Markscheme

May 2015

Physics

Higher level

Paper 2

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use RM™ Assessor annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

5. Personal codes/notations are unacceptable.

6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, use the "ZERO" annotation to award zero marks. Where a candidate has not attempted the part question, use the "SEEN" annotation to show you have looked at the question. RM™ Assessor will apply "NR" once you click complete.

7. If a candidate has attempted more than the required number of questions within **Section B** (QIG 6), mark all the answers. RM™ Assessor will only award the highest mark or marks in line with the rubric.

8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp "SEEN" on any additional pages that contain work not related to the QIG you are currently marking, or are blank or where the candidate has crossed out his/her work.

9. There is no need to stamp an annotation when a candidate has not chosen an optional question in **Section B** (QIG 6). RM™ Assessor will apply "NR" once you click complete.

10. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the "CON" stamp.

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]**.
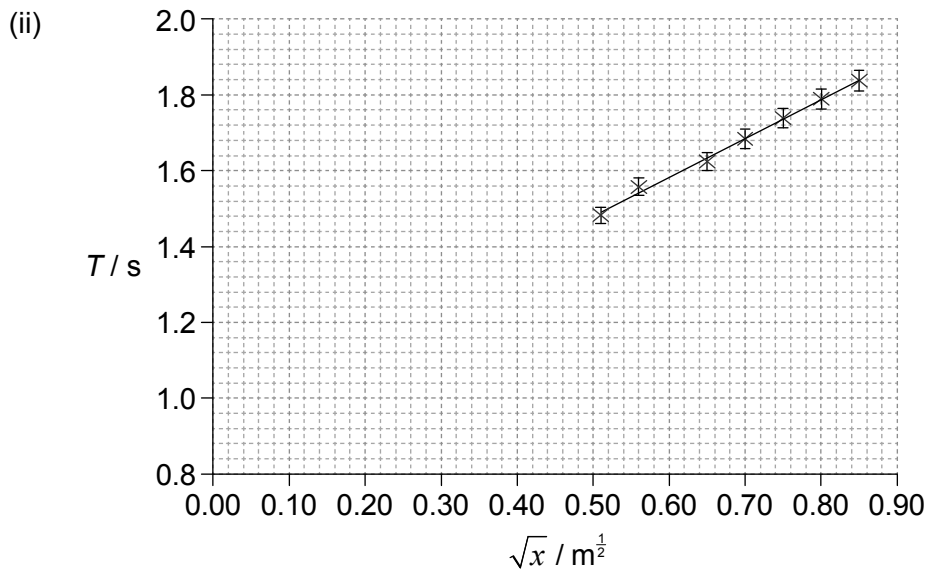
1.　A markscheme often has more marking points than the total allows. This is intentional.

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 <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)**   fractional uncertainty in $l = \dfrac{1}{880}$ **or** 0.00114

and fractional uncertainty in $T = \dfrac{1}{19}$ **or** 0.0526;

       (both needed)
(accept percentage, or fraction here
– allow candidate to quote $\dfrac{2}{19}$
directly if added correctly later)

fractional uncertainty in $g = (2 \times 0.0526 + 0.00114 =)0.106$;   *(accept percentage, do not accept fraction)*   **[2]**

(b)   **(i)**   half of cycle takes $\pi\sqrt{\dfrac{L}{g}}$ other half takes $\pi\sqrt{\dfrac{x}{g}}$ and combine to give result;

$$\left(\dfrac{\pi}{g}\left(\sqrt{L} + \sqrt{x}\right)\right)$$ **[1]**

(ii)

$\sqrt{x}\ /\ \mathrm{m}^{\frac{1}{2}}$

straight line of any length through all error bars;   **[1]**
Do not accept kinked, fuzzy, doubled lines.

(iii)   more than half line of their line used for gradient determination;
read-offs correct;
correct working leading to their gradient; *(best straight line gives 1.03)*   **[3]**
At least two significant figures are required in answer.

