Q1.

2 (a) (i) distance from a (fixed) point M1
in a specified direction A1
(Allow 1 mark for 'distance in a given direction')

(ii) (displacement from start is zero if) car at its starting position ..... B1 [3]

(b) (i)1 $v^2 = u^2 + 2as$
$28^2 = 2 \times a \times 450$ (use of component of 450 scores no marks) C1
$a = 0.87 \text{ m s}^{-2}$ .... A1 [2]
(-1 for 1 sig. fig. but once only in the question)

(i)2 $v = u + at$ or any appropriate equation
$28 = 0.87t$ or appropriate substitution C1
$t = 32$ s .... A1 [2]

(i)3 $E_k = ½mv^2$ C1
$= ½ \times 800 \times 28^2$
$= 3.14 \times 10^5$ J .... A1 [2]

(i)4 $E_p = mgh$ C1
$= 800 \times 9.8 \times 450 \sin 5$ C1
$= 3.07 \times 10^5$ J .... A1 [3]

(ii) power = energy/time C1
$= (6.21 \times 10^5)/32.2$ C1
$= 1.93 \times 10^4$ W .... A1 [3]
(power = Fv with $F = mg \sin\theta$ scores no marks)

(iii) some work also done against friction forces M1
location of frictional forces identified .... A1 [2]

(allow reasonable alternatives)

Q2.

5	**(a)**	**(i)**	distance = $2\pi nr$	B1	
		(ii)	work done = $F \times 2\pi nr$ *(accept e.c.f.)*	B1	**[2]**
	(b)		total work done = $2 \times F \times 2\pi nr$	B1	
			but torque $T = 2Fr$	B1	
			hence work done = $T \times 2\pi n$	A0	**[2]**
	(c)		power = work done/time (= 470 x 2π x 2400)/60)		
			$= 1.2 \times 10^5$ W	A1	**[2]**
			Total		**[6]**

Q3.

3	(a) (i)	$\Delta E_p = mg\Delta h$	C1	
		$= 0.602 \times 9.8 \times 0.086$		
		$= 0.51$ J	A1	[2]
		(do not allow g = 10, m = 0.600 or answer 0.50 J)		
	(ii)	$v^2 = (2gh =)\ 2 \times 9.8 \times 0.086$ or $(2 \times 0.51)/0.602$	M1	
		$v = 1.3$ (m s^{-1})	A0	[1]
	(b)	$2 \times V = 602 \times 1.3$ (allow 600)	C1	
		$V = 390$ m s^{-1}	A1	[2]
	(c) (i)	$E_k = ½mv^2$	C1	
		$= ½ \times 0.002 \times 390^2$		
		= 152 J or 153 J or 150 J	A1	[2]
	(ii)	E_k not the same/changes		
		or E_k before impact > E_k after/E_p after	M1	
		so must be inelastic collision	A1	[2]
		(allow 1 mark for 'bullet embeds itself in block' etc.)		

Q4.

4	(a) (i)	(change in) potential energy = mgh	C1	
		$= 0.056 \times 9.8 \times 16$		
		= 8.78 J (*allow 8.8*)	A1	[2]
	(ii)	(initial) kinetic energy = $½mv^2$	C1	
		$= ½ \times 0.056 \times 18^2$		
		= 9.07 J (*allow 9.1*)	C1	
		total kinetic energy = 8.78 + 9.07 = 17.9 J	A1	[3]
	(b)	kinetic energy = $½mv^2$		
		$17.9 = ½ \times 0.056 \times v^2$ and $v = 25(.3)$ m s^{-1}	B1	[1]
	(c)	horizontal velocity = 18 m s^{-1}	B1	[1]
	(d) (i)	correct shape of diagram		
		(two sides of right-angled triangle with correct orientation)	B1	
	(ii)	angle = 41° → 48° (allow trig. solution based on diagram)	A2	[3]
		(*for angle 38° → 41° or 48° → 51°, allow 1 mark*)		

Q5.

