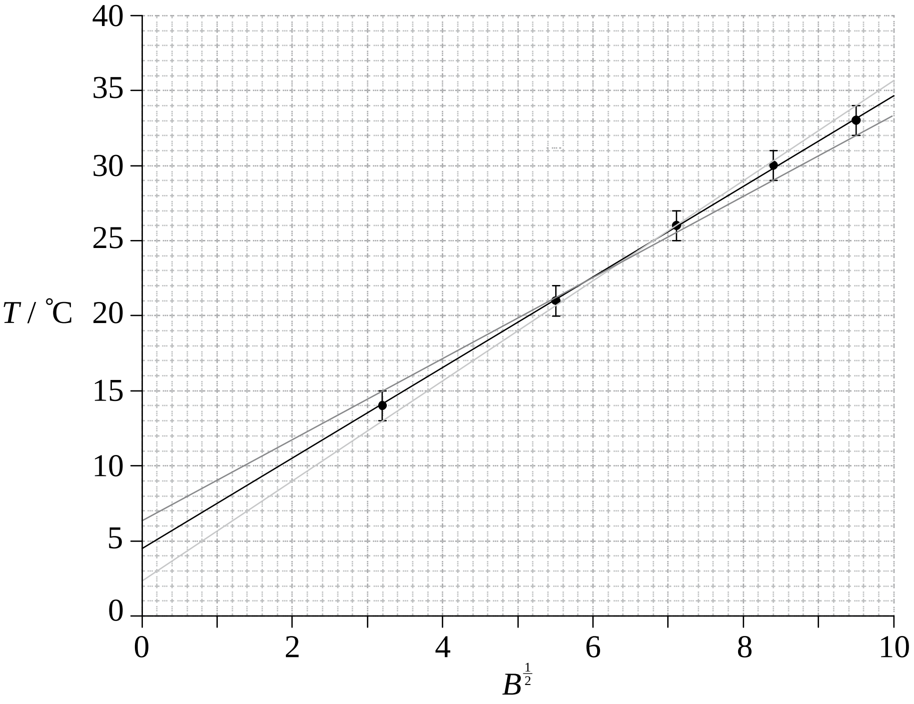
or

fractional uncertainties are $0.07/\frac{1}{14}/7\,\%$ for $B = 10$ and $0.03/\frac{1}{33}/3\,\%$ for $B = 90$;
fractional uncertainty is smaller for $B = 90$;

(iii) smooth curve passing through all error bars; ***[1]***
Do not allow thick or hairy or doubled lines, or lines where the curvature changes abruptly.

(iv) the line is not straight/is a curve/does not have a constant gradient/is not linear;
it does not pass through the origin/(0, 0)/zero; ***[2]***

(b) (i)



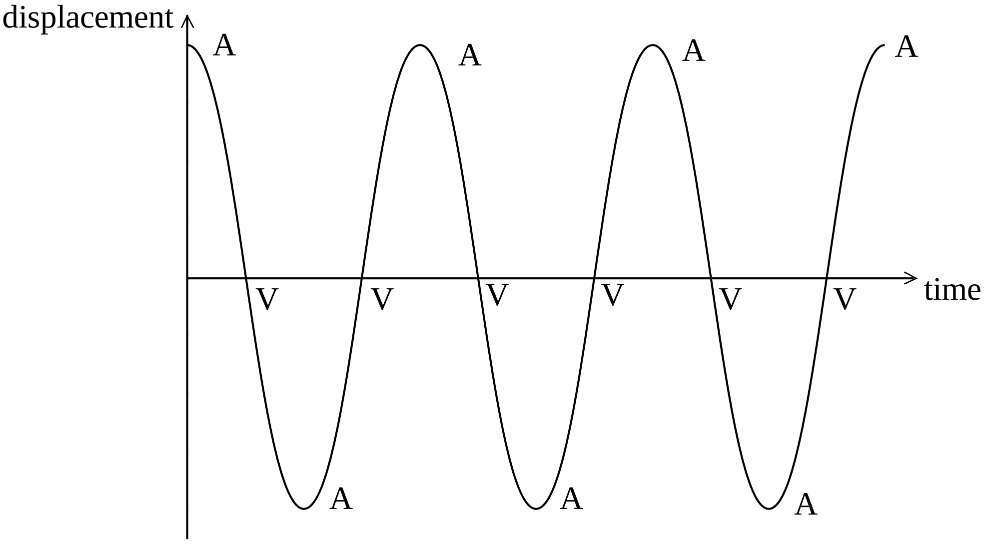
intercept read as 4.7; *(ignore significant figures, allow range of 4.5 to 4.9)*
two worst fit lines drawn through extremes of error bars;
uncertainty found from worst fit lines;
uncertainty rounded to 1 significant digit expressed in the form as ± (value) and intercept rounded to same precision; ***[4]***
*Award **[4]** for a statement of 5 ± 2 and lines drawn.*