(iv)   their intercept ± half a square; *(best straight line gives 0.96 s)*   **[1]**

(v)   makes correct substitution for $T = 0$;

correct answer from own data including negative sign;   *(unit not required $-0.93\ m^{\frac{1}{2}}$)*   **[2]**

*Allow substitution into equation for straight line, but data point used **must** lie on candidate line.*
N.B. x in $y = mx + c$ is $\sqrt{x}$ on the axis – give BOD if not clear but answer correct.*

(vi) $L =$ candidate value for $b(v)^2$; } *(= 0.93² = 0.87 for best straight line.* **[1]**
Allow ECF from (b)(v))

The candidate value should be b(v)² – if value differs from this, award [0].
N.B. *the experimental value of g from the data in this experiment is*
     not *9.8 m s⁻² so award [0] for use of this value.*

2.   (a)   energy released when a nucleus forms from constituent nucleons /
(minimum) energy needed/work done to break a nucleus up into its constituent
nucleons;   **[1]**
Award [0] for energy to assemble nucleus.
Do not allow "particles" or "components" for "nucleons".
Do not accept "energy that binds nucleons together" OWTTE.

(b)   (i)   generally correct shape with maximum shown, trending down to U-235;
maximum shown somewhere between 40 and 70;   **[2]**
Award [0] for straight line with positive gradient from origin.
Award [1] if maximum position correct but graph begins to rise or flatlines
beyond or around U-235.

(ii)   identifies fission as occurring at high nucleon number / at right-hand side of
graph;
fission means that large nucleus splits into two (or more) smaller nuclei/nuclei
to left of fissioning nucleus (on graph);
(graph shows that) fission products have higher (average) binding energy per
nucleon than U-235;
energy released related to difference between initial and final binding energy; **[3 max]**
Award [2 max] if no reference to graph.

(c)   (i) $^{235}_{92}\text{U} \rightarrow {}^{231}_{90}\text{Th} + {}^{4}_{2}\alpha$; *(allow He for α; treat charge indications as neutral)*   **[1]**

(ii) $\lambda = \dfrac{\ln 2}{7.0 \times 10^8}\,(= 9.9 \times 10^{-10}\ \text{year}^{-1})$;

$m_0 = 5.6\text{e}^{3.9\times10^9 \times 9.9\times10^{-10}}$ (mg);

266 mg; } *(unit must match eg: allow 266 mg or 0.226 g but not 266 g or* **[3]**
0.266 kg)

or

number of half-lives $= \left(\dfrac{3.9 \times 10^9}{7 \times 10^8} = \right) 5.57$;

initial mass $= 5.6 \times 2^{5.57}$;

266 mg; } *(unit must match eg: allow 266 mg or 0.226 g but not 266 g or*
0.266 kg)
Award [3] for a bald correct answer.

3. (a) heat/thermal energy is the sum of PE and KE in a body / heat/thermal energy is
flow/transfer of energy;
temperature is measure of average KE of particles / indicates direction of heat flow;
temperature is measured in K **and** thermal energy measured in J; *(both needed)* **[3]**

 (b) (i) mass lost in $300\,\text{s} = (1.880 - 1.580) = 0.3\,(\text{kg})$;
(energy supplied $= 750\,\text{kJ}$) *(do not award credit for this line)*
$L = 2.5\,\text{MJ}\,\text{kg}^{-1}$; *(unit must appear correctly here)* **[2]**
Award [2] for a bald correct answer.

 (ii) energy will be transferred to surroundings; $\Big\}$ *(accept energy is lost by/from kettle to surroundings)*

 so calculated energy to water is too large / change in mass too large;
(hence overestimate) **[2]**
Award [0] for a bald correct answer.
Treat references to energy gained by kettle as neutral; the kettle is at a constant temperature.

4. (a) mention of interference;
interference is between reflected waves from both reflectors;
minimum caused (by destructive interference) when crest meets trough/when path
difference is $\dfrac{\lambda}{2}$ / (completely) out of phase / phase difference of $\pi / 180^\circ$ / *OWTTE*;

 minimum occurs when twice the distance between plates is $(n + \frac{1}{2})\lambda$; **[3 max]**
Ignore references to standing waves.

