MARKSCHEME

November 2005

PHYSICS

Higher Level

Paper 2

15 pages

General Marking Instructions

Subject Details: Physics HL Paper 2 Markscheme

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in (…) in the markscheme are not necessary to gain the mark.
- The order of points does not have to be as written (unless stated otherwise).
- If the candidate's answer has the same "meaning" or can be clearly interpreted as being the same as that in the markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalising them for what they have not achieved or what they have got wrong.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded.
- Units should always be given where appropriate. Omission of units should only be penalized once. Ignore this, if marks for units are already specified in the markscheme.
- Deduct **1 mark in the paper** for gross sig dig error *i.e.* for an **error of 2 or more digits**.

  e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

  However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

SECTION A

A1. (a) any line (curve) through the origins;
straight-line; ***[2]***

(b) (i) a straight-line drawn with (ruler);
which is appropriate *i.e.* does not or would not go through the origin; ***[2]***
*Award **[2 max]** for answers that confuse random with systematic but are otherwise correct. Award **[1 max]** for stating that there is only one type of error with correct explanation. Award **[0]** if points joined "dot to dot".*

(ii) data subjected to both types of error;
Can be implied in subsequent answer.
random since points are scattered above and below the line;
systematic since line does not/would not go through origin; ***[3]***
Accept answers that get this general idea across but do not accept answers that try to explain the source of the error without naming type of error.

(iii) use of "large triangle" for gradient (seen or implied);
Hypotenuse of triangle used should be at least half the distance between the first and the last point on the graph i.e. 5 cm.
to get gradient $= 0.59 \times 10^{-6} = 5.9 \times 10^{-7}$; ***[2]***
*Ignore any units. Award **[1 max]** for 0.59 without power of ten. Accept from* 5.3 *to* 6.5×10^{-7}.
*Award **[0]** if using a single point unless student's line goes through that point **and** the origin as well. Award **[0]** if using two data points as opposed to the gradient unless both data points are on candidate's line.*

(iv) use of Coulomb's law (seen or implied);
correct identification of gradient $= \mathrm{k}\, q_1 q_2 = \mathrm{k}\, q^2$;
$q^2 = 6.56 \times 10^{-17}\ \mathrm{C}^2$;
$q = 8.1 \times 10^{-9}\ \mathrm{C}$; ***[4]***
*Award **[3 max]** for a bald answer without any working. Award **[1 max]** if the candidate uses a point on the graph to calculate q.*

(c) correct taking of lgs of Coulomb's law;
e.g. $lg F = lg\,(q_1 q_2) - 2\, lg\, r$
to identify a straight-line graph of form $y = mx + c$;
of gradient $= -2$, which does not go through the origin; (*accept* $c = lg(kq_1 q_2)$) ***[3 max]***

A2. (a) zero; ***[1]***

(b) resultant vertical force from ropes $= (2.15\times10^3 - \text{weight}) = 237\text{ N}$;
equating their result to $2T\sin 50$;
i.e. $2T\sin 50 = 237$
calculation to give $T = 154.7\text{ N} \approx 150\text{ N}$; ***[3]***
*Accept any value of tension from 130 N to 160 N. Award **[2]** for missing factor of 2 but otherwise correct i.e. 309 N.*