(ii) °C; ***[1]***

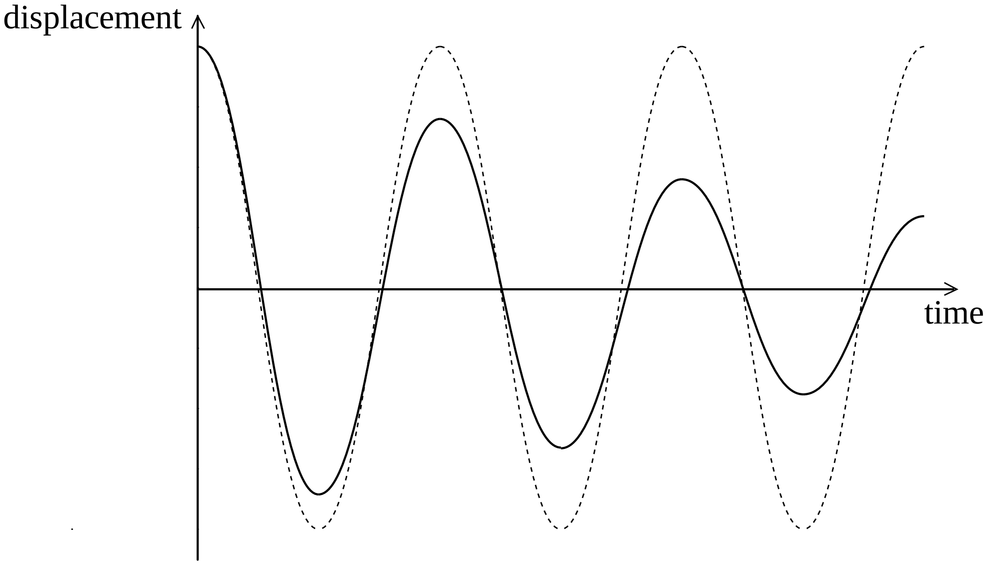
2. (a) the force (of the spring on the object)/acceleration (of the object/point O) must be proportional to the displacement (from the equilibrium position/centre/point O);
and in the opposite direction to the displacement / always directed towards the equilibrium position/centre/point O; ***[2]***

(b) (i) one A correctly shown; ***[1]***

(ii) one V correctly shown; ***[1]***

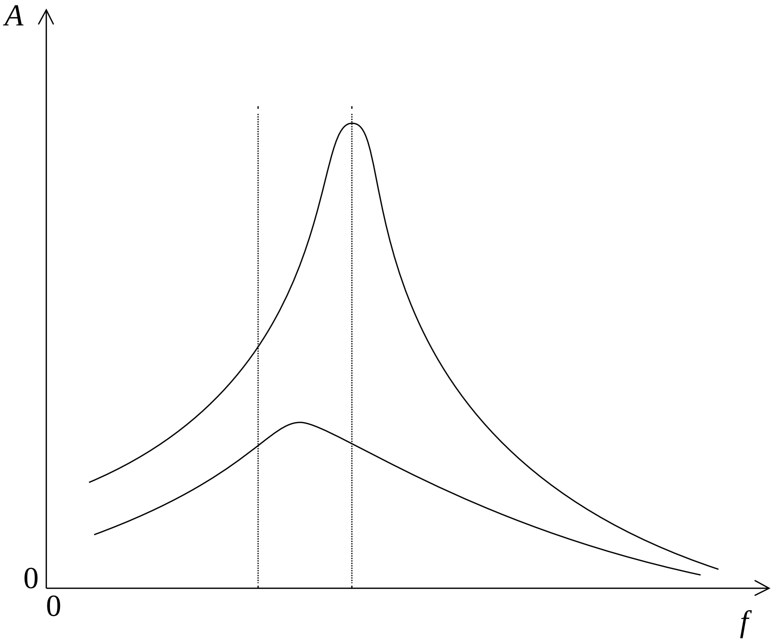


(iii) same period; *(judge by eye)*
amplitude decreasing with time; ***[2]***



(c) (i) resonance is where driving frequency equals/is close to natural/resonant frequency;
the natural/resonant frequency is at/near the maximum amplitude of the graph; ***[2]***