 (b) least distance moved between maxima $= \frac{1}{2}$ wavelength ($= 16\,\text{mm}$);

 $\text{frequency} = \dfrac{\text{speed of plate}}{\text{distance between successive maxima}}\ \Big(= \dfrac{0.75}{0.016}\Big)$;

 47 (Hz); **[3]**
Award [2] for 0.047 Hz (power of ten error).
Award [0] for $c = f\lambda$ approach.

 Award [0] for Doppler effect approach (calculation of f of wave and $\Delta f = \dfrac{vf}{c}$ will

 be seen) yields 23.5 Hz or 47 Hz.

 (c) (i) spreading out of a wave; *(do not allow "bending" even if context is obstacle)*
when it meets an aperture/gap/slit/obstacle; **[2]**
Allow credit for answers appearing on clear labelled diagram for both marks.

 (ii) $\Big(\theta = \dfrac{32}{60} = \Big)\ 0.533\,(\text{rad})$ *or* $30.6(^\circ)$; **[1]**
Award [0] for calculation that uses 1.22 (0.65 rad).
Award [0] for 0.533° or 30.6 rad.
At least one centre is using the abbreviation ^{c} for rad. Please allow this.

 (d) sound waves (in air) are longitudinal;
longitudinal waves cannot be polarized / only transverse waves can be polarized; **[2]**
Award [0] for any suggestion that ultrasound is an electromagnetic wave.

5. (a) speed as the whole of the coil enters the field $= \sqrt{2 \times 9.81 \times 0.05}$ $(= 0.99 \, \text{m s}^{-1})$;

$\left(\varepsilon = (-)\dfrac{\Delta \varphi}{\Delta t} \right) = 0.05 \times 0.99 \times 25 \times 10^{-3}$;

1.23 (mV) *or* 1.24 (mV); *(allow use of g = 10 to give 1.25 (mV))* **[3]**
Award [3] for a bald correct answer.
Use of factor 4 appears if candidate thinks all sides of coil contribute to emf
[2 max].

(b) current (induced) in the coil;
this will act so as to oppose the movement / reference to Lenz's law;
force will be upwards/resistive/counteracts the effect of gravitational force; **[3]**

Section B

6. **Part 1**   Renewable energy

(a)   (i)   total wind power required $= \dfrac{750\,000}{0.3}$;

maximum wind power required per turbine, $P = \dfrac{750\,000}{5 \times 0.3} \, (= 500 \, \text{kW})$;

$d = \left(\dfrac{8P}{\rho \pi v^3} \right)^{\frac{1}{2}} = 40 \, \text{(m)}$;   **[3]**

*Award **[1 max]** for an answer of 48.9 (m) as it indicates 5 and 0.3 ignored.*
*Award **[2 max]** for 22 (m) as it indicates 0.3 ignored.*
*Award **[2 max]** for 89 (m) as it indicates 5 ignored.*

(ii)   not all kinetic energy can be extracted from wind / losses in cables to community /
turbine rotation may be cut off/"feathered" at high or low wind speeds;   **[1]**
Do not allow "wind speed varies" as question gives the average speed.

(iii)   less kinetic energy available / wind speed less for turbines behind;
turbulence/wake effect; *(do not allow "turbines stacked too close")*   **[2]**

(iv)   *implications*: average wind speeds are greater / more space available;

limitations: installation/maintenance cost / difficulty of access / wave damage;   **[2]**
*Must see one each for **[2]**.*

(b)   (i)   mass of coal per second $(= 0.0214 \, \text{kg})$;
77.1 (kg);   **[2]**

or

energy saved per hour $= 0.75 \times 3600 \, (= 2700 \, \text{MJ h}^{-1})$;

mass of coal saved $= \left(\dfrac{2700}{35} = \right) 77.1 \, \text{(kg)}$;

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

(ii)   *advantage*:
energy is free (apart from maintenance and start-up costs) / energy is renewable
/ sufficient for small community with predominance of wind / supplies energy to
remote community / independent of national grid / any other reasonable
advantage;
Answer must focus on wind farm not coal disadvantages.

disadvantage:
wind energy is variable/unpredictable / noise pollution / killing birds/bats /
large open areas required / visual pollution / ecological issues / need to
provide new infrastructure;   **[2]**