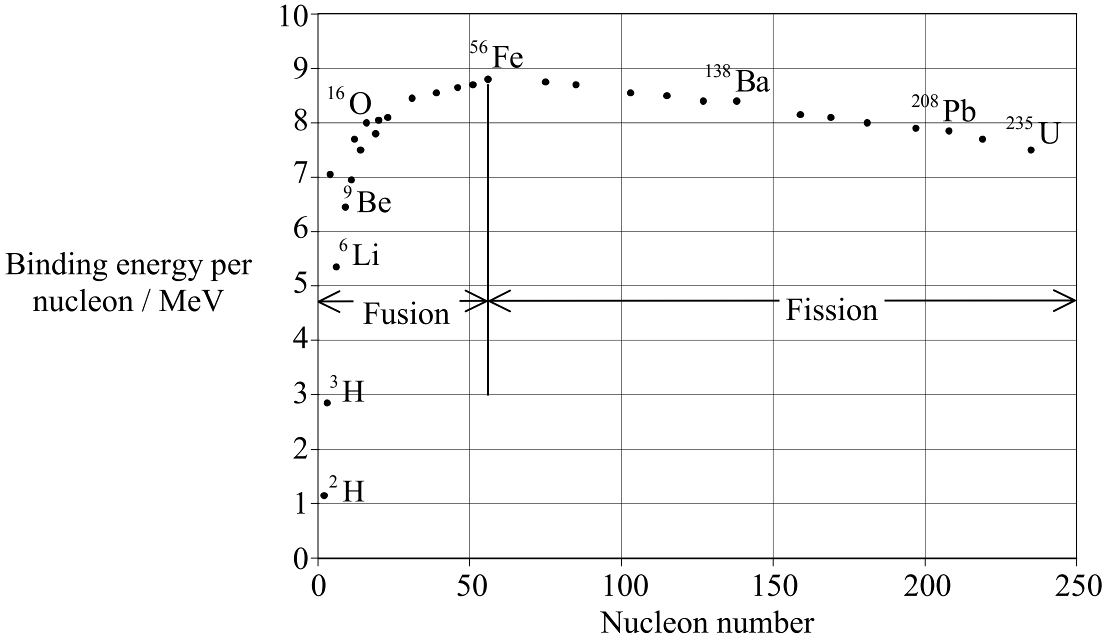
(c) correct <u>substitution</u> into $F = ma$;
to give $a = \dfrac{237}{1.95\times10^2} = 1.21\text{ m s}^{-2}$; ***[2]***
Watch for ECF.
N.B. *Depending on value of g answers will vary from $1.0(3)\text{ m s}^{-2}$ to $1.2(3)\text{ m s}^{-2}$ all of which are acceptable.*

(d) statement that air friction increases with increased speed seen/implied;
in 10 seconds friction goes from 0 N to 237 N / force increases from zero until it equals the net upward accelerating force; ***[2]***

A3. (a) (a nucleon is either) a proton <u>or</u> a neutron / *OWTTE*; ***[1]***

(b) appropriate definition; ***[1]***
e.g. energy released when a nucleus is formed from its constituent nucleons / (minimum) energy needed to break a nucleus up into its constituent nucleons

(c) appropriate identification of fission *e.g.* being possible at right hand end of the graph;
appropriate identification of fusion *e.g.* being possible at left hand end;



discussion in terms of energy release being possible as products have higher (average) binding energy per nucleon; ***[3]***

(d) (i) proton and nucleon numbers correct for boron;
Ignore mistakes in chemical symbol used for boron.
inclusion of neutrino; ***[2]***
Reject antineutrino.
$${}^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{1}\beta^{+} + \nu$$

(ii) number of moles $= \dfrac{1.0\times10^{-15}}{0.011} = 9.09\times10^{-14}$;
therefore, number of nuclei $N_0 = 9.09\times10^{-14}\times6.02\times10^{23}$;
$= 5.47\times10^{10} \approx 5.5\times10^{10}$ ***[2]***

(iii) decay constant $\lambda = \dfrac{\ln 2}{1230} = 5.64\times10^{-4}\ \text{s}^{-1}$;
therefore, activity $= \lambda N_0 = 3.1\times10^{7}$ Bq ; ***[2]***

SECTION B

B1. Part 1 Electrical circuits

(a) (i) resistance $= 15\,\Omega$; ***[1]***

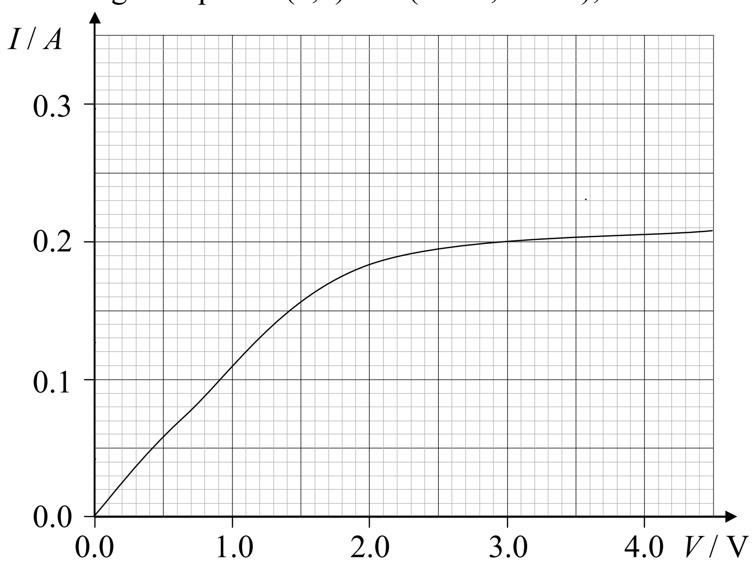
(ii) power $= 0.6\,\text{W}$; ***[1]***

(b) (i) resistance of circuit too high;
identification of high resistance component / other appropriate and relevant comment; ***[2]***
*Reject answers that do not explain why the lamp does not light e.g. award **[0]** for "the voltmeter should be in parallel" as this is not sufficient.*