(ii) lower amplitude everywhere on graph, bit still positive;
maximum in same place/moved slightly *(that is, between the lines)* to left on graph; ***[2]***



3. (a) $F = qE$ ***or*** $1.6\times10^{-19}\times2.0\times10^{3}$;
$= 3.2\times10^{-16}\,(\text{N})$; ***[2]***

(b) (i) $\left(F = qvB \Rightarrow\right) B = \frac{F}{qv}$ ***or*** $\left(Eq = qvB \Rightarrow\right) B = \frac{E}{v}$;
$\left(= \frac{3.2\times10^{-16}}{1.6\times10^{-19}\times1.6\times10^{4}}\right) = 0.13$ ***or*** $0.125\,(\text{T})$;
directed into the page / *OWTTE*; ***[3]***

(ii) both electric and magnetic forces double / both forces increase by the same factor / both forces scale with *q/*charges and cancel;
so straight line followed; *(only award if first mark awarded)* ***[2]***

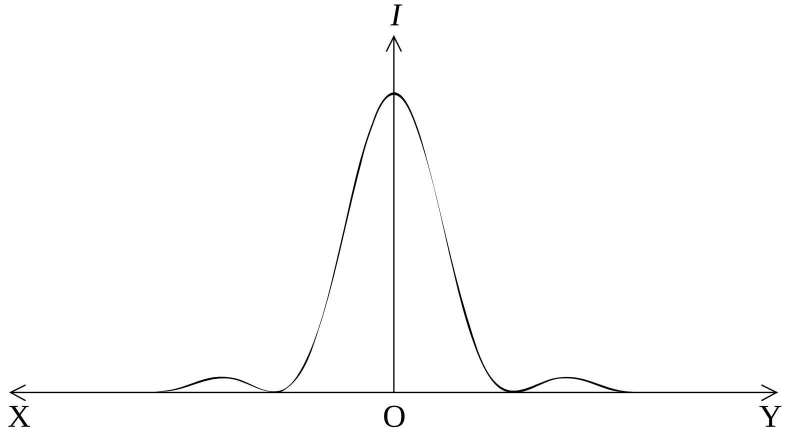
or

straight line followed if $qE = qvB \Rightarrow E = vB$;
E, *v* and *B* constant (so straight line followed);

4. (a) (i) diagram showing (circular) wavefronts around source, so that wavefronts are closer together on side of observer;
speed of sound waves for observer is the same (as for stationary case) but observed wavelength is smaller;
since $f' = \frac{v}{\lambda'}$, (observed frequency is larger); ***[3]***

(ii) $f'\left(= f\left[\frac{v}{v-u_s}\right]\right) = 275\left[\frac{330}{330-20}\right]$;
$= 293\,(\text{Hz})$; ***[2]***
*Award **[0]** for use of moving observer formula.*
*Award **[1]** for use of $v + u_s$ to give 259 (Hz).*
*Award **[2]** for a bald correct answer.*

(b) (i) central symmetrical maximum;
at least one secondary maximum on each side, no more than one third the height of the central maximum; *(judge by eye)*
minima drawn to zero, *ie* touching axis;
width of the secondary maximum half the width of the primary maximum; *(judge by eye)* ***[3 max]***



(ii) greater distance between maxima/minima / pattern more spread out; ***[1]***

(c) (i) in a polarized wave, the oscillations/vibrations are in one direction/plane only;
in an unpolarized wave, the oscillations/vibrations are in all directions/planes (perpendicular to the direction of energy transfer); ***[2]***
Must see mention of oscillations or vibrations in first or second marking point.

