# MARKSCHEME

## NOVEMBER 2004

## PHYSICS

## Higher Level

## Paper 2

# 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.

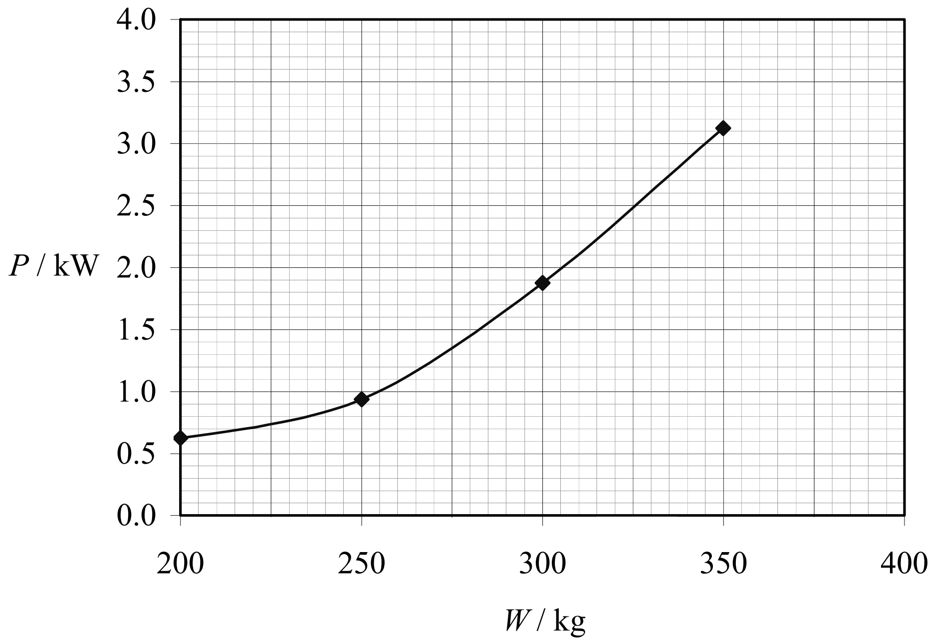
## SECTION A

**A1.** (a) (i) 2.0 kW; (± 0.10 kW) ***[1]***

(ii) $F = \frac{P}{v}$;

$= 1000\,\text{N}$; (± 50 N) ***[2]***

(b) (i)




sensible use of grid and suitable $P$ scale; *(at least half of grid used)*
labelled $P$ axis with correct units;
data point (200, 0.65);
data point (250, 0.95);
data points (300, 1.9), (350, 3.1);
*Allow ± 0.20 kW.*
line of best fit; ***[6]***

(ii) 2.6 kW; (±0.10 kW) *(watch for ecf)* ***[1]***

(c) $\log P = n \log v + \log k$;
therefore $n =$ slope / attempt at finding gradient shown on the graph;
choice of suitable values to show that $n = 2$ ($\Delta P$ at least 0.3); ***[3]***

**A2.** (a) $v_V = 8.0 \sin 60 = 6.9\,\text{m}\,\text{s}^{-1}$;

$h = \dfrac{v^2}{2g}$;

to give $h = 2.4\,\text{m}$; ***[3]***

*Award* ***[1]*** *if* $v = 8.0\,\text{m}\,\text{s}^{-1}$ *to get* $h = 3.2\,\text{m}$ *is used.*

(b) $v_H = 8.0 \cos 60$;

range $= v_H t = 8.0 \cos 60 \times 3 = 12\,\text{m}$; ***[2]***

*Award* ***[1]*** *if* $v = 8.0\,\text{m}\,\text{s}^{-1}$ *to get* $R = 2.4\,\text{m}$ *is used.*

**A3.** (a) ***Note****: for part (i) and (ii) the answers in brackets are those arrived at if 19.3 is used as the value for the height.*

(i) height raised $= 30 \sin 40 = 19\,\text{m}$;

gain in PE $= mgh = 700 \times 19 = 1.3 \times 10^4\,\text{J}\ (1.4 \times 10^4\,\text{J})$; ***[2]***

(ii) $48 \times 1.3 \times 10^4\,\text{J} = 6.2 \times 10^5\,\text{J}\ (6.7 \times 10^5\,\text{J})$; ***[1]***

(iii) the people stand still / don't walk up the escalator / their average weight is 700 N / ignore any gain in KE of the people; ***[1 max]***

