1. (a) statement that gravitational mass and inertial mass have the same numerical value;
understanding of what gravitational mass means;
e.g. "a quantity that determines the gravitational force on the object"
understanding of what inertial mass means;
e.g. "a quantity that determines the acceleration of the object" 3 max

(b) (i) the acceleration = gradient of first section of graph;
acceleration = 0.80 / 0.50 = 1.6 m s^{-2}; 2 max
Accept bald correct answer for full marks.

(ii) the total distance travelled by the lift = area under graph;
distance = (11 × 0.80) + (0.50 × 0.80) = 8.8 + 0.4 = 9.2 m; 2 max
Accept bald correct answer for full marks.

(iii) the work done = P.E. gained (= force × distance);
work done = 2500 × 9.2 = 23000 J = 23 kJ; 2 max
Accept bald correct answer for full marks.

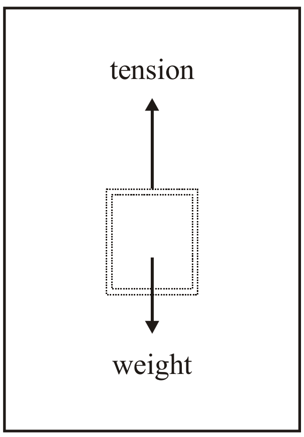
(iv) correct substitution into power = work done / time taken
= 23000 / 12;
= 1916 W
= 1.9 kW; 2 max

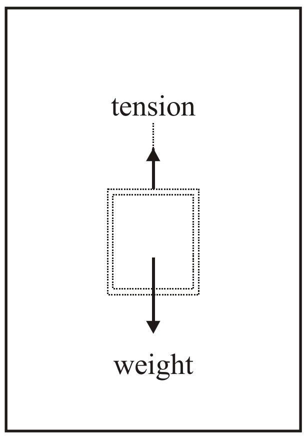
(v) correct substitution into efficiency = power out / power in
= 1.9 / 5.0;
= 0.38 = 38 %; 2 max

(c) graphs should show curving or "shoulders" at the changes;
since acceleration must be finite / speed cannot change instantaneously / *OWTTE*; 2 max

(d) *Mark part (i) and (ii) together.*
weight arrow the same in both diagrams;
magnitude of tension (size of arrow) **equal to** weight in (i);
magnitude of tension (size of arrow) **less than** weight in (ii);

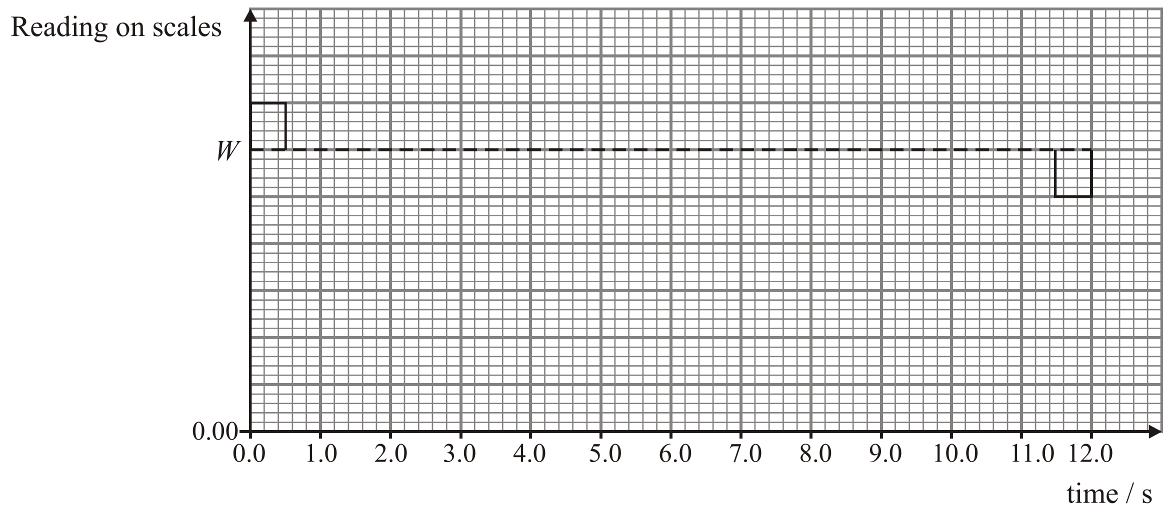
(i) 0.50 to 11.50 s (ii) 11.50 to 12.00 s