(ii) voltmeter reads 3V; *(accept just below 3V)*
because most of the p.d. is across the voltmeter / resistance is too high / there is no current in the circuit; ***[2]***
*Award **[1 max]** if candidate attempts to calculate the precise value of the p.d. using the total resistance of the circuit.*

(c) correct location of ammeter in series with bulb;
correct location of voltmeter in parallel with bulb; ***[2]***

(d) line is initially practically straight;
and that curves;
in the right direction;
goes through the points (0,0) and (3.0 V, 0.2 A); ***[4]***



*Award **[2 max]** for a straight-line if it goes through (3.0 V , 0.2 A). Omit part of the graph from 3.0 volts but do not penalize if there.*

(e) resistance of filament increases as temperature increases;
so $\frac{I}{V}$ decreases with increasing *V* / *OWTTE*; ***[2]***
Allow ECF for a straight-line in (d) only if followed by "temperature is constant" so "I is proportional to V / so ohm's law is obeyed".

B1. Part 2 The physics of cooling

(a) temperature is proportional to a measure of the average kinetic energy;
of the molecules of the substance;

or:
idea that temperature shows natural direction of the flow of thermal energy;
from high to low temperature / *OWTTE*; *(do not accept "hot to cold")* ***[2]***
*Award **[1 max]** for a rough and ready answer and **[2 max]** for a more detailed answer.*

(b) a curve of gradually decreasing rate of loss of temperature;
that is asymptotic to $20\,^\circ\mathrm{C}$; ***[2]***
*Award **[0]** for a straight-line graph.*

(c) (i) temperature is falling because of thermal energy transfer to the surroundings;
with a decreasing rate;
the rate thermal energy transfer / heat loss in this region is greater;
because the temperature difference with the surroundings is greater / *OWTTE*; ***[2 max]***

(ii) realization that substance is still losing thermal energy; ***[1]***

*Award **[3 max]** for other relevant points*:
e.g. liquid and solid present / phase change taking place;
temperature stays constant until no more liquid;
at a constant rate;
loss of P.E. of atoms = thermal energy transfer;
because P.E. decreases;
K.E. of atoms constant; ***[4 max]***
*Award **[2 max]** for an answer that fails to realize that the liquid solidifies.*

(d) (i) calculation of the temperature rate of change in the range $(2.4-3.5)\times10^{-2}\ ^\circ\mathrm{C\,s^{-1}}$;

$$\frac{\Delta Q}{\Delta t}=mc\frac{\Delta Q}{\Delta t};$$

$$=0.11\times1300\times2.9\times10^{-2};$$

$$\simeq 4(\pm1)\,\mathrm{W};$$ ***[3 max]***

(ii) energy lost while solidifying $E=3600-6000\,\mathrm{J}$;

$$L=\frac{E}{m};$$

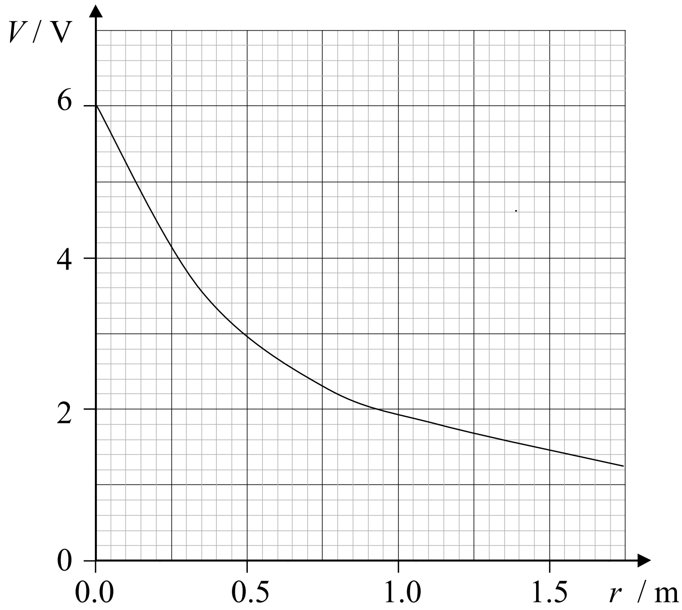
$$L=33-55\,\mathrm{kJ\,kg^{-1}};$$ ***[3]***