(iii)   greenhouse gas molecules are excited by/absorbed by/ ⎫ *(must refer to infrared*
resonate as a result of infrared radiations;   ⎰ *not "heat")*

this radiation is re-emitted in all directions;

less greenhouse gas means less infrared/heat ⎫ *(consideration of return direction*
returned to Earth;   ⎰ *is essential for mark)*

temperature falls (to reach new equilibrium);   **[3 max]**

Part 2 Motion of a rocket

(c) gravitational potential energy is being gained;
this is at the expense of kinetic energy (and speed falls); **[2]**

(d) $\left(\text{acceleration} = \dfrac{(v-u)}{t} = \dfrac{4.25 \times 10^3 - 4.38 \times 10^3}{60} = \right)(-)2.17\,(\text{m s}^{-2})$;

gravitational field strength = acceleration of rocket ($= 2.17\,\text{N kg}^{-1}$); *(allow g = a in symbols)* **[2]**

or

computes potential difference from KE per unit mass change (5.61×10^5),

computes distance travelled (0.259 Mm), uses $g = \dfrac{(-)\Delta V}{\Delta r}$;

$g = (-)2.17\,(\text{m s}^{-2})$;

(e) (i) $(\text{gravitational force}) = mg' = \dfrac{GMm}{r^2}$;

$(\text{kinetic energy}) = \dfrac{mv^2}{2} = \dfrac{GMm}{r}$;

$v^2 = 2\dfrac{GM}{r^2}r\ (= 2g'r)$; **[3]**

Award [0] for centripetal force argument as rocket is not in orbit.

(ii) calculation of speed at a relevant distance *eg*: $\sqrt{2 \times g' \times 13 \times 10^6} = 7500\,(\text{m s}^{-1})$;

speed is less than this so will not escape; *(allow ECF from (d) which could lead to rocket able to escape)* **[2]**

Award [1 max] for use of g = 9.81 and r which gives 16 000 m s⁻¹.

(f) the satellite has velocity/kinetic energy as it is orbiting with the space station; **[1]**

7. **Part 1**   Simple harmonic motion (SHM)

(a) $ma = -kx$;

$a = -\dfrac{k}{m}x$; *(condone lack of negative sign)*

$\left(\omega^2 = \dfrac{k}{m}\right)$ **[2]**

or

implied use of defining equation for simple harmonic motion $a = -\omega^2 x$;

$\left(\text{so } \omega^2 = \dfrac{k}{m}\right)$

$ma = -kx$ so $a = -\left(\dfrac{k}{m}\right)x$;
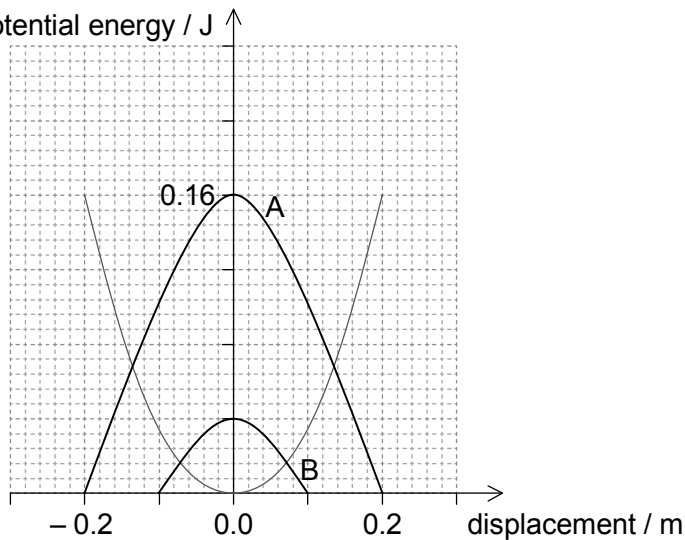
(b) (i)   0.833 (Hz); **[1]**

(ii)   frequency/period is the same so ω is the same;
k is the same (as springs are identical);
(so m is the same) **[2]**

(iii) defines simple harmonic motion as acceleration proportional to
negative displacement / $x = x_0 \sin \omega t$;
correct method for showing how graph leads to the definition; **[2]**

