MARKSCHEME

May 2006

PHYSICS

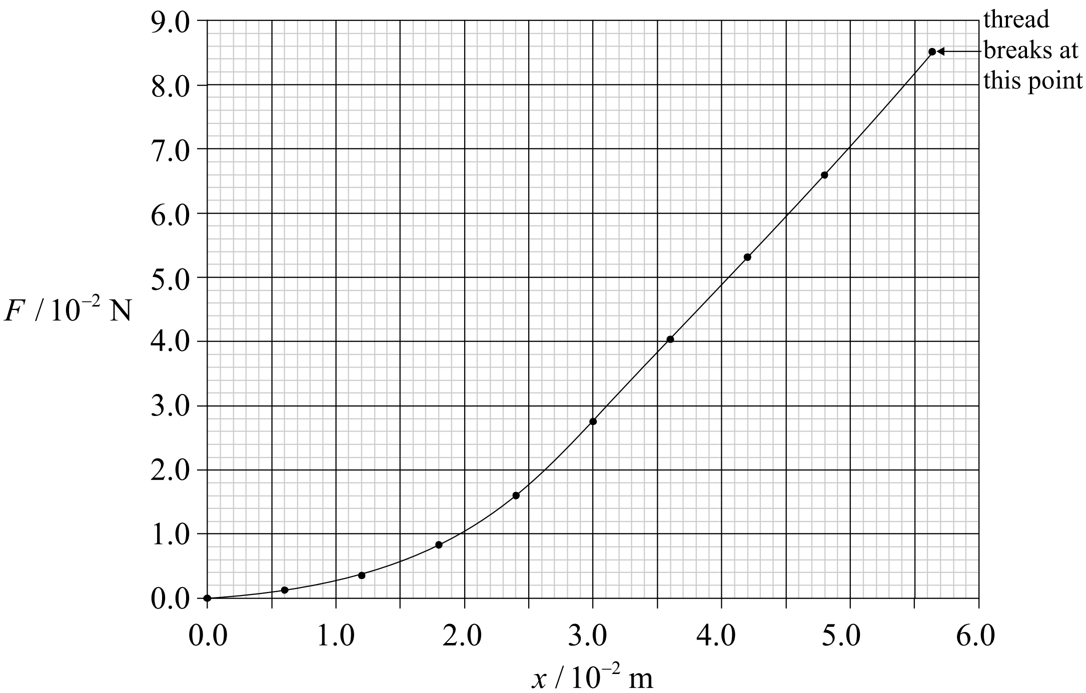
Higher Level

Paper 2

15 pages

SECTION A

A1. (a)



correct line of best fit; ***[1]***

The line should go through a majority of the points.

(b) $\lg(F)$ against $\lg(x)$;

$\lg(F) = \lg(k) + n\lg(x)$;

slope/gradient $= n$; ***[3]***

*Award **[2 max]** for a plot of* $\lg(F/k) = n\lg x$.

(c) from the graph breaking load $= 8.5(\pm 0.1) \times 10^{-2}$ N;

breaking stress $= \dfrac{8.5 \times 10^{-2}}{3.14 \times (4.5)^2 \times 10^{-12}} = 1.3 \times 10^9$ Pa ***or*** N m^{-2};

some statement of conclusion; ***[3]***

(d) % uncertainty in $r = \dfrac{0.1}{4.5} \times 100 = 2\%$;

uncertainty in $r^2 = 0.04 / 4\%$; ***[2]***

(e) (i) work = area under graph;
between $(2.4\times10^{-2}, 1.6\times10^{-2})$ and $(5.6\times10^{-2}, 8.5\times10^{-2})$;
$=(1.6\times3.2)\times10^{-4}+\frac{1}{2}(3.2\times6.9)\times10^{-4}$;
$=1.6\times10^{-3}$ J
If incorrect line of best fit in (a), allow first marking point only.

or

work = average force × distance/displacement/extension;
average force $=5.1\times10^{-2}$ N;
extension $=3.2\times10^{-2}$ m;
to give 1.6×10^{-3} J ***[3]***

(ii) KE of insect = work needed to break web $=1.6\times10^{-3}$ J;
$v=\sqrt{\dfrac{2\text{KE}}{m}}$;
$=\sqrt{\dfrac{3.2\times10^{-3}}{1.5\times10^{-4}}}=4.6\,\text{m s}^{-1}$; ***[3]***
No ECF from (e)(i) i.e. the value 1.6×10^{-3} J *must be used.*

A2. (a) the work done per unit mass;
in bringing a small/point mass;
from infinity to the point (in the gravitational field); ***[3]***

(b) $V_0 = -G\dfrac{M}{R_0}$;

$GM = g_0 R_0^{\ 2}$ to give $V_0 = -g_0 R_0$; ***[2]***

Do not award mark for data book expression $V = -G\dfrac{m}{r}$.