3 **(a)** *either* energy (stored)/work done represented by area under graph
or energy = average force × extension B1
energy = ½ × 180 × 4.0 × 10^{-2} C1
= 3.6 J .... A1 [3]

(b) **(i)** *either* momentum before release is zero M1
so sum of momenta (of trolleys) after release is zero A1
or force = rate of change of momentum (M1)
force on trolleys equal and opposite (A1)
or impulse = change in momentum (M1)
impulse on each equal and opposite (A1) [2]

(ii) **1** $M_1V_1 = M_2V_2$ .... B1 [1]

2 $E = ½ M_1V_1^2 + ½ M_2V_2^2$ .... B1 [1]

(iii) **1** $E_K = ½mv^2$ and $p = mv$ combined to give M1
$E_K = p^2 / 2m$ .... A0 [1]

2 m smaller, E_K is larger because p is the same/constant M1
so trolley B .... A0 [1]

Q6.

2 **(a)** work done is the force × the distance moved / displacement in the direction of the force
or
work is done when a force moves in the direction of the force B1 [1]

(b) component of weight = 850 × 9.81 × sin 7.5° C1
= 1090 N A1 [2]
(*use of incorrect trigonometric function, 0/2*)

(c) **(i)** ΣF = 4600 – 1090 = (3510) M1
deceleration = 3510 / 850 A1
= 4.1 m s^{-2} A0 [2]

(ii) $v^2 = u^2 + 2as$
0 = 25^2 + 2 × – 4.1 × s C1
s = 625 / 8.2
= 76 m A1 [2]
(*allow full credit for calculation of time (6.05 s) & then s*)

(iii) **1.** kinetic energy = ½ mv^2 C1
= 0.5 × 850 × 25^2
= 2.7 × 10^5 J A1 [2]

2. work done = 4600 × 75.7
= 3.5 × 10^5 J A1 [1]

(iv) difference is the loss in potential energy (*owtte*) B1 [1]

Q7.

3	**(a)** evidence of use of area below the line	B1	
	distance = 39 m (*allow* ±*0.5 m*)	A2	[3]
	(*if > ±0.5 m but ≤ 1.0 m, then allow 1 mark*)		
	(b) (i) 1 $E_K = \frac{1}{2}mv^2$	C1	
	$\Delta E_K = \frac{1}{2} \times 92 \times (6^2 - 3^2)$		
	= 1240 J	A1	[2]
	2 $E_P = mgh$	C1	
	$\Delta E_P = 92 \times 9.8 \times 1.3$		
	= 1170 J	A1	[2]
	(ii) $E = Pt$	C1	
	$E = 75 \times 8$		
	= 600 J	A1	[2]
	(c) (i) energy = (1240 + 600) – 1170	M1	
	= 670 J	A0	[1]
	(ii) force = 670/39 = 17 N	A1	[1]
	(d) frictional forces include air resistance	B1	
	air resistance decreases with decrease of speed	B1	[2]

Q8.

3	**(a) (i)** work done equals force × distance moved / displacement in the direction of the force	B1	[1]
	(ii) power is the rate of doing work / work done per unit time	B1	[1]
	(b) (i) kinetic energy $= \frac{1}{2} mv^2$	C1	
	$= 0.5 \times 600\ (9.5)^2$	C1	
	= 27075 (J) = 27 kJ	A1	[3]
	(ii) potential energy $= mgh$		
	$= 600 \times 9.81 \times 4.1$	M1	
	= 24132 (J)	A1	
	= 24 kJ	A0	[2]
	(iii) work done = 27 – 24 = 3.0 kJ	A1	[1]
	(iv) resistive force = 3000 / 8.2 (distance along slope = 4.1 / sin 30°)	C1	
	= 366 N	A1	[2]

Q9.