B2. Part 1 Fields and potential

(a) energy/work per unit charge;
in bringing a small <u>positive</u> test charge / <u>positive</u> point charge from infinity / <u>positive</u> test charge; ***[2]***
*Award **[0]** for quoting formula without definition of symbols.*

(b) (i) any roughly drawn circle drawn concentric to the sphere; ***[1]***
*Ignore any shape inside the sphere. Award **[0]** if other lines also shown.*

(ii) curve starting from $6.0\,\text{V}$;
curves downwards;
asymptotically to zero potential at infinity;
going through the point $(0.5\,\text{m}, 3.0\,\text{V})$; ***[4]***



(iii) idea that $E = (-)$ potential gradient seen/implied;
so draw tangent at $r = 0$ and find gradient; ***[2]***

(c) at least four radial lines evenly spaced around the sphere;
with arrows away from centre; ***[2]***
*Award **[1 max]** if any line inside sphere.*

(d) use of $F = \dfrac{GMm}{R^2}$ and $g = \dfrac{F}{m}$;
working to get $g = \dfrac{GM}{R^2}$;
m and R defined/identified/implied; ***[3]***
Ignore inclusion, or not, of negative (minus) signs.
*Award **[0]** for a bald answer* $g = \dfrac{GM}{R^2}$.

(e) rearrangement to get $M = \dfrac{g\,R^2}{G}$;

substitution to give $M = \dfrac{9.8 \times (6.40 \times 10^6)^2}{6.67 \times 10^{-11}} = 6.0 \times 10^{24}$ kg; ***[2]***

(f) at least four radial lines evenly spaced around the Earth;
with arrows in towards the centre; ***[2]***
Ignore any line inside sphere.

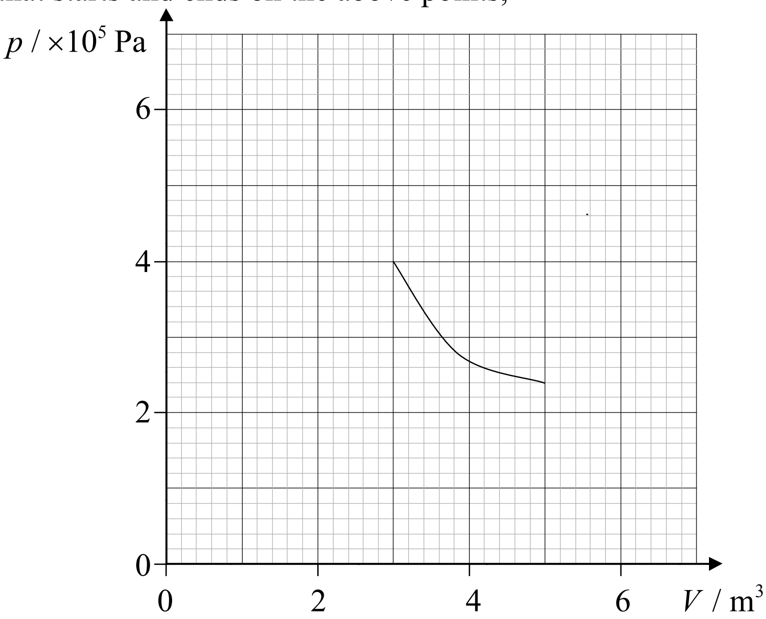
(g) each sensible and relevant comment;
e.g. astronaut has a resultant force towards the Earth;
which provides centripetal force to stay in orbit / acceleration of astronaut and satellite are identical / both in free fall together;
hence no contact force between the two *i.e.* apparently weightless / *OWTTE*; ***[3 max]***

(h) each sensible and relevant comment;
e.g. both vary inversely proportional to distance;
gravitational potential increases with distance whereas in this setup, electric potential decreases with distance / *OWTTE*;
in both, the field is (negative) potential gradient; ***[2 max]***
Reject answers that do not mention potential.