(c) from the graph $V_0 = 3.9(\pm 0.2)\times 10^7\ \mathrm{J\,kg^{-1}}$;

$g_0 = \dfrac{V_0}{R_0} = \dfrac{39}{5}$;

$= 7.8(\pm 0.4)\ \mathrm{N\,kg^{-1}}$; ***[3]***

Ignore any sign (+ or –)

(d) $2.0\times 10^7\ \mathrm{m}$ above surface is $2.5\times 10^7\ \mathrm{m}$ from centre;

ΔV between surface and $2.5\times 10^7\ \mathrm{m} = (3.9-1.0)\times 10^7 = 2.9(\pm 0.2)\times 10^7\ \mathrm{J\,kg^{-1}}$;

$v = \sqrt{\dfrac{2m\Delta V}{m}} = \sqrt{2\Delta V}$;

$= \sqrt{6.2\times 10^7} = 7.6(\pm 0.3)\times 10^3\ \mathrm{m\,s^{-1}}$; ***[4]***

*Award **[3 max]** if the candidate forgets that the distances are from the centre (answer* $4.5\times 10^3\ \mathrm{m\,s^{-1}}$*), i.e. the candidate must show* ΔV.

A3. (a) (i) $P \propto \frac{1}{V}$ ***or*** $V \propto \frac{1}{P}$ ***or*** $pV = \text{constant}$ ***or*** pressure inversely proportional to volume *etc*.; ***[1]***

(ii) $V \propto T$ *etc*.; ***[1]***

(b) (i) $\frac{P_1}{T_1} = \frac{P_2}{T'}$ ***or*** $P_1T' = P_2T_1$; ***[1]***

(ii) $\frac{V_1}{T'} = \frac{V_2}{T_2}$ ***or*** $V_1T_2 = V_2T'$; ***[1]***

(c) from (i) $T' = \frac{P_2T_1}{P_1}$;

from (ii) $T' = \frac{V_1T_2}{V_2}$;

equate to get $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$;

so that $\frac{PV}{T} = \text{constant}$ ***or*** $PV = KT$; ***[4]***

SECTION B

B1. (a) the rate of working / work $\div$ time; *[1]*
If equation is given, then symbols must be defined.

(b) $P = \frac{W}{t} = \frac{F \times d}{t}$;
$v = \frac{d}{t}$ therefore, $P = Fv$; *[2]*

(c) (i) $t = \frac{d}{v}$;
$= \frac{4800}{16} = 300\,\text{s}$; *[2]*

(ii) $W = mgh = 1.2 \times 10^4 \times 300 = 3.6 \times 10^6\,\text{J}$; *[1]*

(iii) work done against friction $= 4.8 \times 10^3 \times 5.0 \times 10^2$;
total work done $= 2.4 \times 10^6 + 3.6 \times 10^6$;
total work done $= P \times t = 6.0 \times 10^6$;
to give $P = \frac{6 \times 10^6}{300} = 20\,\text{kW}$; *[4]*

(d) (i) $\sin\theta = \frac{0.30}{6.4} = 0.047$;
weight down the plane $= W \sin\theta = 1.2 \times 10^4 \times 0.047 = 5.6 \times 10^2\,\text{N}$;
net force on car $F = 5.6 \times 10^2 - 5.0 \times 10^2 = 60\,\text{N}$;
$a = \frac{F}{m}$;
$\frac{60}{1.2 \times 10^3} = 5.0 \times 10^{-2}\,\text{m}\,\text{s}^{-2}$; *[5]*

(ii) $v^2 = 2as = 2 \times 5 \times 10^{-2} \times 6.4 \times 10^3$;
to give $v = 25/26\,\text{m}\,\text{s}^{-1}$; *[2]*