3 max

(e) a constant value **greater** than W from 0.00 to 0.50 s;
a constant value **equal** to W from 0.50 to 11.50 s;
a constant value **less** than W from 11.50 to 12.00 s;



3 max

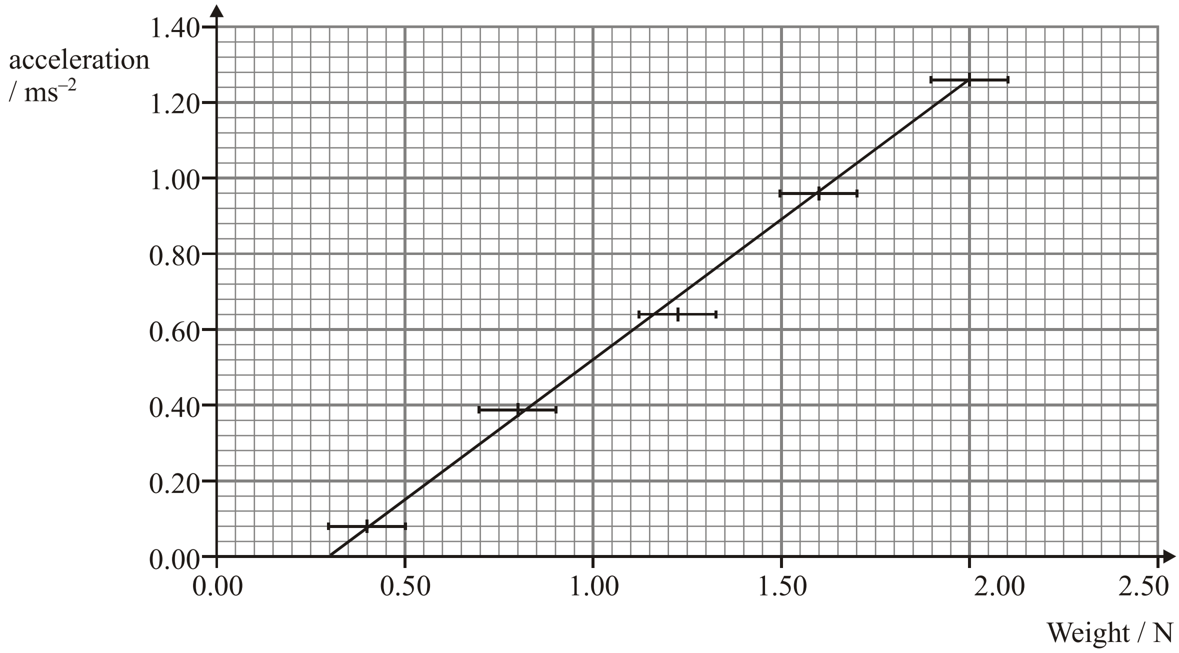
(f) ***[1]** for each appropriate and valid point. Essentially **[2]** for journey up and **[2]** for journey down. Some explanation or justification is required for full marks e.g.*
the law of conservation of energy does apply to round trip;
energy is all dissipated into heat and sound;
on the way up, most electrical energy converted into g.P.E., initially some electrical energy is converted into K.E;
on the way down electrical energy does work "breaking" lift some (not all) g.P.E. is converted into K.E.; 4 max

Reject answers that imply that P.E. converts into K.E. as lift falls.

[25]

2. (a) a straight line; through the origin; 2 max

(b) any straight line; that fits within ALL the error bars; 2 max



(c) (i) a *systematic* error is when every data point deviates from the "correct" value;
by the same fixed amount as seen by intercept on graph / *OWTTE*; 2 max

Accept answers that explain by giving an example of a possible systematic error e.g. friction.