(c) (i)   potential energy / J

correct shape;
maximum at 0.16 J; **[2]**

(ii)   end displacements correct ± 0.01 m;
maximum lower than 0.16 J;
maximum equal to 0.04 J $\pm$ half square; **[3]**

(d)   maximum speed of oscillator $\left(= \omega x_0 = 2\pi \times 0.833 \times 0.2\right) = 1.05\,(\mathrm{m\,s^{-1}})$; $\Big\}$ *(N.B.*

$\hfill \omega = 5.24\,rad\,s^{-1})$

maximum energy read-off $= 0.16\,(\mathrm{J})$; $\Big\}$ *(condone ECF for incorrectly drawn*
maximum kinetic energy value in (c)(i))

use to $\frac{1}{2}mv^2$ to give mass value $(= 0.292\,\mathrm{kg}$ using correct data); **[3]**

or

read-off from graph of $ke_{max} = 0.16\,(\mathrm{J})$ **and** $x_{max} = 0.2\,(\mathrm{m})$; *(both needed)*

$0.16 = \dfrac{1}{2}m \times (2\pi f)^2 \times (0.2)^2$;

0.292 (kg); *(use of 0.8 Hz gives 0.32)*
Allow any alternative method if correct, eg: T from graph, k evaluated (8 N m⁻¹).

Part 2   Gas in an engine

(e)   vertical line identified;   **[1]**
Do not penalize candidate who identifies both vertical lines.
Award [0] if vertical and another line identified.

(f)   *at point X:* $nR = \dfrac{1.42 \times 1 \times 100}{310} = 0.4581$;

at point Y: $T = \left(\dfrac{0.44 \times 5.2 \times 100}{0.4581} = \right) 500\,\mathrm{K}$;   **[2]**

Award [2] for a bald correct answer.
Must be clear what units are here, $^\circ C$ unacceptable unless converted correctly.

(g)   (i)   (net) work done by engine in one cycle; $\Big\}$ *(must imply "by engine" and*   **[1]**
"one cycle")

(ii)   efficiency $= \dfrac{610}{1300}$;

0.47 **or** 47 %;   **[2]**
Award [2] for a bald correct answer.
Award [1] for $\dfrac{610}{(610 + 1300)} = 0.32.$
Award [0] for any fraction that would exceed 1 even if later fudged.

Award [0] for efficiency $= \dfrac{T_C - T_H}{T_H} = 38\,\%,$ *question does not imply that this is*
a Carnot cycle.

(iii)   it has gone to the surroundings / it is dissipated;
it cannot be used for further useful work;   **[2]**

(h) $\Delta Q = 0$;
210 (J); *(do not accept negative sign)*   **[2]**

8. **Part 1** Momentum

(a) total momentum does not change/is constant; *(do not allow "momentum is conserved")*

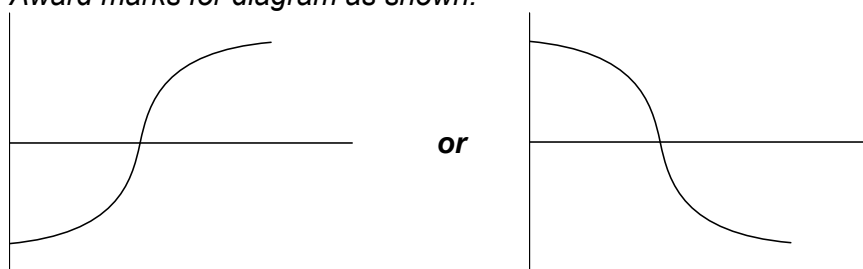provided external force is zero / no external forces / isolated system; **[2]**

(b) (i) clear attempt to calculate area under graph;
initial momentum is half change in momentum;
$\left(\frac{1}{2} \times \frac{1}{2} \times 24 \times 0.16\right) = 0.96$ (kg m s^{-1}); **[3]**
Award [2 max] for calculation of total change (1.92 kg m s^{-1})

(ii) initial speed $= \left(\frac{0.96}{0.8} = \right) 1.2$ m s^{-1};

$a = \frac{1.2 - (-1.2)}{0.16}$ *or* $a = \frac{-1.2 - 1.2}{0.16}$;

-15 (m s^{-2}); *(must see negative sign or a comment that this is a deceleration)* **[3]**

or

average force $= 12$ N;
uses $F = 0.8 \times a$;
-15 (m s^{-2}); *(must see negative sign or a comment that this is a deceleration)*
Award [3] for a bald correct answer.
Other solution methods involving different kinematic equations are possible.