Give full credit for (i) and (ii) to candidates who use energy argument to calculate v and then use this to calculate a.
gain in *k.e.* = loss in *p.e.* – work done against friction;
$\frac{1}{2}mv^2 = mgh - Fd$;
$\frac{1}{2}mv^2 = 3.6 \times 10^6 - 5.0 \times 10^2 \times 6.40$;
$0.6 \times 10^{-3}\,v^2 = 3.6 \times 10^6 - 5.0 \times 10^2 \times 6.40$;
$v = 25/26\,\text{m}\,\text{s}^{-1}$;
$a = \frac{v^2}{2s}$;
$= 5.0/5.1 \times 10^{-2}\,\text{m}\,\text{s}^{-2}$;

(e) 5.6×10^2 N ; ***[1]***

(f) (i) a compression <u>or</u> expansion / change in state (of the gas);
in which no (thermal) energy is exchanged between the gas and the surroundings / in which the work done is equal to the change in internal energy of the gas; ***[2]***

(ii) isobaric; ***[1]***

(g) (i) Q_H absorbed $B \rightarrow C$;
Q_C ejected $D \rightarrow A$; ***[2]***

(ii) $Q_H - Q_C$; ***[1]***

(iii) a Carnot engine has the greatest efficiency of all engines / *OWTTE*;
so for the same operating temperatures, more work per cycle will be done;
therefore, greater since the area equals the work done; ***[3]***

(h) (for real engine) $\frac{20}{P_H} = 0.32$ to give $P_H = 63\,\text{kW}$;
time for one cycle $= 0.02\,\text{s}$;
$Q_H = P_H \times \text{time}$ to give $Q_H = 6.3 \times 10^4 \times 0.02$;
$= 1.3\,\text{kJ}$

or

$eff = \frac{W}{Q_H}$;

$W = \frac{2 \times 10^4}{50} = 400\,\text{J}$;

$0.32 = \frac{400}{Q_H}$ to give $Q_H = 1.3\,\text{kJ}$; ***[3]***

B2. (a) no energy is propagated along a standing wave / *OWTTE*;
the amplitude of a standing wave varies along the wave / standing wave has nodes and antinodes;
in standing wave particles are either in phase or in antiphase / OWTTE; ***[2 max]***

(b) medium 1;
wavelength is greater than in medium 2;
and $c = f\lambda$ and frequency is same in both media; ***[3]***
*Award **[1]** if the candidate answers medium 2, because wavelength is greater. Award **[1]** for correct medium and mention of bending towards normal when entering medium 2. Award **[0]** for correct medium but incorrect or no explanation.*

(c) *measurement of wavelength*:
$\lambda_1 = 2.5\,\text{cm}$;
$\lambda_2 = 1.0\,\text{cm}$;
$\frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = 2.5(\pm 0.2)$;

or

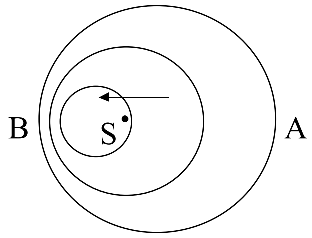
measurement of incident and refraction angles:
$\theta_1 = 60^\circ$;
$\theta_2 = 20^\circ$;
$\frac{c_1}{c_2} = \frac{\sin\theta_1}{\sin\theta_2} = 2.5$; ***[3]***
*Award **[2]** if the candidate gets it the wrong way round in either method, but they must have answered medium 2 in (b).*

(d) *Look for these main points.*
when the tube is vibrated, a wave travels along the tube and is reflected at B;
the wave is inverted on reflection;
the reflected wave interferes with the forward wave;
the maximum displacements occurs midway between A and B;
since there is always a node at A and B, then the pattern shown will be produced / *OWTTE*; ***[5]***
*Award **[1]** for essentially two waves in opposite directions, **[1]** for π out of phase, **[1]** for interference and **[2]** for condition to produce shape.*

(e) (i) $f = \frac{v}{\lambda}$;
to get $f = \text{constant}\sqrt{T}$ since λ constant;
therefore, a plot of f^2 against *T* ***or*** *f* against $\sqrt{T}$;
should produce a straight-line through the origin / *OWTTE*; ***[4]***

(ii) $\lambda = 4.8\,\text{m}$;
$v = f\lambda = 1.8 \times 4.8 = 8.6\,\text{m s}^{-1}$;
$k = \frac{v}{\sqrt{T}} = \frac{8.6}{3} = 2.9$; ***[3]***
Ignore any units.

