WORK, ENERGY AND POWER

1.	Using $v = u + at$: $20 = 30a$ so $a = \frac{2}{3}$ ms^{-2}	M1 A1.
	Resultant force = F – R	
	Newton II $\Rightarrow$ $F - R = 900 \times \frac{2}{3}$ i.e. $F - R = 600$	M1 A1
	$P = Fv$ $\therefore$ $24000 = F \times 15$	M1 A1
	so $F = 1600$	
	$\therefore$ $1600 - R = 600$	
	$\Rightarrow$ R = 1000N	A1 cao
		[7]

2.	Initial and final k.e. = 0	B1
	Loss in p.e. = 0.4gh	M1 A1
	Work done against friction = total loss of energy	M1
	Work done against friction = $F \times 4h$	A1
	$F \times 4h = 0.4gh$	M1
	i.e. F = 0.98 N	A1
		[7]

3.	a) Resultant force = F – 400	M1
	When steady speed, acceleration is zero $\therefore F = 400$	A1
	$P = Fv$	M1
	$\therefore$ $3000 = 400v$ $\Rightarrow$ $v = 7.5$ ms^{-1}	A1
		[4]
	b) Speed increased to 15 ms^{-1} in 60 seconds	
	$\therefore$ using $v = u + at$ $\Rightarrow$ $a = 0.125$	M1 A1 f.t.
	Resultant force = mass $\times$ acceleration	
	$\therefore$ Resultant force = $1200 \times 0.125 = 150$	M1 A1 f.t.
	$\therefore$ $F - 400 = 150$ $\Rightarrow$ $F = 550$	A1 f.t.
	$P = Fv$ $\Rightarrow$ $P = 550 \times 15$	M1
	P = 8.25 kW	A1 cao
		[7]

4.	a) Resultant force up the hill is $F - 1000\sin\theta - 450$	M1 A1
	constant speed $\Rightarrow$ no acceleration	B1
	$F = 100 + 450 = 550$	A1
	$P = Fv$	B1
	$\therefore$ $P = 550 \times 30$ $\Rightarrow$ P = 16500 W (16.5 kW)	A1 cao
		[6]
	b) Resultant force down the hill $= F_1 + 1000\sin\theta - 450$	M1 A1
	$= F_1 - 350$	
	$\therefore$ At constant speed $F_1 = 350$	A1
	$P = F_1v$ gives $16500 = 350v$ so $v = 47.1$ ms^{-1} (3 SF)	M1 A1
		[5]

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5. a) Considering car + caravan } M1
Resultant force = F – 600
Steady speed $\therefore$ no acceleration $\therefore$ F = 600 A1

Speed = 70 kmh^{-1} = $70 \times \frac{1000}{3600}$ ms^{-1} = $\frac{175}{9}$ ms^{-1} M1 A1

$\therefore$ Rate of working = Fv M1
= $600 \times \frac{175}{9}$ = 11.7 kW (3 SF) A1 cao

[6]

b) For caravan only:
Resultant force = T – 200 M1
Steady speed $\therefore$ T – 200 = 0 i.e. T = 200N A1
[2]

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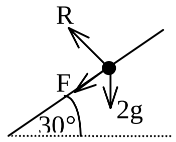
6. a) Initial k.e. = $\frac{1}{2}$mv^2 = $\frac{1}{2} \times 2 \times 25$ = 25 J } M1 A1
Final k.e. = 0
No change in p.e. B1
$\therefore$ Loss in energy = 25 J

Loss in energy = work done against friction M1
Work done against friction = F × S = 1.5F M1
1.5F = 25 M1
Force = $16\frac{2}{3}$ N, acting along line of motion, in opposite direction to motion B1

F = μR ⇒ μ = $\frac{16\frac{2}{3}}{2g}$ = 0.85 B1

[8]

b)



R = 2g cos30° = $\sqrt{3}$g
F = μR = 0.85$\sqrt{3}$g } M1 A1

Taking starting point as p.e. = 0:
Initial energy = $\frac{1}{2} \times 2 \times v^2 = v^2$ B1
Final energy = 2g × 1.5 sin30° = 1.5g M1 A1

Loss in energy = v^2 –1.5g B1
Work done against friction = 0.85$\sqrt{3}$g × 1.5 B1
v^2 – 1.5g = 0.85$\sqrt{3}$g × 1.5 ⇒ v = 6.03 ms^{-1} M1 A1
[9]

WORK, ENERGY AND POWER

7.	Resolving horizontally: resultant force = Tcos30 – F = 0	M1 A1
	Resolving vertically and no motion in that direction	
	$\Rightarrow$ Tsin30 + N – 10g = 0	M1 A1
	$\Rightarrow \dfrac{F}{\sqrt{3}} + N - 10g = 0$	
	Moving $\therefore$ F = μN = 0.4N	M1
	$\therefore \dfrac{F}{\sqrt{3}} + \dfrac{F}{0.4} = 10g$	
	F = 31.846N	A1 cao
	$\therefore$work done against friction = Fs	M1
	= 31.846 × 8 = 254.8	A1 f.t.
		[8]