(iii) goes through $t = 0.08$ s **and** from negative momentum to positive / positive momentum to negative;
constant sign of gradient throughout;
curve as shown; **[3]**
Award marks for diagram as shown.

or

(c) impulse is the same/similar in both cases / momentum change is same;
impulse is force $\times$ time / force is rate of change of momentum;
time to come to rest is longer for car B;
force experienced by car B is less (so less likely to be damaged); **[4]**

Part 2   DVD

(d)   a (binary) digit / either 0 or 1; *(just writing a digital number eg: 1001 is not enough)*
       least-significant bit determines whether the number is odd or even / least value bit /
       right-most bit of binary number;   **[2]**

(e)   the surface of the DVD has pits and lands;

       at edge of pit/land there is interference between beams⎫ *(must be clear that it is*
       from pit and land;   ⎬ *"edge")*
                                                              ⎭

       height difference is quarter of a wavelength;
       so (that at edge) there is a path difference of half wavelength between beams;
       leading to destructive interference;   **[4 max]**
       Award credit to a clear labelled diagram showing the above marking points.

(f)   each second there are $48\,000 \times 2 \times 16$ bits $= 1.54 \times 10^6$ bits;

       these have a length of $1.54 \times 10^6 \times 2.2 \times 10^{-6} = 3.38\,\text{m}$;

       so running time $= \dfrac{12\,000}{3.38}$; *(condone power of ten error in distance)*

       $(3.55\,\text{ks} =)$ conversion to 59 (mins);   **[4]**

       or

       number of bits $= \dfrac{12 \times 10^3}{2.2 \times 10^{-6}} (= 5.45 \times 10^9)$;

       number of samples $= \dfrac{5.45 \times 10^9}{2 \times 16} (= 1.7 \times 10^8)$;

       total playing time $= \dfrac{1.7 \times 10^8}{48\,000} (= 3541\,\text{s})$;

       conversion to 59 (mins);
       *Award **[4]** for bald correct answer.*

9.   Part 1   Current electricity

(a)   (i) $l = \dfrac{\pi d^2 R}{4\rho}$ seen / correct substitution

into equation: $24 = \dfrac{l \times 1.7 \times 10^{-8}}{\pi \times (0.15 \times 10^{-3})^2}$;
$\left.\begin{array}{l}\\\\\\\end{array}\right\}$ *(condone use of r for $\dfrac{d}{2}$ in first alternative)*

99.7 (m);   **[2]**
Award [2] for bald correct answer.
Award [1 max] if area is incorrectly calculated, answer is 399 m if conversion to radius ignored, ie: allow ECF for second marking point if area is incorrect provided working clear.

(ii)   electric field $= \left(\dfrac{12}{99.7} = \right) 0.120\,(V\,m^{-1})$; *(allow ECF from (a)(i))*

electric force $= (e \times E = 0.120 \times 1.6 \times 10^{-19} =)\, 1.92 \times 10^{-20}$ (N);

acceleration $= \left(\dfrac{F}{m} = \dfrac{1.92 \times 10^{-20}}{9.1 \times 10^{-31}} = \right) 2.11 \times 10^{10}\,(m\,s^{-2})$; $\left.\begin{array}{l}\\\\\\\end{array}\right\}$ *(5.27 × 10⁹ if radius used in (a)(i), allow as ECF)*   **[3]**

or

work done on electron $= (Vq =)\, 12 \times 1.6 \times 10^{-19}$;

energy gained by electron $= m_e \times a \times$ distance travelled $= 9.11 \times 10^{-31} \times a \times 99.8$;

$2.11 \times 10^{10}\,(m\,s^{-2})$;
Award [3] for a bald correct answer.