(f) (i)



smaller wavelength and larger wavelengths in appropriate position relative to S;
quality of diagram *e.g.* position of S and consistency of wavelength; ***[2]***

(ii) B hears higher frequency than A / A hears lower frequency than B;
since λ smaller for B / since λ larger for A; ***[2]***

(g) (i) when two (sound) waves of nearly the same frequency <u>interfere</u>;
the intensity of the resulting wave varies with a frequency which is called the beat frequency / *OWTTE*; ***[2]***

(ii) recognize to use $f' = f\left(\dfrac{1}{1-\frac{v}{c}}\right)$ ***or*** $f' = f\left(1+\dfrac{v}{c}\right)$ because $\underline{v \ll c}$;

combine with $f_{\text{beat}} = f' - f = f\left(\dfrac{1}{1-\frac{v}{c}} - 1\right)$;

substitute to get $f_{\text{beat}} = 636\,\text{Hz}$;

but incident wave is also Doppler shifted so $f_{\text{beat}} = 1270\,\text{Hz}$; ***[4]***

B3. (a) (i) correct labelling of A and V; ***[1]***

(ii) P on resistor at "bottom"; ***[1]***

(b) (i) $I = 0.40\,\text{A}$;

$R = \frac{V}{I} = \frac{10}{0.40} = 25\,\Omega$; ***[2]***

(ii) the rate of increase of *I* decreases with increasing *V* / *OWTTE*;
because: the conductor is (probably) heating up as the current increases / *OWTTE*;
and resistance (of a conductor) increases with increasing temperature; ***[3]***

(c) (i) from graph, current in $\text{Y} = 0.30\,\text{A}$;
current in $\text{X} = 0.20\,\text{A}$ to give total current $= 0.50\,\text{A}$; ***[2]***

(ii) potential across $\text{Z} = 7.0\,\text{V}$;

therefore, $R = \frac{7.0}{0.50} = 14\,\Omega$; ***[2]***

(iii) resistance of parallel combination $\frac{14}{7} \times 5$ ***or*** $\frac{5.0}{0.50}$;

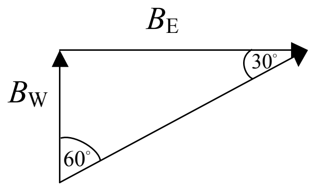
$= 10\,\Omega$;

or

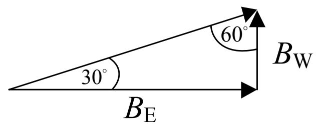
resistance of $\text{Y} = \frac{5.0}{0.30} = 17\,\Omega$ and resistance of X is $25\,\Omega$;

so combination $= \frac{25 \times 17}{42} = 10\,\Omega$; ***[2]***

(d) (i) upwards
the direction of the compass needle is the resultant of two fields / *OWTTE*;
the field must be into the plane of the (exam) paper to produce a resultant field in the direction shown / *OWTTE*; ***[2]***
*Award **[1]** for "upwards because of the right hand rule" / OWTTE.*

(ii) 

or



vector addition with correct values of two angles shown $30^\circ, 60^\circ$ ***or*** 90°;

from diagrams $B_E = B_W \times \tan 60$ ***or*** $B_E = \dfrac{B_W}{\tan 30}$; ***[2]***

(iii) $B_W = \dfrac{\mu_0 I}{2\pi r} = \dfrac{2\times10^{-7}\times4}{2\times10^{-2}} = 4.0\times10^{-5}\ \text{T}$;
$B_E = B_W \times \tan 60 = 6.9\times10^{-5}\ \text{T}$; ***[2]***

(e) (i) the e.m.f. induced in a circuit/coil/loop is equal to/proportional to;
the rate of change of flux linking the circuit/coil/loop; ***[2]***
Do not allow "induced current".

(ii) the induced e.m.f. / current is in such a direction that its effect is to oppose the change to which it is due / *OWTTE*; ***[1]***

(f) (i) *description*:
on closing the switch, the reading of the voltmeter will increase to a maximum value;
then drop back to zero;

explanation:
on closing the switch, a magnetic field is established in the solenoid so a flux links the loops;
the field is changing with time / the current is changing with time so an e.m.f. is induced in the loops;
when the current reaches a maximum there is no longer a time changing flux so there is no induced e.m.f.; ***[4 max]***

(ii) *description*:
on opening the switch, the reading on the voltmeter will increase to a maximum value but in the opposite direction;
and then drop to zero;

explanation:
when the switch is opened the field drops to zero – so again a time changing flux which will induce an e.m.f. in the opposite direction as the e.m.f. will now be such as to oppose the field falling to zero/Lenz's law;
when the current reaches zero, there will no longer be a flux change; ***[4]***