(b) (i) power required $= \dfrac{6.2 \times 10^5}{60} = 10\,\text{kW}\ (11\,\text{kW})$;

$Eff = \dfrac{P_{\text{out}}}{P_{\text{in}}},\ P_{\text{in}} = \dfrac{P_{\text{out}}}{Eff}$;

$P_{\text{in}} = 14\,\text{kW}\ (16\,\text{kW})$; ***[3]***

(ii) the escalator can in theory return to the ground under the action of gravity / *OWTTE*; ***[1]***

(c) power will be lost due to friction in the escalator / *OWTTE*; ***[1]***

*The location of the friction must be given to obtain the mark.*

**A4.** (a) all particles have a wavelength associated with them / *OWTTE*;

the de Broglie hypothesis gives the associated wavelength as $\lambda = \frac{h}{p}$;

where $h$ is the Planck constant and $p$ is the momentum of the particle; ***[3]***

*If answers just quote the formula from the data book then award **[1]** for showing at least they recognize which formula relates to the hypothesis.*

(b) (i) $\text{KE} = Ve = 850 \times 1.6 \times 10^{-19}\ \text{J} = 1.4 \times 10^{-16}\ \text{J}$; ***[1]***

(ii) use $E = \frac{p^2}{2m}$ to get $p = \sqrt{2mE}$;

substitute $p = \sqrt{2 \times 9.1 \times 10^{-31} \times 1.4 \times 10^{-16}} = 1.6 \times 10^{-23}\ \text{N s}$; ***[2]***

(iii) $\lambda = \frac{h}{p}$;

substitute $\lambda = \frac{6.6 \times 10^{-34}}{1.6 \times 10^{-23}} = 4.1 \times 10^{-11}\ \text{m}$; ***[2]***

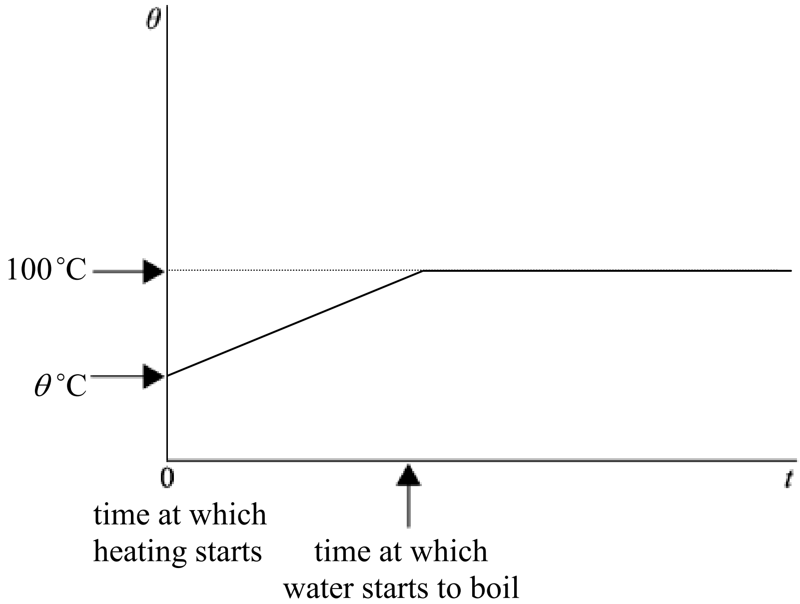
## SECTION B

**B1. Part 1** Specific heat capacity and specific latent heat

(a) specific heat capacity is the amount of energy required to raise the temperature of unit mass through 1 K; ***[1]***

(b) raising the temperature means increasing the KE of the molecules;
there are different numbers of molecules of different mass in unit mass of aluminium and water (accept different densities) and therefore different amounts of energy will be needed / *OWTTE*; ***[2]***

(c) (i)




general shape (but constant $\theta$ range must be clear); ***[1]***

(ii) $\theta \rightarrow 100\,^{\circ}\mathrm{C}$:
the KE of the molecules is increasing;

$100\,^{\circ}\mathrm{C}$:
when the water starts to change phase, there is no further increase in KE;
the energy goes into increasing the PE of the molecules;
so increasing their separation;
until they are far enough apart to become gas / their molecular bonds are broken / until they are effectively an infinite distance apart / *OWTTE*; ***[5]***