(ii) 0.3 N; 1

Accept 0.25 N → 0.35 N. ***N.B.*** *Watch for use of wrong axis!*

(iii) realization that mass = $(\text{gradient})^{-1}$;

Award this mark for full Newton II equation (with friction)

to give mass = 1.4 kg *(Accept 1.2 kg → 1.6 kg.)*; 2 max

Use of F = ma for 1 data point receives ***[0]*** *(unless candidate's line is through origin).*

Watch for ecf from candidate's own line.

[9]

3. (a) if the total external force acting upon a system is zero / for an isolated system;

the momentum of the system is constant; 2

Award ***[1 max]*** *if the answer is in terms of collisions.*

(b) 131 g of xenon contains 6.02×10^{23} / N_A atoms;

mass of 1 atom = $\frac{131}{6.02 \times 10^{23}} = 2.2 \times 10^{-22} = 2.2 \times 10^{-25}$ kg;

or

mass of nucleon 1.66×10^{-27} kg;

mass of xenon atom = $131 \times 1.66 \times 10^{-27}$ kg = 2.2×10^{-25} kg; 2

(c) time = $1.5 \times 3.2 \times 10^{7} = 4.8 \times 10^{7}$ s;

no of atoms per second = $\frac{81}{2.2 \times 10^{-25} \times 4.8 \times 10^{7}} = 7.7 \times 10^{18}\ \text{s}^{-1}$;

or

no of atoms in original mass = $\frac{81}{2.2 \times 10^{-25}} = 3.7 \times 10^{26}$;

time = $\frac{3.7 \times 10^{26}}{7.7 \times 10^{18}} = 4.8 \times 10^{7}$ s = 1.5 years; 2

(d) rate of change of momentum of the xenon atoms

$= 7.7 \times 10^{18} \times 2.2 \times 10^{-25} \times 3.0 \times 10^{4}$;

$= 5.1 \times 10^{-2}$ N;

= mass × acceleration;

where mass = (540 + 81) kg;

to give acceleration of spaceship = $\frac{5.1 \times 10^{-2}}{6.2 \times 10^{2}}$;

$= (8.2 \times 10^{-5}\ \text{m s}^{-2})$ 5

Accept if mass of fuel omitted (= $9.4 \times 10^{-5}\ \text{m s}^{-2}$*).*

(e) $a = \frac{F}{m}$;

since m is <u>decreasing</u> with time, then a will be <u>increasing</u> with time; 2

(f) change in speed = area under graph;

$= (8.2 \times 4.8) \times 10^2 + \frac{1}{2}(4.8 \times 1.3) \times 10^2$;

final speed $= (8.2 \times 4.8) \times 10^2 + \frac{1}{2}(4.8 \times 1.3) \times 10^2 + 1.2 \times 10^3$;

5.4×10^3 m s^{-1};

or

use of $v = u + at$

$u = 1.2 \times 10^3$ m s^{-1};

average acceleration from the graph $= \frac{1}{2}(8.2 + 9.45) \times 10^{-5}$;

$= 8.8 \times 10^5$ m s^{-2};

final speed $= 4.8 \times 10^7 \times 8.8 \times 10^{-5} + 1.2 \times 10^3 = 5.4 \times 10^3$ m s^{-1}; 4

(g) $t = \frac{s}{v} = \frac{4.7\times 10^{11}}{5.4\times 10^3} = 8.7 \times 10^7$ s;

so total time $4.8 \times 10^7 + 8.7 \times 10^7$ s $\approx$ 4.2y ; 2

[19]

4. (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 and opposite force acts on another body somewhere in the universe; 1 max

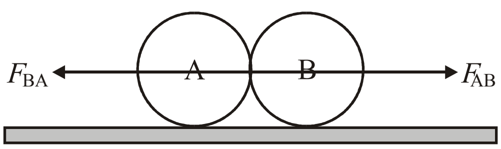
*Award **[0]** for "action and reaction are equal and opposite" unless they explain what is meant by the terms.*

(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

(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 $-M(v_A - V) = Mv$;
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, $V^2 = (v_B + v_A) = v_B^2 + v_A^2 + 2v_Av_B$ 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.