(ii) sound waves are longitudinal / the oscillations/vibrations are always parallel to direction of energy transfer; ***[1]***

5. (a) field caused by (induced) current must be downwards;
to oppose the change that produced it;
hence the current must be clockwise; ***[3]***

(b) $\varepsilon = \left(\frac{\Delta\Phi}{\Delta t} = \right) \frac{2.4\times10^{-5} - 1.2\times10^{-5}}{2.0\times10^{-3}}$ ***or*** $6.0\times10^{-3}\,(\mathrm{v})$;

$I = \left(\frac{\varepsilon}{R} = \frac{6.0\times10^{-3}}{3.0\times10^{-3}} = \right) 2.0\,(\mathrm{A})$; ***[2]***

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

SECTION B

6. **Part 1** Solar radiation and the greenhouse effect

(a) power/energy per second emitted is proportional to surface area;
and proportional to fourth power of absolute temperature / temperature in K; ***[2]***
Accept equation with symbols defined.

(b) solar power given by $4\pi R^2\sigma T^4$;
spreads out over sphere of surface area $4\pi d^2$; ***[2]***
Hence equation given.

(c) $\left(\frac{\sigma R^2 T^4}{d^2}=\right)\frac{5.7\times10^{-8}\times\left[7.0\times10^{8}\right]^2\times\left[5.8\times10^{3}\right]^4}{\left[1.5\times10^{11}\right]^2}$;
$=1.4\times10^{3}\ \left(\text{Wm}^{-2}\right)$; ***[2]***
*Award **[2]** for a bald correct answer.*

(d) some energy reflected;
some energy absorbed/scattered by atmosphere;
depends on latitude;
depends on time of day;
depends on time of year;
depends on weather (*eg* cloud cover) at location;
power output of Sun varies;
Earth-Sun distance varies; ***[2 max]***

(e) power radiated = power absorbed;
$T=\sqrt[4]{\frac{240}{5.7\times10^{-8}}}\ (=250\,\text{K})$; ***[2]***
Accept answers given as 260 (K).

(f) radiation from Sun is re-emitted from Earth at longer wavelengths;
greenhouse gases in the atmosphere absorb some of this energy;
and radiate some of it back to the surface of the Earth; ***[3]***

(g) more CO_2/other named greenhouse gas released into the atmosphere;
hence more energy is absorbed and radiated back to Earth's surface; ***[2]***

Part 2 Orbital Motion

(h) (i) gravitational force / gravitational attraction / weight; *(do not accept gravity)* ***[1]***

(ii) astronauts and spaceship have the same acceleration;
acceleration is towards (centre of) planet;
so no reaction force between astronauts and spaceship; ***[3]***

or

astronauts and spaceships are both falling towards the (centre of the) planet;
at the same rate;
so no reaction force between astronauts and spaceship;

(i) gravitational force equated with centripetal force / $\frac{GmM}{r^2}=\frac{mv^2}{r}$;

$\Rightarrow v^2=\frac{GM}{r}\Rightarrow\left(v=\sqrt{\frac{GM}{r}}\right)$; ***[2]***

(j) (i) thermal energy is lost;
total energy decreases; ***[2]***

(ii) since E decreases, r also decreases;
as r decreases v increases / E_k increases so v increases; ***[2]***

7. **Part 1** Nuclear reactions

(a) (i) one twelfth of the mass of a carbon-12 atom/$^{12}_{6}\text{C}$; ***[1]***

Do not allow nucleus.

(ii) $255.09 \times 931.5 = 237\,600 \left(\text{MeVc}^{-2}\right)$; ***[1]***

*Award **[1]** for a bald correct answer.*

(b) a particle is fired at a nucleus;
a different nucleus/nuclide/element forms; ***[2]***

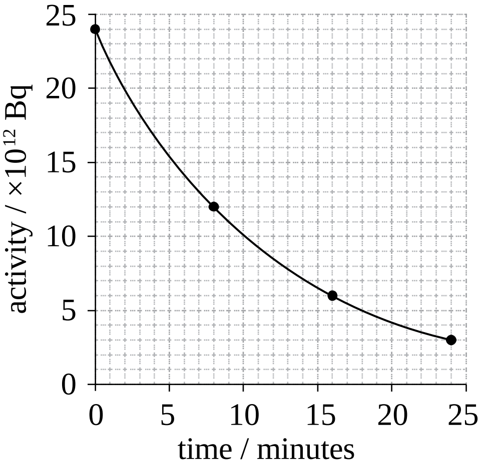
(c) (i) neutron/$^{1}_{0}\text{n}$; ***[1]***