(d) (i) total energy supplied $= 400 \times 600 = 2.4 \times 10^5$ J ; ***[1]***

(ii) energy required to raise temperature of water $= 0.30 \times 80 \times 4.2 \times 10^3 = 1.0 \times 10^5$ J ;
energy available to convert water to steam $= (2.4 - 1.0) \times 10^5 = 1.4 \times 10^5$ J ;
mass of water converted to steam $= \dfrac{(1.4 \times 10^5)}{2.3 \times 10^6} \approx 60\,\text{g}$ ; ***[3]***

(iii) energy is lost to the surroundings *(must specify where the energy is lost)* /
water might bubble out of pan whilst boiling / anything sensible; ***[1 max]***

**B1. Part 2** Radioactivity and nuclear energy levels

(a) (i) time for the activity to halve in value / time for the number of nuclei to transmute to nuclei of another element / *OWTTE*; ***[1]***

(ii) the probability that a nucleus will decay in unit time; ***[1]***

(b) use of $N = N_o e^{-\lambda t}$ with $N = \frac{1}{2} N_o$;

to give $e^{-\lambda T_{\frac{1}{2}}} = \frac{1}{2}$ from which $\lambda T_{\frac{1}{2}} = \ln 2$; ***[2]***

(c) $\lambda = \dfrac{\ln 2}{18} = 0.039\,\mathrm{d}^{-1}$;

substitute into $A = A_o e^{-\lambda t}$ to get $A = 4.5 \times 10^4$ Bq; ***[2]***

(d) (i) mass defect $= 227.0278 - (223.0186 + 4.0026) = 0.0066\,\mathrm{u}$;

$= 6.148\,\mathrm{MeV\,c^{-2}}$;

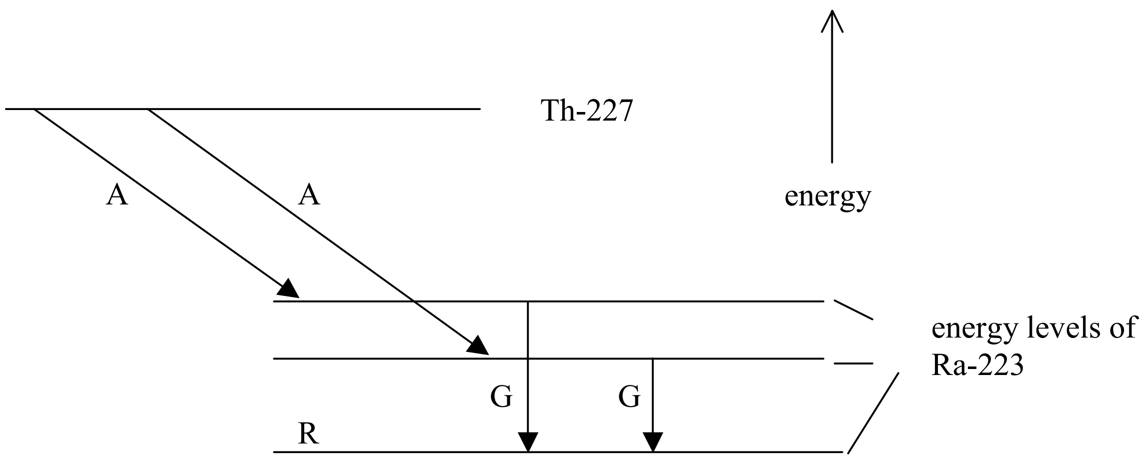
therefore energy of $\gamma = 6.148 - 5.481 = 0.667\,\mathrm{MeV}$; ***[3]***

(ii) use $f = \dfrac{E}{h}$;

$E = 0.667 \times 10^6 \times 1.60 \times 10^{-19}\,\mathrm{J}$;

to give $f = 1.62 \times 10^{20}\,\mathrm{Hz}$; ***[3]***

(e)




(i) two correct A’s; ***[1]***

(ii) two correct G’s; ***[1]***

(iii) correct R; ***[1]***

(f) $5.481 + 0.667 = 6.148\,\mathrm{MeV}$; ***[1]***

**B2. Part 1** Electric circuits

(a) (i) when connected to a 3 V supply, the lamp will be at normal brightness;
and energy is produced in the filament at the rate of 0.6 W;
*Look for the idea that 3 V is the operating voltage and the idea of energy transformation.*
***or***
when connected to a 3 V supply the lamp will be at normal brightness;
and the resistance of the filament is $15\,\Omega$ / the current in the filament is $0.2\,\text{A}$; ***[2 max]***