8.	a) Initial k.e. = 0	M1 A1
	Taking p.e. as zero initially gives initial energy = 0	
	Final k.e. = $\frac{1}{2} \times 3 \times (0.4)^2 = 0.24$	
	Depth parcel falls is 1.5sin30^o = 0.75 m	B1
	So final p.e = - 3 × 9.8 × 0.75 = -22.05	M1 A1
	So final energy = - 21.81J	
	So loss of energy = 21.81J	A1 f.t.
	Work done against friction = loss in energy	M1
	Work done = F × 3	A1
	$\therefore F = \dfrac{21.81}{3} = 7.27$ N	A1 cao
		[9]
	b) Parcel treated as particle	
	Frictional force assumed constant	B2 (any 2)
	No other forces but frictional resistance and gravity	
		[2]

WORK, ENERGY AND POWER

9. a) Initial k.e. = 0 Final k.e. = $\frac{1}{2}mu^2$ B1

Initial p.e. = 0 Final p.e. = 3mgh B1

$\therefore$ Gain in energy = $\frac{1}{2}mu^2 + 3mgh$

$\therefore$ Work done = gain in energy = $\frac{mu^2}{2} + 3mgh$ M1 A1 f.t.

[4]

b) Initial k.e. = $\frac{1}{2}m\left(\frac{u}{2}\right)^2 = \frac{mu^2}{8}$ B1

$\therefore$ Gain in energy = $\frac{3mu^2}{8} + 3mgh$

i.e. Work done = $\frac{3mu^2}{8} + 3mgh$ B1 f.t.

Does $\left(\frac{mu^2}{2} + 3mgh\right) - \left(\frac{3mu^2}{8} + 3mgh\right)$ less work M1

i.e. $\frac{mu^2}{8}$ J less work done A1 cao

[4]

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10. For a dog, resolving horizontally:

resultant force = X – Tcos30° – F (X = tractive force exerted by dog) M1 A1

since steady speed, no acceleration B1

$\therefore$ X = Tcos30° + F

Since moving, F = μN M1

and N = W $\Rightarrow$ F = 0.2 W A1

$\therefore$ X = $\frac{T\sqrt{3}}{2} + 0.2W$

For sleigh: resolving horizontally and steady speed give

$3T\cos 30 - F_1 = 0$ M1 A1

and $F_1 = 0.1 \times 5W \Rightarrow F_1 = 0.5W$ A1

$0.5W = \frac{3\sqrt{3}T}{2}$ i.e. $T = \frac{W}{3\sqrt{3}}$ A1

$\therefore$ X = $\frac{W}{3\sqrt{3}} \times \frac{\sqrt{3}}{2} + 0.2W$ so X = $\frac{11W}{30}$ A1

Rate of working = $\frac{11W}{30} \times 2 = \frac{11W}{15}$ M1 A1 f.t.

[12]

WORK, ENERGY AND POWER

11. Volume of water per second = $\frac{3\times10^6}{60}\text{cm}^3$ B1

Mass of water per second = $\frac{\frac{3\times10^6}{60}}{10^3}$ kg B1

$\therefore$ mass per second = 50 kg B1

$\therefore$ Gain in k.e. per second = $\frac{1}{2}\times 50\times 10^2 = 2500$ J M1 A1

Gain in p.e. per second = $50\times g\times 7 = 350g = 3430$J M1 A1

Maximum power = increase in energy per second M1
= 2500 + 3430 W A1 f.t.
= 5.93 kW A1 f.t.
[10]

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12. a) Gain in k.e. = $\frac{1}{2}mv^2 = \frac{1}{2}\times 0.4\times 10^2 = 20$ M1 A1

Gain in p.e. = mgh = $0.4\times 9.8\times 1.5 = 5.88$ M1 A1

Work done = gain in energy M1
$\therefore$ work done = 20 + 5.88 = 25.88 J A1 f.t.
[6]

b) If initial speed is v:
Total energy = $\frac{1}{2}\times 0.2v^2 + 0.2\times 9.8\times 1.5$ M1 A1
$25.88 = 0.1v^2 + 2.94$ M1
so v = 15.1 ms^{-1} A1 cao
[4]

WORK, ENERGY AND POWER

13.a)	Total mass of train = 56 tonnes = 56×10^3 kg	B1
	Total resistance = $40 \times 56 = 2240$ N	B1
	Resultant force along horizontal track = F – 2240 since steady speed, resultant force = 0, so F = 2240	M1 A1 f.t.
	P = Fv P = 2240×50	B1 M1
	P = 112 kW	A1 f.t.
		[7]
b) i)	When downhill resultant force $= 2240 + 56 \times 10^3 g\sin\theta - 2240$	M1
	$= 27440 = 2.744 \times 10^4$	A1
	Newton II $\Rightarrow 2.744 \times 10^4 = 56 \times 10^3 a$	M1
	$\therefore$ a = 0.49	A1 cao
		[4]
ii)	Constant acceleration $\therefore$ can use equation of motion	B1
	At bottom of slope using $v^2 = u^2 + 2as$	M1
	$v^2 = 50^2 + 2 \times 400 \times 0.49$	
	$v = 53.77 = 53.8\ ms^{-1}$	A1
	$\therefore$ Power of engine $= 2240 \times 53.77 = 120$ kW (3 SF)	A1 cao
		[4]