(ii) the (rest) mass of the products is greater than that of the reactants;
energy must be given to supply this extra mass; ***[2]***

(iii) $\Delta m = [37\,216.560 + 938.272] - [37\,214.694 + 939.565] = 0.573 \left(\text{MeVc}^{-2}\right)$;
energy required for reaction $= 0.573 (\text{MeV})$;
kinetic energy $= (8.326 - 0.573 =) 7.753 (\text{MeV})$; ***[3]***
*Award **[3]** for a bald correct answer.*

(d) (i) time for the activity of a sample to halve / time for half the radioactive nuclei to decay; ***[1]***

(ii) four data points (0, 24) (8, 12) (16, 6) (24, 3) correct;
smooth curve through points; ***[2]***



(iii) 2 hours $(= 120 \text{ minutes}) = 15$ half-lives;

activity $= \dfrac{24 \times 10^{12}}{2^{15}} = 7.3 \times 10^{8}$ (Bq); ***[2]***

or

$\lambda = \dfrac{\ln 2}{8}$; *($A = A_o e^{-\lambda t}$ method)*

$= 7.3 \times 10^{8}$ (Bq);

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

Part 2 A heat engine

(e) (i) a process in which temperature remains constant; ***[1]***

(ii) calculation to show that $pV = 16\left(\times 10^{2}\right)$ at any point from A to B;
calculation to show that $pV = 16\left(\times 10^{2}\right)$ at any other point from A to B;
pV is constant; ***[3]***

(f) isochoric / isovolumetric / occurs at constant volume; ***[1]***

(g) $\Delta U = 0$;
$Q = W = 550\ (\mathrm{J})$; ***[2]***

(h) the gas/system must return to original conditions (*P*, *V*, and *T*);
(to do that) some of the thermal energy absorbed by gas must be given off to the surroundings;
hence not all thermal energy absorbed by gas can be converted to work;
it is the second law of thermodynamics; ***[3 max]***

8. **Part 1** Two children on a merry-go-round

(a) (i) 2.0 ***or*** $0\,(\mathrm{m\,s^{-1}})$; ***[1]***

(ii) 1.0 ***or*** $0\,(\mathrm{m\,s^{-1}})$; ***[1]***

(b) (i) her direction is changing;
hence her velocity is changing; ***[2]***

or

since her direction/velocity is changing;
a <u>resultant/unbalanced/net</u> force must be acting on her (hence she is accelerating);

(ii) arrow from Aibhe towards centre of merry-go-round; ***[1]***
Ignore length of arrow.

(iii) the force of the merry-go-round on <u>Aibhe</u>/<u>her</u>; ***[1]***

(iv) no force is acting on the upper body towards the centre of the circle / no centripetal force acting on the upper body (to maintain circular motion);
upper body (initially) continues to move in a straight line at constant speed/ velocity is tangential to circle; ***[2]***

(c) distance travelled by Euan $= 4.0 \times 2\pi \times 1.5\,(= 37.70\,\mathrm{m})$;
$W\left(= F_{av}d = 45 \times 37.70\right) = 1700\,(\mathrm{J})$; ***[2]***

(d) (i) Aibhe's period of revolution is the same as before;
from $v = \dfrac{2\pi r}{T}$, since r is halved, v is halved;
$v = 0.5\,(\mathrm{m\,s^{-1}})$; ***[3]***
*Award **[3]** for a bald correct answer.*

(ii) $a\left(= \dfrac{v^2}{r}\right) = \dfrac{0.5^2}{0.75}$;
$a = 0.33\,(\mathrm{m\,s^{-2}})$; ***[2]***
Allow ECF from (d)(i).
*Award **[2]** for a bald correct answer.*

Part 2 Charge-coupled devices (CCDs)

(e) incident photons cause electrons to be given off/produce electron-hole pairs;
the electrons/holes migrate to an electrode;
charge gathers/is stored on the electrodes (hence causing a potential difference); ***[3]***

(f) (i) energy of photon $(= hf) = 6.6\times10^{-34}\times4.4\times10^{14}(=2.9\times10^{-19})$;

number of photons $\left(=\frac{\text{total energy}}{\text{energy of photon}}\right)=\frac{1.4\times10^{-3}\times42\times10^{-3}\times4\times10^{-10}}{2.9\times10^{-19}}$; ***[2]***