[17]

5. (a) mass × velocity; 1

(b) (i) momentum before = 800 × 5 = 4 000 N s;
momentum after = 2 000v;
conservation of momentum gives $v = 2.0$ m s^{-1}; 3

(ii) KE before = 400 × 25 = 10 000 J KE after = 1 000 × 4 = 4 000 J;
loss in KE = 6 000 J; 2

(c) transformed/changed into;
heat (internal energy) (and sound); 2

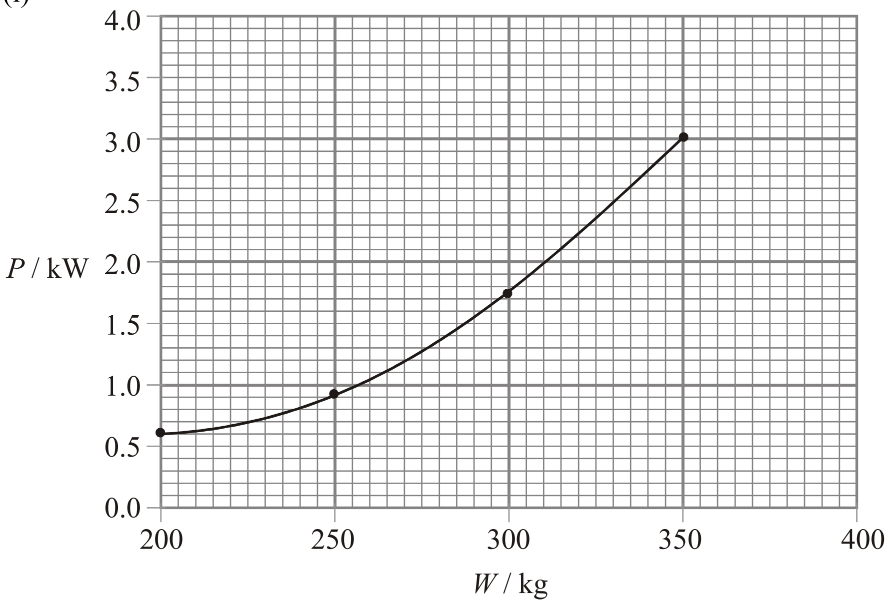
Do not accept "deformation of trucks".

[8]

6. (a) (i) 2.0 kW; (± 0.10 kW) 1

(ii) $F = \frac{P}{v}$;
= 1000 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 ±0.2 kW.

line of best fit; 6

(ii) 2.6 kW; (±0.1 kW) *(watch for ecf)* 1

[10]

7. (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 m;
gain in PE = mgh = 700 × 19 = 1.3 × 10^4 J (1.4 × 10^4 J); 2

(ii) 48 × 1.3 × 10^4 J = 6.2 × 10^5 J (6.7 × 10^4 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 = $\frac{6.2\times 10^5}{60}$ = 10 kW (11 kW);
$Eff = \frac{P_{out}}{P_{in}}$, $P_{in} = \frac{P_{out}}{Eff}$;
P_{in} = 14 kW (16 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.

[9]

8. (a) momentum of object = 2 × 10^3 × 6.0;

momentum after collision = $2.4 \times 10^3 \times v$;
use conservation of momentum, $2 \times 10^3 \times 6.0 = 2.4 \times 10^3 \times v$;
to get $v = 5.0 \text{ m s}^{-1}$; 4

*Award **[2 max]** for mass after collision = 400 kg and $v = 30 \text{ m s}^{-1}$.*

(b) KE of object and bar + change in PE = $1.2 \times 10^3 \times 25 + 2.4 \times 10^3 \times 10 \times 0.7533$;
use $\Delta E = Fd$, $4.8 \times 10^4 = F \times 0.75$;
to give $F = 64$ kN;

*Award **[2 max]** if PE missed F = 40 kN.*

or

$a = \frac{v^2}{2s}$;
$F - mg = ma$;
to give $F = 64$kN; 3

*Award **[2 max]** if mg missed.*

[7]