2 **(a)** **(i)** $v^2 = u^2 + 2as$
$= (8.4)^2 + 2 \times 9.81 \times 5$ — C1
$= 12.99\ \text{m s}^{-1}$ *(allow 13 to 2 s.f. but not 12.9)* — A1 [2]

(ii) $t = (v - u) / a$ or $s = ut + ½at^2$
$= (12.99 - 8.4) / 9.81$ or $5 = 8.4t + ½ \times 9.81t^2$ — M1
$t = 0.468\ \text{s}$ — A0 [1]

(b) reasonable shape — M1
suitable scale — A1
correctly plotted 1st and last points at (0,8.4) and (0.88 – 0.96,0)
with non-vertical line at 0.47 s — A1 [3]

(c) **(i)** **1.** kinetic energy at end is zero so $\Delta KE = ½\,mv^2$ or $\Delta KE = ½\,mu^2 - ½\,mv^2$ — C1
$= ½ \times 0.05 \times (8.4)^2$
$= (-)\ 1.8\ \text{J}$ — A1 [2]

2. final maximum height = $(4.2)^2 / (2 \times 9.8) = (0.9\ (\text{m}))$
change in PE = $mgh_2 - mgh_1$ — C1
$= 0.05 \times 9.8 \times (0.9 - 5)$ — C1
$= (-)\ 2.0\ \text{J}$ — A1 [3]

(ii) change is – 3.8 (J) — B1
energy lost to ground (on impact) / energy of deformation of the ball / thermal energy in ball — B1 [2]

Q10.

3 **(a)** loss in potential energy due to decrease in height (as P.E. = mgh) — (B1)
gain in kinetic energy due to increase in speed (as K.E. = $½\,mv^2$) — (B1)
special case 'as PE decreases KE increases' (1/2)
increase in thermal energy due to work done against air resistance — (B1)
loss in P.E. equals gain in K.E. and thermal energy — (B1)
max. 3 [3]

(b) **(i)** kinetic energy $= ½\,mv^2$ — C1
$= ½ \times 0.150 \times (25)^2$ — C1
$= 46.875 = 47\ \text{J}$ — A1 [3]

(ii) **1.** potential energy (= mgh) = $0.150 \times 9.81 \times 21$ — C1
loss = KE – mgh = 46.875 – (30.9) — C1
= 15.97 = 16 J — A1 [3]

2. work done = 16 J
work done = force × distance — C1
$F = 16 / 21 = 0.76\ \text{N}$ — A1 [2]

Q11.

4 (a)	force × distance <u>moved</u>	…………	M1	
	in the direction of the force	…………	A1	[2]
(b)	weight / force = mg	…………	M1	
	$\Delta E_p = mg \times \underline{\Delta h}$	…………	A1	[2]
	(no marks for quote of $mg\Delta h$)			

Q12.

8	(a)		product of force and distance moved in the direction of the force	M1 A1	**[2]**
	(b)	(i)	falls from rest decreasing acceleration reaches a constant speed	B1 B1 B1	**[3]**
		(ii)	straight line with negative gradient y-axis intercept above maximum E_K reasonable gradient (same magnitude as that for E_K initially)	B1 B1 B1	**[3]**

Q13.

1	(a)	(i)	product of force and distance <u>moved</u> (by force) in the direction of the force	M1 A1	[2]
		(ii)	work (done) per unit time (*idea of ratio needed*)	B1	[1]
	(b)		*either* work/time *or* power = (force × distance)/time to give power = force × velocity	M1 A1	[2]
	(c)	(i)	kinetic energy (= ½mv^2) = ½ × 1900 × 27^2 power = 692550 / 8.1 = 8.55 × 10^4 W	C1 A1	[2]
		(ii)	*either* for equal increments of speed, increments of E_K are different so longer time (to increase speed) at high speeds *or* air resistance increases with speed (M1) so driving force (and acceleration) reduced (A1) *or* P (= Fv) = mav (M1) (P and m constant) so when v increases, a decreases (A1)	M1 A1	[2]

Q14.

3 **(a)** **(i)** potential energy: stored energy available to do work — B1 [1]

(ii) gravitational: due to height/position of mass OR distance from mass OR moving mass from one point to another — B1
elastic: due to deformation/stretching/compressing — B1 [2]

(b) **(i)** height raised = (61 – {61 cos18} =) 3.0 cm — C1
energy = (mgh = 0.051 × 9.8 × 0.030 =) 1.5×10^{-2} J — A1 [2]

(ii) moment = force × perpendicular distance
= 0.051 × 9.8 × 0.61 × sin18 — C1
= 0.094 N m — A1 [2]

Q15.

