Solution 1

(10 marks)

(a) On the diagram above, draw an arrow to show the direction of acceleration of Clown 1's centre of mass at the point of maximum height. (1 mark)

Description	Marks
Arrow should be pointed downwards at the top point of the parabola. Slightly to the left is acceptable, but not to the right.	1
Total	**1**

(b) Describe qualitatively **two** effects of air resistance on projectile motion in this case. (2 marks)

Description	Marks
Clown 1 will not reach maximum height	1
Clown 1's horizontal velocity will not be constant and decrease over time. Range decreases or horizontal distance is less.	1
Total	**2**

(c) Show by calculation that the total time Clown 1 is in the air is just over 1.1 s. Ignore air resistance. (4 marks)

Description		Marks
$v_v = v \cos \theta = 7 \cos 15^0$ $= 6.76 \text{ m s}^{-1}$		1–2
$s = ut + ½at^2$ $1.5 = 6.76t + ½(-9.8)t^2$	Or $s = ut + ½at^2$ $s = 6.76(1.1) + ½(-9.8)(1.1)^2$	1
t= 1.102 s (just over)	s=1.507 m (not quite to 1.5m)	1
	Total	**4**

(d) Determine the initial horizontal distance between Clown 1 and Clown 2. Ignore air resistance. Show **all** workings. (3 marks)

Description	Marks
$v_h = v \sin \theta = 7 \sin 15°$ $= 1.81 \text{ m s}^{-1}$	1–2
$s_h = v_h \times t = 1.81 \times 1.10$ $s_h = 1.99 \text{ m}$	1
Total	**3**

Solution 2

(4 marks)

When a satellite is launched it is placed in an initial circular orbit around the Earth. Later some small jets on board the satellite will fire compressed gas for a set period of time to move it to the precise final circular orbit required. These gas jets point backward relative to the satellite's motion only and **not** toward or away from the Earth.

How can backward facing gas jets be used to raise the satellite to a higher final circular orbit?

Description	Marks
The gas jets increase speed and E_k	1
The E_k is converted to E_p	1
This results in a higher orbit	1
This higher orbit is at a slower speed ($r \propto 1/v^2$)	1
Total	**4**

Solution 3

(13 marks)

(a) The vehicle moves between Position I and Position II in 3.00 s, driven by a 3.00 V, 20.0 mA motor. The energy conversion efficiency of the vehicle is 70.0% and the mass of the vehicle is 120.0 g. You may assume that air resistance and frictional forces acting on the vehicle are negligible.

Show that the velocity of the vehicle at Position II is 1.45 m s^{-1}. (3 marks)

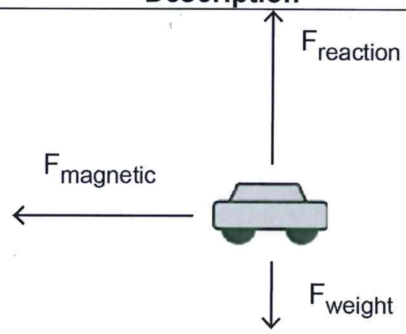
Description	Marks
$P=VI = 3 \times 20\times10^{-3} = 60\times10^{-3}$ J s^{-1}	1
For 3s at 70% efficient energy supplied = $60 \times 10^{-3}\times3.00\times0.70 = 0.126$ J	1
$E_K = ½ mv^2$ so $v= \sqrt{(2\times0.126)/0.12} = 1.45$ m s^{-1}	1
Total	**3**

(b) The motor is switched off at Position II and the vehicle continues to move from Position II to Position V, and then back through Position IV. The metal rails are 0.170 m apart and a magnetic field, B, is arranged so that the field strength acting anywhere along the rails between Position IV and Position V is perpendicular to the rails, and has magnitude 0.550 T .

Calculate the induced EMF when the vehicle is at position IV. (4 marks)

Description	Marks
Gain in energy due to fall = mgh = $0.12\times9.8\times0.75 = 0.882$ J	1
New E_k. = 0.882+0.126 = 1.008 J	1
$v= \sqrt{(2\times1.008)/0.12} = 4.1$ m s^{-1} $\quad E_K = ½ mv^2 \quad v = \sqrt{2E_K / m}$	1
EMF $=\ell vB = 0.170 \times 4.1 \times 0.55 = 0.383$ V	1
Total	**4**

(c) Draw a labelled free body diagram to show the forces acting on the vehicle at Position IV. (3 marks)

<table>
<tr><th>Description</th><th>Marks</th></tr>
<tr><td>

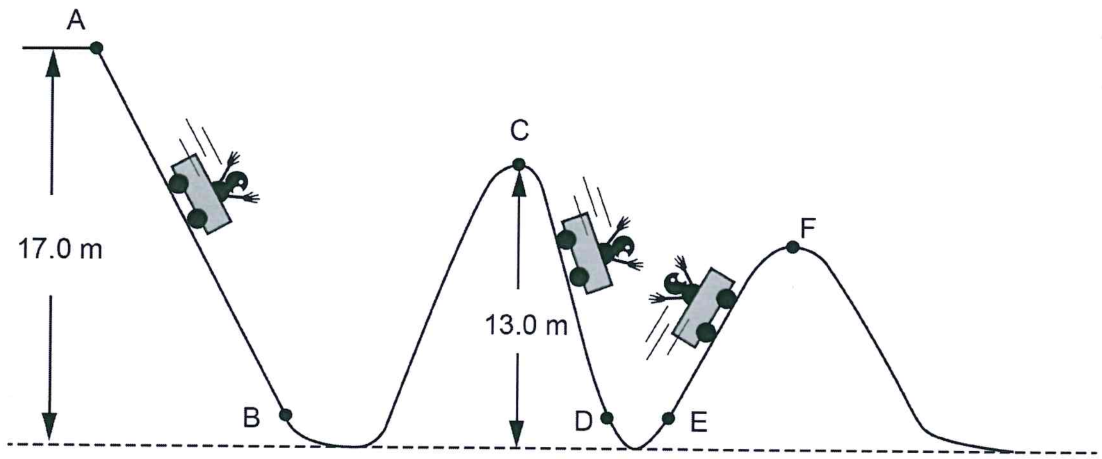
3 marks, take 1 off for each force missing or each ‘imaginative’ force
Note: when car is stationary $F_{reaction}$ = weight when car is moving then $F_{reaction} = mg + mv^2/r$</td><td>1–3</td></tr>
<tr><td>Total</td><td>3</td></tr>
</table>