B2. Part 2 Expansion of a gas

(a) 2.4×10^{5} Pa ; ***[1]***

(b) any line through (3.0, 4.0) and (5.0, 2.4);
that is a smooth curve in correct direction;
that starts and ends on the above points;



[3]

(c) (i) work done = area under line/curve/graph;
to get 6.1×10^{5} J ; ***[2]***
Accept $5.5\rightarrow6.7\times10^{5}$ *J.*

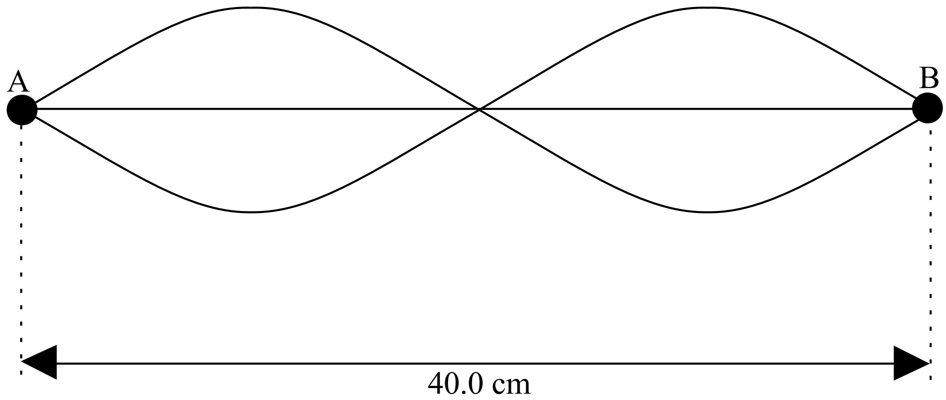
(ii) work done would be less as adiabatic line is steeper than isothermal line / *OWTTE*;

or:
no energy/heat has to be transferred to the surroundings to maintain constant temperature / *OWTTE*; ***[1]***

B3. (a) standing waves have varying amplitude whereas travelling waves have a fixed amplitude;
energy transfer in travelling waves whereas no energy transfer in standing waves; ***[2]***
Allow any appropriate diagrams or descriptions that shows understanding.
*Award **[2]** for just <u>one</u> difference if it is fully described or explained.*

(b) (i) 80 cm; ***[1]***

(ii) appropriate sketch *i.e.* one wavelength, two "loops"; ***[1]***



(iii) only the standing waves that have a wavelength that fits the boundary conditions are possible / *OWTTE*;
*The above can be implied. Award **[2]** for "there always has to be a node at either end" / OWTTE.*
in this situation the boundary conditions are a node at each end / *OWTTE*; ***[2]***

(iv) use of $v = f\lambda$ with $\lambda = 40\,\text{cm}$;
to give $500\,\text{Hz}$; ***[2]***

(v) frequency of fundamental $= 250$ Hz / frequency of second harmonic $= 2 \times$ fundamental;
therefore, ratio $= \dfrac{500^2}{250^2} = 4$; ***[2]***

(c) (i) any appropriate statement;
e.g. all particles can be represented as (probability) waves;
which predict the probability of locating the particle;
de Broglie relationship with definition of the symbols;
wavelength determined by momentum; ***[2 max]***

(ii) use of $p = \frac{h}{\lambda}$ and $E_{\mathrm{K}} = \frac{p^2}{2m}$;

$E_k = \frac{h^2}{2m\lambda^2}$;

to get $\lambda = \frac{h}{\sqrt{2mE_{\mathrm{K}}}}$ ***[2]***

No credit is awarded for final answer. Award marks for derivation.