(ii) $I = \frac{P}{V}$;
to give $I = 0.20\,\text{A}$; ***[2]***

(b) (i) at maximum value, the supply voltage divides between the resistance of the variable resistor, internal resistance and the resistance of the filament;
*i.e. must show the idea of the voltage dividing between the various resistances in the circuit. Do not penalize if internal resistance is not mentioned here.*
at zero resistance, the supply voltage is now divided between the filament resistance and the internal resistance of the supply; ***[2]***

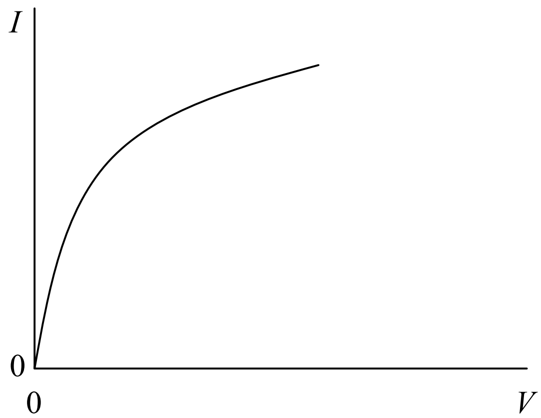
(ii) when resistance of variable resistor is zero, $\text{e.m.f.} = Ir + V_{\text{lamp}}$;
$3.0 = 0.2r + 2.6$;
to give $r = 2.0\,\Omega$; ***[3]***

(c) (i) $3.3\,\Omega$; ***[1]***

(ii) $13\,\Omega$; ***[1]***

(d) at the higher pd, greater current and therefore hotter;
the resistance of a metal increases with increasing temperature;
*OWTTE*; ***[2 max]***

(e)




correct approximate shape (*i.e.* showing decreasing gradient with increasing *V*); ***[1]***

(f) parallel resistance of lamp and YZ is calculated from $\frac{1}{R}=\frac{1}{4}+\frac{1}{12}$;

to give $R = 3.0\,\Omega$;

3.0 V therefore divides between $3.0\,\Omega$ and $12.0\,\Omega$;

to give pd across the lamp $= 0.60\,\text{V}$;

*Give relevant credit if answers go via the currents i.e.*

calculation of total resistance $= 15.0\,\Omega$;

total current $= 0.20\,\text{A}$;

current in lamp $= 0.15\,\text{A}$;

pd across lamp $= 0.15 \times 4 = 0.60\,\text{V}$; ***[4 max]***

**B2. Part 2** Orbiting satellite

(a) the force exerted per unit mass;
on a point mass; ***[2]***
*Accept small mass or particle.*

(b) (i) $E_p = -G\dfrac{Mm}{r}$;

$GM = g_0 R^2$ and substitute to get $E_p = -\dfrac{mg_0 R^2}{r}$ ; ***[2]***

(ii) $F_{cent} = \dfrac{mv^2}{r}$

$= G\dfrac{Mm}{r^2}$;

to get $mv^2 = G\dfrac{Mm}{r}$;

so $\frac{1}{2}mv^2 = E_k = \dfrac{mg_0 R^2}{2r}\left(= \frac{1}{2}\left|E_P\right|\right)$; ***[3]***

(c) (i) recognize that PE at surface of the Earth $= mg_0 R$;

therefore PE of satellite in orbit $= \dfrac{9.6\times10^{10}\times6.4\times10^{6}}{4.3\times10^{7}} = 1.4\times10^{10}$ J ; ***[2]***

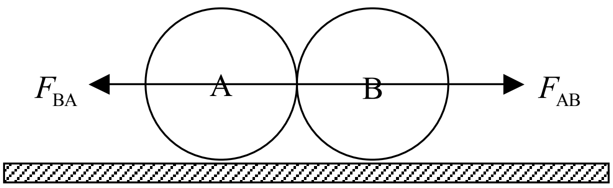
(ii) $\Delta$PE in moving from surface to orbit $= (9.6-1.4)\times10^{10} = 8.2\times10^{10}$ J ;
KE $= \frac{1}{2}(1.4\times10^{10}) = 0.7\times10^{10}$ J ;
so minimum energy required $= \Delta\text{PE} + \text{KE} = 8.9\times10^{10}$ J ; ***[3]***
*Award **[2 max]** if answers forget the ΔPE and use* $E_{tot} = \dfrac{3}{2}E_p$.
($E_{tot} = 2.1\times10^{10}$ *J*).