Note: $F_{reaction}$ must be greater than F_{weight}.
Note: $F_{magnetic}$ can be in the opposite direction to that shown.

Solution 4

(14 marks)

A roller-coaster is 17.0 m high at its highest point, the release point A. The diagram below is a simple representation of the first part of the ride.



(a) The car is released from a stationary position at A and has no independent locomotion. Indicate the direction of the car's acceleration in each of the following regions by circling the correct answer. (3 marks)

(i)	A to B	up slope	down slope
(ii)	C to D	up slope	down slope
(iii)	E to F	up slope	down slope

Description	Marks
down slope	1
down slope	1
down slope	1
	Total 3

(b) If the length of track between A and B is 21.0 m and the car is released from rest at A and reaches a velocity of 18.5 m s^{-1} at B, what is the magnitude of the acceleration it experiences between A and B? (4 marks)

Description	Marks
$a = (v^2 - u^2)/2s$	1
$= 18.5^2/2\times21$	1
$a = 8.15$ m s^{-2}	1
Correct units	1
	Total 4

(c) If the car **just** makes it to point C, what proportion (fraction) of the energy has been lost as heat? (3 marks)

Description	Marks
E_{GP} proportional to h	1
Change in h = 17 – 13 = 4 m	1
percentage lost = $\frac{4}{17}$ = (accept 23.5% or 0.235)	1
	Total 3

Solution 4 cont

(d) In relation to this energy lost as heat, how is it generated and where does it go? (2 marks)

Description	Marks
Friction generates heat → main cause of energy loss	1
Very small amount to sound, light (sparks?) and wear (deformation) Heat lost to tracks and air.	1
	Total 2

(e) Will the velocity of the car be greater at point B or point D? Give a reason for your answer. (2 marks)

Description	Marks
Will be greatest at B	1
Earlier in the ride = less heat loss therefore same height E_K is greater at B	1
	Total 2

Solution 5

(3 marks)

The engine of a toy crane lifts a small block of wood of mass 0.130 kg to a height of 0.700 m at a constant velocity. Calculate the work done in joules to achieve this.

Description	Marks
Work = mgh	1
Work = 0.130 × 9.8 × 0.700	1
Work = 0.892 J	1
Total	**3**

Solution 6

(3 marks)

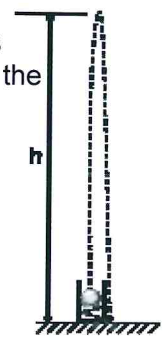
On a hot day, Sam stepped off a bridge into the water below. Using the idea of conservation of energy, calculate Sam's speed, in metres per second, when he reached the water 3.40 m below. Show **all** workings.

Description	Marks
E_p lost = E_k gained mgh = ½ mv^2 m cancels gh = ½ v^2 $v = \sqrt{2gh}$ $v = \sqrt{(2 \times 9.8 \times 3.40)}$	1–2
v = 8.16 or 8.2 or 8.1	1
Total	**3**

Solution 7

(16 marks)

A vertical cylinder contains a spring. A ball sits on the top of the spring, as shown in the diagram. The length of the cylinder is 0.500 m and the uncompressed length of the spring is 0.400 m. The spring is then squashed down to 0.100 m and released. The kinetic energy of the ball (m = 0.500 kg) when it leaves the spring is 100 J.



(a) Calculate the average force that the spring exerts on the ball to launch it. (3 marks)

Description	Marks
(a) $W = Fs \Rightarrow F = \frac{W}{s}$	1
$= \frac{100}{0.300}$	1
F = 333N upward	1
	Total 3

(b) Calculate the velocity of the object when it leaves the top of the spring. (2 marks)

Description	Marks
$E_k = ½ mv_0^2$; $100J = ½ \times 0.5 \times v_0^2$;	1
$v_0 = 20\ m\ s^{-1}$ upward	1
	Total 2

(c) Determine the height, h, the object reaches above the ground. (4 marks)

Description	Marks
$v^2 = u_0^2 + 2as$; or $E_k = E_p = m \times g \times s$;	1
$s = 20^2/(2 \times 9.8)$ or $s = \frac{100}{4.9}$	1
s = 20.4m	1
h = s + 0.400 = 20.8 m above the ground	1
	Total 4

(d) Determine the acceleration of the object at the highest point. (1 mark)

Description	Marks
$a = g = -9.8\ m\ s^{-2}$ down	1
	Total 1

(e) Determine the final velocity of the object, the instant before it hits the ground. (3 marks)

Description	Marks
$v_f^2 = u_0^2 + 2ah$ $r^2 = u^2 + 2 a 5$	1
$v_f^2 = 0 + 2(9.8)\times(20.4+0.40)$;	1
$v_f = -20.2\ m\ s^{-1}$ down (-1 if no direction)	1
	Total 3

(f) Calculate the time needed for the object to reach the ground from the highest point. (3 marks)

Description	Marks
$v_f = u_0 + at$;	1
$t_2 = -20.2/-9.8$	1
= 2.06 s	1
	Total 3