(iii) *Each relevant piece of detail.*
e.g. accelerated electrons bombard (powdered) graphite target;
in a vacuum;
suitable detector / screen;
description of what is observed;
conclusion showing wave nature of electrons; ***[5]***

(d) (i) 1×10^{-10} m; ***[1]***

(ii) wavelength is smaller / frequency is higher;
hence kinetic energy greater; ***[2]***

(e) (i) electron is attracted to nucleus / *OWTTE*;
so work must be done (on electron) to move it away from the nucleus;
and so electrical potential energy increases as distance increases;

or:

the potential due to the nucleus is $V = k\frac{Q}{r}$ where Q is the nuclear charge;

since P.E. $= -V|e|$; *(do not award if minus sign is missing)*

the P.E. of the electron is becoming less negative as the electron moves away; ***[3]***

(ii) total energy of the electron constant;
so K.E. decreases as distance increases (since P.E. increases); ***[2]***

(iii) because the K.E. decreases ;
wavelength must increase;
as the electron moves away from the nucleus; ***[3]***

B4. Part 1 The properties of sound waves

(a) substitution into speed = distance / time to get
distance $=1500\times0.012=18\,\text{m}$;
therefore, depth $=18\div2=9\,\text{m}$; ***[2]***

(b) (i) appropriate wavefronts shown in geometric shadow region;
of constant wavelength; ***[2]***

(ii) substitution of correct values into $v=f\lambda$
to get $\lambda=0.025\,\text{m}$;
so obstacle (fish) significantly larger than wavelength hence diffraction effect small / *OWTTE*; ***[2]***
or the wavelength is very small;
so diffraction will be small for any reasonably sized fish;

(c) (i) change in received frequency of sound (wave);
as a result of relative motion of source and observer; ***[2]***
Accept other general descriptions but award ***[1 max]*** *for an answer that just gives an example of the Doppler effect.*

(ii) $490=\dfrac{f}{1-\dfrac{v}{340}}$;

$410=\dfrac{f}{1+\dfrac{v}{340}}$;

$\dfrac{490}{410}=\dfrac{340+v}{340-v}$;

to get $v=30\,\text{m}\,\text{s}^{-1}$;

or:

$490=\dfrac{f}{1-\dfrac{v}{340}}$;

with $f=450\,\text{Hz}$;
justification of $f=450\,\text{Hz}$;
to get $v=28\,\text{m}\,\text{s}^{-1}$;

or:

$410=\dfrac{f}{1+\dfrac{v}{340}}$;

with $f=450\,\text{Hz}$;
justification of $f=450\,\text{Hz}$;
to get $v=33\,\text{m}\,\text{s}^{-1}$; ***[4]***

B4. Part 2 Kinematics

(a) appropriate statement of principle of conservation of energy; ***[1]***
e.g. "Energy can not be created or destroyed, it just changes form."

(b) knowledge that the aircraft starts with chemical energy (in the fuel) and ends with kinetic energy;
realisation (seen or implied) that kinetic energy at end is less than chemical energy used up;
appropriate use of the principle of conservation of energy to explain where the energy "difference" goes; ***[3]***
e.g. some energy is lost as thermal energy and sound – escapes with exhaust gases / doing work against friction / OWTTE.
Look for precision in the answers "energy goes into friction" does not gain full credit.
Answers that consider other parts of the aircraft's journey should be ignored.

(c) (i) substitution into minimum force $= \mu R$;
to get minimum force $= 2720\,\text{N} = 2.7\,\text{kN}$; ***[2]***
*Award **[1]** for 272 N (forgetting g).*

(ii) calculation of $\text{K.E.} = \frac{1}{2}\times 8000\times 75^2 = 2.25\times 10^7\,\text{J}$;
appropriate use of $\text{force}\times\text{distance} = \text{work done}$;
to get $321.4\,\text{m} \approx 320\,\text{m}$;
alternatives, of course, possible e.g.
calculation of acceleration $= \dfrac{F}{m} = 8.75\,\text{m}\,\text{s}^{-2}$;
appropriate use of $v^2 = u^2 + 2as$;
to get $321.4\,\text{m} \approx 320\,\text{m}$; ***[3 max]***
Watch for ECF. Accept 321 m but remove significant digit mark if more quoted.

(d) (i) attempt at substitution into $F = \dfrac{mv^2}{r}$

$= \dfrac{8000\times 90^2}{500}$;
$= 129.6\,\text{kN} \approx 130\,\text{kN}$; ***[2]***

(ii) in towards the centre of the circle; ***[1]***

(e) (i) use of $v^2 = 2gh$;
to get vertical velocity $= 141\,\text{m}\,\text{s}^{-1}$;
realisation that horizontal velocity $= 90\,\text{m}\,\text{s}^{-1}$;
vector addition to get velocity $= 167 \approx 170\,\text{m}\,\text{s}^{-1}$;
with direction of 33° to the vertical; ***[5]***

(ii) direction will be more vertical / *OWTTE*; ***[1]***