(iii)   free electrons collide with ions and other electrons;
speed decreases during collisions / transfer their kinetic during collisions;
kinetic energy transferred to heat / wires have resistance;
and speed increases/acceleration until next collision;   **[3 max]**

(b)   (i)   use of total resistance = 11 Ω ; *(can be seen in second marking point)*
$\dfrac{1}{11} = \dfrac{1}{R} + \dfrac{1}{24}$;
20.3 (Ω) ;   **[3]**

(ii)   as current is same in resistor network and cell and resistance is same, half of emf must appear across resistor network;
6.0 (V);   **[2]**

or

$I = \dfrac{12}{(11+11)} = 0.545\,(A)$;

$V = (0.545 \times 11 =)\, 6.0\,(V)$;
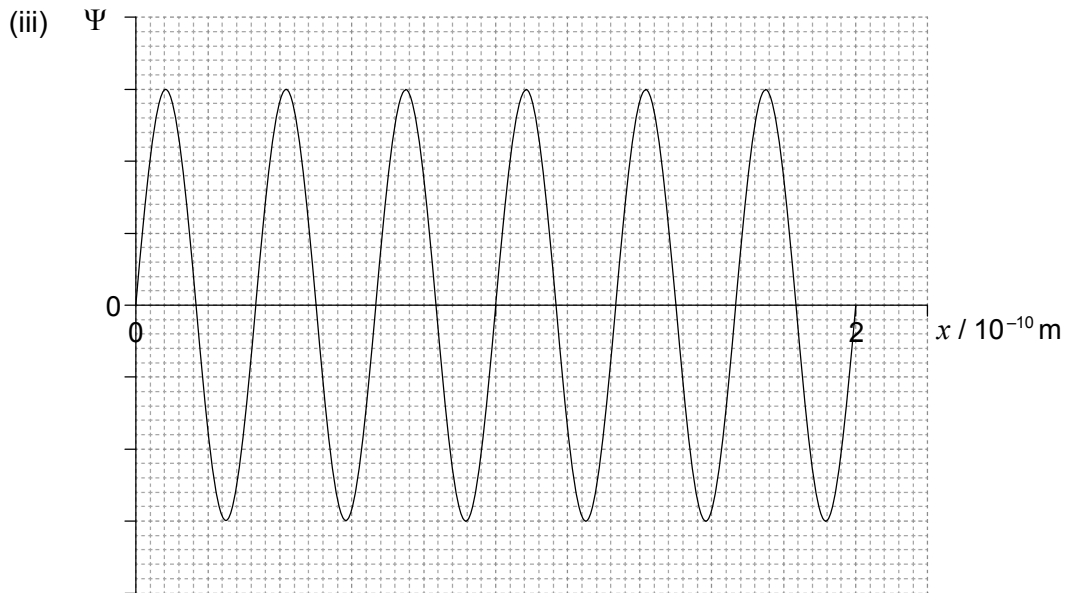*Other calculations are acceptable.*
Award [2] for a bald correct answer.

(iii)   pd across 24 Ω = 6.0 V; *(allow ECF from (b)(ii))*
$\left(\dfrac{V^2}{R} = \dfrac{36}{24} = \right) 1.5\,(W)$;   **[2]**
Award [2] for a bald correct answer.

Part 2   Atoms

(c)   measure of the probability of finding an electron (at a particular place and time);   **[1]**

(d)   (i) $\Delta p = \dfrac{h}{4\pi\Delta x}$ and $\Delta x = 2.0\times 10^{-10}$; *(both needed)*

           2.64×10^{-25} (N s); *(also accept 5.28 × 10⁻²⁵ (N s))*   **[2]**
           Award [2] for a bald correct answer.

       (ii) $\lambda = \dfrac{h}{p}\left(= \dfrac{6.63\times 10^{-34}}{2\times 10^{-23}}\right)$;

           3.3×10^{-11} (m);   **[2]**
           Award [2] for a bald correct answer.

       (iii)

           periodic behaviour shown anywhere between 0 nm and 0.2 nm;

           6 loops/repetitions shown anywhere between 0 nm and 0.2 nm;   *(allow ECF for division of 2 × 10⁻¹⁰ by answer to d(ii))*

           wavefunction completely fills from 0 nm to 0.2 nm and does not go beyond;   **[3]**

       (iv)   amplitude of Ψ /graph;
           squared;   **[2]**