$(=8.1\times10^{4})$

(ii) photons that emit and electron $=8.1\times10^{4}\times0.60(=4.86\times10^{4})$;

charge created $=4.86\times10^{4}\times1.6\times10^{-19}(=7.8\times10^{-15})$;

pd $\left(=\frac{q}{C}=\frac{7.776\times10^{-15}}{16\times10^{-12}}\right)=4.9\times10^{-4}$ (V); ***[3]***

Accept answers in the range of 4.8 to 4.9×10^{-4} *(V).*

(g) the potential difference across a pixel/number of electrons emitted is proportional to the intensity of the incident light;
the pixel position on the screen matches the pixel position on the CCD; ***[2]***

9. **Part 1** Thermal energy transfer

(a) the energy (absorbed/released) when a unit mass/one kg;
of liquid freezes (to become solid) <u>at constant temperature</u> / of solid melts (to become liquid) <u>at constant temperature</u>; ***[2]***

(b) (i) use of $\Delta Q = mc\Delta T$ and mL;
$0.020 \times 3.3 \times 10^5 + 0.020 \times 4200 \times (T - 0) = 0.25 \times 4200 \times (80 - T)$;
$T = 68\,(^\circ\text{C})$; ***[3]***
*Allow **[3]** for a bald correct answer.*
*Award **[2]** for an answer of T=74(°C) (missed melted ice changing temperature).*

(ii) no energy given off to the surroundings/environment;
no energy absorbed by beaker;
no evaporation of water; ***[2 max]***

Part 2 Electric circuits

(c) $\dfrac{\text{potential difference across the wire}}{\text{current through the wire}}$; ***[1]***
Accept equation with symbols defined. Accept p.d. Do not accept voltage.

(d) resistance of two resistors in parallel $= 3.0\,(\Omega)$, so total resistance $= 6.0 + 3.0 = 9.0\,(\Omega)$;
$I = \left(\dfrac{V}{R} = \right)\dfrac{12}{9.0}(=1.333)$ (A);
$P = (VI = 12 \times 1.333 =)16$ (W); ***[3]***

or

resistance of two resistors in parallel $= 3.0\ (\Omega)$, so total resistance $= 6.0 + 3.0 = 9.0\ (\Omega)$;
$P = \left(\dfrac{V^2}{R} = \right)\dfrac{144}{9.0}$;
$P = 16$ (W);

(e) total resistance is smaller $(= 4.0\,\Omega)$;
p.d./voltage is the same so current is greater $(= 3.0\,\text{A})$;
since $P = VI$ ***or*** $P = I^2R$, power is greater $(= 36\,\text{W})$; ***[3]***

or

total resistance is smaller $(= 4.0\,\Omega)$;
p.d./voltage is the same;
since $P = \dfrac{V^2}{R}$, power is greater $(= 36\,\text{W})$;
*Award **[1]** for a bald calculation of 36 (W).*
The marks are for an explanation.

Part 3 The photoelectric effect and the Heisenberg uncertainty principle

(f) (i) light consists of photons/quanta/packets of energy;
(each) photon has energy $E = hf$ / photon energy depends on frequency;
a single photon interacts with a single electron giving up all its energy;
a certain amount of energy is required to eject an electron from the metal;
if photon energy is less than this energy/work function/frequency below threshold, no electrons are emitted; ***[4 max]***

(ii) increasing the intensity increases the photoelectric current;
photocurrent will change as a different metal has a different work function/ threshold frequency; ***[2]***

(g) (i) $E_K = [6.6 - 3.7] \times 10^{-19} = 2.9 \times 10^{-19}\ (\text{J})$;

$E_K = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE_K} = \sqrt{2 \times 9.1(1) \times 10^{-31} \times 2.9 \times 10^{-19}}$;

$p = 7.2 \times 10^{-25}\ (\text{kg m s}^{-1})$; *(allow answers in the range of 7.2 to 7.3 × 10^{-25})* ***[3]***

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

(ii) $\Delta p = \frac{\frac{h}{4\pi}}{\Delta x} = \frac{\frac{6.6(3) \times 10^{-34}}{4\pi}}{5.0 \times 10^{-9}}$;

$= 1.1 \times 10^{-26}\ (\text{kg m s}^{-1})$; ***[2]***

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