**B3. Part 1** Conservation of momentum and energy

(a) when two bodies A and B interact the force that A exerts on B is equal and opposite to the force that B exerts on A;
***or***
when a force acts on a body, an equal an opposite force acts on another body somewhere in the universe; ***[1 max]***
*Award **[0]** for "action and reaction are equal and opposite" unless they explain what is meant by the terms.*

(b) if the net external force acting on a system is zero;
then the total momentum of the system is constant (or in any one direction, is constant); ***[2]***
*To achieve **[2]** answers should mention forces and should show what is meant by conserved. Award **[1 max]** for a definition such as "for a system of colliding bodies, the momentum is constant" and **[0]** for "a system of colliding bodies, momentum is conserved".*

(c)




arrows of equal length;
acting through centre of spheres;
correct labelling consistent with correct direction; ***[3 max]***

(d) (i) *Ball B*:
change in momentum $= Mv_B$;
hence $F_{AB}\Delta t = Mv_B$; ***[2]***

(ii) *Ball A*:
change in momentum $= M(v_A - V)$;
hence from Newton 2, $F_{BA}\Delta t = M(v_A - V)$; ***[2]***

(e) from Newton 3, $F_{AB} + F_{BA} = 0$ ***or*** $F_{AB} = -F_{BA}$;
therefore $-M(v_A - V) = Mv_B$;
therefore $MV = Mv_B + Mv_A$;
that is, momentum before equals momentum after collision such that the net change in momentum is zero (unchanged) / *OWTTE*; ***[4]***
*Some statement is required to get the fourth mark i.e. an interpretation of the maths result.*

(f) from conservation of momentum $V = v_B + v_A$ ;
from conservation of energy $V^2 = v_B{}^2 + v_A{}^2$ ;
if $v_A = 0$, then both these show that $v_B = V$ ;
***or***
from conservation of momentum $V = v_B + v_A$ ;
from conservation of energy $V^2 = v_B{}^2 + v_A{}^2$ ;
so, $V^2 = (v_B + v_A)^2 = v_B{}^2 + v_A{}^2 + 2v_A v_B$ therefore $v_A$ has to be zero; ***[3 max]***
*Answers must show that effectively, the only way that both momentum and energy conservation can be satisfied is that ball A comes to rest and ball B moves off with speed V.*

**B3. Part 2** Electromagnetic induction

(a) move the ring over the end of the magnet / *OWTTE*; *[1]*
*i.e. magnet stationary, ring moved.*

(b)

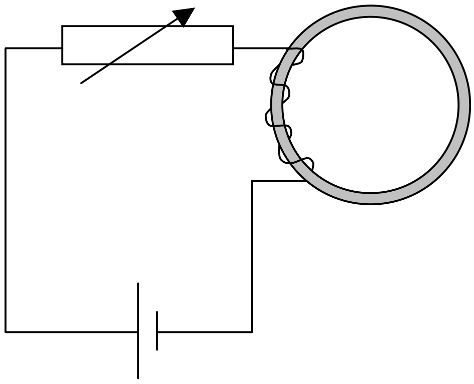
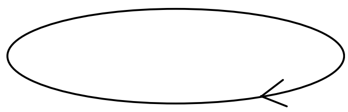


diagram showing wire wrapped around part of the ring;
and appropriate connections to battery and variable resistor;
as the current is changed by altering the value of the resistance;
a current is induced in the ring; *[4]*
*Mark diagram and description together – look for any sensible description of the production of transformer induced currents.*

(c) (i) the emf induced in the ring;
is equal/proportional to the rate of change of magnetic flux linking the ring; *[2]*

(ii)



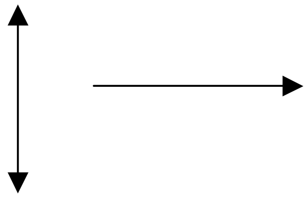
clockwise;
Lenz's law: induced current is such as to oppose the change / *OWTTE*;
current in this direction induces a field in the opposite direction to the changing field / *OWTTE*; *[3]*

(iii) $\text{area} = 3.14 \times (1.2)^2 \times 10^{-2} = 4.5 \times 10^{-2}\ \text{m}^2$ ;
$\text{rate of flux change} = 4.5 \times 10^{-2}\ \text{m}^2 \times 1.8 \times 10^{-3} = \text{emf} = 8.1 \times 10^{-5}\ \text{V}$ ;
$\text{current} = \dfrac{(8.1 \times 10^{-5})}{1.5 \times 10^{-2}} = 5.4\,\text{mA}$ ; *[3]*