4 **(a)** electrical potential energy (stored) when charge moved and gravitational potential energy (stored) when mass moved — B1
due to work done in electric field and work done in gravitational field — B1 [2]

(b) work done = force × distance moved (in direction of force)
and force = mg — M1
$mg \times h$ or $mg \times \Delta h$ — A1 [2]

(c) **(i)** $0.1 \times mgh = \frac{1}{2} mv^2$ — B1
$0.1 \times m \times 9.81 \times 120 = 0.5 \times m \times v^2$ — B1
$v = 15.3\,\text{m s}^{-1}$ — A0 [2]

(ii) $P = 0.5\, m\, v^2 / t$ — C1
$m / t = 110 \times 10^3 / [0.25 \times 0.5 \times (15.3)^2]$ — C1
$= 3740\,\text{kg s}^{-1}$ — A1 [3]

Q16.

3 **(a)** **(i)** power = work done per unit time / energy transferred per unit time / rate of work done — B1 [1]

(ii) Young modulus = stress / strain — B1 [1]

(b) **(i)** **1.** $E = T / (A \times \text{strain})$ *(allow strain = ε)* — C1
$T = E \times A \times \text{strain} = 2.4 \times 10^{11} \times 1.3 \times 10^{-4} \times 0.001$ — M1
$= 3.12 \times 10^4$ N — A0 [2]

2. $T - W = ma$ — C1
$[3.12 \times 10^4 - 1800 \times 9.81] = 1800a$ — C1
$a = 7.52$ m s^{-2} — A1 [3]

(ii) **1.** $T = 1800 \times 9.81 = 1.8 \times 10^4$ N — A1 [1]

2. potential energy gain $= mgh$ — C1
$= 1800 \times 9.81 \times 15$
$= 2.7 \times 10^5$ J — A1 [2]

(iii) $P = Fv$ — C1
$= 1800 \times 9.81 \times 0.55$ — C1
input power $= 9712 \times (100/30) = 32.4 \times 10^3$ W — A1 [3]

Q17.

3 **(a)** (work =) force × distance <u>moved</u> / displacement in the direction of the force
OR when a force moves in the direction of the force work is done — B1 [1]

(b) kinetic energy $= \frac{1}{2} mv^2$ — C1
$= \frac{1}{2}\, 0.4\, (2.5)^2 = 1.25 / 1.3$ J — A1 [2]

(c) **(i)** area under graph is work done / work done $= \frac{1}{2} Fx$ — C1
$1.25 = (14\, x) / 2$ — C1
$x = 0.18\ (0.179)$ m [allow $x = 0.19$ m using kinetic energy = 1.3 J] — A1 [3]

(ii) smooth curve from $v = 2.5$ at $x = 0$ to $v = 0$ at Q — M1
curve with increasing gradient — A1 [2]

Q18.

4 **(a)** gravitational PE is energy of a mass due to its position in a gravitational field — B1

elastic PE energy stored (in an object) due to (a force) changing its shape / deformation / being compressed / stretched / strained — B1 [2]

(b) **(i)** **1.** kinetic energy = $\frac{1}{2}mv^2$ — C1

$= \frac{1}{2} \times 0.065 \times 16^2 = 8.3(2)$ J — A1 [2]

2. $v^2 = 2gh$ OR PE = mgh — C1

$h = 16^2 / (2 \times 9.81) = 13(.05)$ m — A1 [2]

(ii) speed at $t = \frac{1}{2}$ total time = 8 (m s^{-1}) or total t =1.63 or $t_{1/2} = 0.815$ s — C1

KE is ¼ or h at $t_{1/2} = 9.78$ (m) — C1

and PE is ¾ of max ratio = 3 or ratio = 9.78 / 3.26 = 3 — A1 [3]

(iii) time is less because (average) acceleration is greater OR average force is greater — B1 [1]