B4. (a) mass of LHS $= 235.0439 + 1.0087 = 236.0526u$;
mass of RHS $= 95.9342 + 137.9112 + 2 \times 1.0087 = 235.8628u$;
$\text{LHS} - \text{RHS} = 0.1898u$;
$= 0.1898 \times 932 = 176.9\,\text{MeV}$; ***[4]***

(b) if the net external force acting on a system is zero / for an isolated system of interacting particles;
the momentum of the system is constant / momentum before collision equals momentum after collision; ***[2]***
*Award **[1]** for momentum before collision equals momentum after collision.*

(c) $2.00\,\text{MeV} = 3.20 \times 10^{-13}\,\text{J}$;
$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{6.40 \times 10^{13}}{1.68 \times 10^{-27}}}$;
$= 1.95 \times 10^{7}\,\text{m s}^{-1}$ ***[2]***

(d) (i) momentum of neutron before $= 1.95 \times 10^{7}\,m$;
momentum of neutron after $= -1.65 \times 10^{7}\,m$;
therefore, $1.95 \times 10^{7}\,m = -1.65 \times 10^{7}\,\text{m} + 12mv$;
to give $v = 0.30 \times 10^{7}\,\text{m s}^{-1}$ ***[3]***
If the candidates go straight to the third marking point do not penalize them.

(ii) $\text{KE}_{\text{before}} = \frac{1}{2}(1.95)^2\,m = 1.90m$ ***or*** $3.19 \times 10^{-13}\,\text{J}$;
$\text{KE}_{\text{after}} = \frac{1}{2}(1.65)^2\,m + 6(0.3)^2\,m = 1.90m$ ***or*** $3.19 \times 10^{-13}\,\text{J}$;
collision is elastic since $\text{KE}_{\text{before}} = \text{KE}_{\text{after}}$; ***[3]***
Accept argument based on approach velocity = separation velocity.

(iii) loss in KE $= 6(0.3)^2\,m = 0.54m$ ***or*** $9.07 \times 10^{-14}\,\text{J}$;
fractional loss $= \frac{0.54}{1.90}$ ***or*** $\frac{0.91 \times 10^{-13}}{3.19 \times 10^{-13}} = 0.285 \approx 0.3\,(30\%)$; ***[2]***

(iv) each collision reduces energy by $\frac{1}{3}$ so after first collision $\frac{2}{3}$ of energy left so second collision reduces energy by $\frac{1}{3}$ of $\frac{2}{3}$ of initial energy, leaving $\frac{4}{9}$;
so to reduce the energy from $2\,\text{MeV}$ to $0.1\,\text{eV}$ therefore, takes quite a lot of collisions / *OWTTE*; ***[2]***
Look for an understanding of the idea that each collision reduces the remaining energy by $\frac{1}{3}$ so a lot of collisions needed to get down to 0.1 eV.

(e) $2.00\,\text{MeV} = 2.00 \times 1.6 \times 10^{-13}$ J

$p = \sqrt{2m_0E}$;

$= \sqrt{2 \times 1.68 \times 10^{-27} \times 3.2 \times 10^{-13}} = 3.28 \times 10^{-18}$ N s ;

$\lambda = \frac{h}{p} = \frac{6.6 \times 10^{-34}}{3.28 \times 10^{-20}}$;

$= 2.01 \times 10^{-14}$ m ;

or

$p = mv = 1.68 \times 10^{-27} \times 1.95 \times 10^{7}$;

$= 3.28 \times 10^{-20}$ N s ;

$\lambda = \frac{h}{p} = \frac{6.6 \times 10^{-34}}{3.28 \times 10^{-20}}$;

$= 2.01 \times 10^{-14}$ m ; ***[4]***

(f) (i) ${}^{138}_{55}\text{Cs} \rightarrow {}^{138}_{56}\text{Ba} + \beta^{-} + \bar{v}$

${}^{138}_{56}\text{Ba}$;

$\bar{v}$; ***[2]***

(ii) (electro)weak force;

W/(charged) vector / exchange boson; ***[2]***

Accept W^{+}, W^{-} *or* Z^{0}.

(g) (i) time to fall from 100% to 50% = 35(±3) minutes ; ***[1]***

(ii) at 250/300 seconds very little caesium is left;

so very little new barium is being formed;

so half-life is time to fall from 20% to 10% ***or*** 18% to 9% = 90(±5) minutes; ***[3]***