**B4. Part 1** Wave properties and interference

Wave properties

(a) (i)

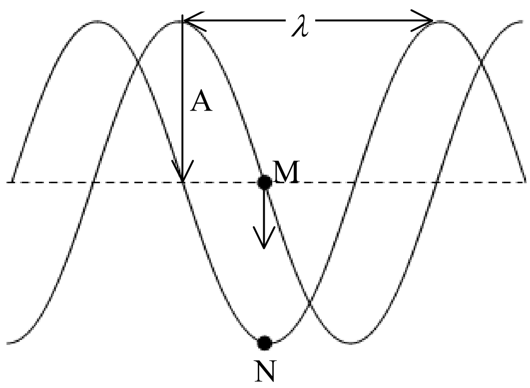


*[1]*

(ii)

*[1]*

(b)




(i) downwards; *[1]*

(ii) correct marking of A; *[1]*

(iii) correct marking of $\lambda$; *[1]*

(iv) +ve sine curve;
correct position of N; *[2]*
*Watch for ecf from (i).*

(c) (i) $f = \dfrac{v}{\lambda}$ to give 2.0 Hz; *[1]*

(ii) $T = 0.5\,\text{s}$;

$s = \dfrac{vT}{4} = 1.25\,(1.3)\,\text{cm}$;

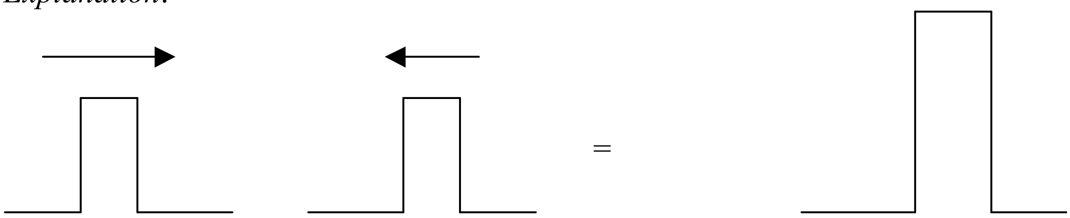
***or***

in $\dfrac{T}{4}$ wave moves forward $\frac{1}{4}\lambda$;

$= \dfrac{5}{4} = 1.25\,(1.3)\,\text{cm}$; ***[2 max]***

(d) *Principle of superposition*:
when two or more waves overlap, the resultant displacement at any point;
is the sum of the displacements due to each wave separately / *OWTTE*;
*Award **[2 max]** for an answer that shows a clear understanding of the principle, **[1]** for a reasonable understanding and **[0]** for a weak answer.*

*Explanation*:



suitable diagram;
when two +ve pulses (or two wave crests) overlap, they reinforce / *OWTTE*; ***[4]***
*Any situation where resultant displacement looks as though it is the sum of the individual displacements. Mark the description of the principle and the description of constructive interference together.*

(e) (i) $S_2X = n\lambda$;
where $n = 0,\ 1,\ 2$; *(Accept "n is an integer")* ***[2]***

(ii) $\sin\theta \approx \theta$;
therefore $\theta = \dfrac{S_2X}{d}$; ***[2]***

(iii) $\phi = \dfrac{y_n}{D}$; ***[1]***
*Award the small angle approximation mark anywhere in (i) or (ii).*

(f) (i) $\theta = \dfrac{S_2X}{d} = \dfrac{n\lambda}{d}$ *so* $\lambda = \dfrac{d\theta}{n}$;
substitute to get $\lambda = 4.73\times10^{-7}$ m; ***[2]***

(ii) $\theta$ and $\phi$ are small;
therefore $\dfrac{\lambda}{d} = \dfrac{y}{D}$;
so $y = \dfrac{D\lambda}{d} = 0.510\,\text{mm}$; ***[3]***

**B4. Part 2** Thermodynamic processes

(a) isothermal: takes place at constant temperature;
adiabatic: no energy exchange between gas and surroundings; ***[2]***

(b) (i) neither; ***[1]***

(ii) $\Delta W = P\Delta V = 1.2\times10^{5}\times0.05 = 6.0\times10^{3}$ J ; ***[1]***

(iii) recognize to use $\Delta Q = \Delta U + \Delta W$ ;
to give $\Delta U = 2.0\times10^{3}$ J ; ***[2]***