14.a)	Initial k.e. = final k.e. = 0	B1
	Taking AB as zero p.e. level:	
	Loss in p.e. = mgh = $25 \times g \times 2 = 50g$	M1 A1
	Work done against resistance = $F \times 4$	M1 A1
	Work done = loss in energy	M1
	$\therefore 4F = 50g$ i.e. F = 12.5g (=122.5)	A1 cao
		[7]
b)	Initial k.e. = $\frac{1}{2}mu^2 = 12.5u^2$ Final k.e. = 0	B1
	$\therefore$ loss in energy = $12.5u^2 + 50g$	B1 f.t.
	Work done against resistance $\leq 12.5\,g \times 4.5 = 56.25\,g$	M1 A1 f.t.
	$\therefore 12.5\,u^2 + 50g \leq 56.25\,g$	M1
	$\Rightarrow u \leq \sqrt{\frac{g}{2}}$ so maximum value of u = $\sqrt{\frac{g}{2}}$ (=2.21ms^{-1})	A1 cao
		[6]
c)	Sonal treated as particle No air resistance. Same conditions for each descent.	B2 (any two)
		[2]

WORK, ENERGY AND POWER

15.a)	Considering the caravan only	
	resultant force = T – 150	M1 A1
	Steady speed $\therefore$ no acceleration	B1
	$\therefore$ T = 150 N	A1
		[4]
b)	For car and caravan F –250 = 0 $\therefore$ F = 250 N	M1 A1
	P = Fv	B1
	90 kmh^{-1} = 25 ms^{-1}	M1 A1
	$\therefore$ P = Rate of working = 250×25 = 6250 W	
	= 6.25 kW	A1 f.t.
		[6]
c)	126 kmh^{-1} = 35 ms^{-1}	B1
	Resultant force = $\frac{6250}{35} + 1700g\sin10° - 250 = 178.57 + 2893 - 25 \approx 2822$	M1 A1
	Acceleration = $\frac{2822}{1700} \approx 1.7$ ms^{-2}	A1
		[4]

16.a)	On level ground, resultant force = $F - k \times 40^2$	B1
	and steady speed $\Rightarrow$ no acceleration $\therefore$ F = 1600k	B1
	P = Fv $\therefore$ 60000 = $F \times 40$ $\Rightarrow$ F = 1500	M1 A1
	$\therefore$ 1500 = 1600k $\Rightarrow$. $k = \frac{15}{16}$	A1
		[5]
b)	When going up a hill :	
	resultant force $= F_1 - 9000\sin\theta - \frac{15}{16} \times 20^2$	M1 A1
	$= F_1 - 2175$	A1 c.a.o.
	$P = F_1v \Rightarrow F_1 = \frac{80000}{20} = 4000$	B1
	$\therefore$ Resultant force = 4000 – 2175 = 1825	B1
	Weight = 9000N i.e. mg = 9000 $\therefore m = \frac{9000}{g}$	B1
	Newton II $\Rightarrow 1825 = \frac{9000}{g} \times a$	M1 A1 f.t.
	a = 1.987 i.e a = 1.99ms^{-2} (3 SF)	A1 c.a.o.
		[9]

WORK, ENERGY AND POWER

17.a)	Uphill, resultant force = F – Mgsinθ – R	M1 A1
	Steady speed so no acceleration $\therefore$ F – Mgsinθ – R = 0	A1
	P = Fv $\therefore$ P = Fu	M1
	$\frac{P}{u}$ – Mg sin θ – R = 0 i.e. P = u(Mgsinθ +R)	A1 f.t.
	For downhill: F_1 + Mgsinθ – R = 0	A1
	P = 2 uF_1 $\therefore$ P = 2u(R – Mgsinθ)	A1 f.t.
	$\therefore$ u(Mgsinθ +R) = 2u(R – Mgsinθ)	M1
	R = 3 Mgsinθ	A1 cao
	$\Rightarrow$ P = 4 Mgusinθ	A1 cao
		[10]
b)	On level ground, resultant force = F_2 – R	M1
	$\therefore$ F_2 = 3 Mgsinθ	A1 f.t.
	P = F_2v $\Rightarrow$ $v = \frac{4Mgu \sin\theta}{3Mg \sin\theta}$	M1
	$\Rightarrow$. max speed on level ground is $\frac{4u}{3}$	A1 c.a.o.
		[4]

WORK, ENERGY AND POWER

18.a)	Frictional resistances = kv, where k is a constant	B1
	For section AB: resultant force = $F - kv - 500\sin\theta$	M1 A1
	Max speed $\therefore$ no acceleration $\therefore$ $F - k \times 10 - 100 = 0$	A1
	P=Fv so $F = \frac{5000}{10} = 500\text{N}$	B1
	$\therefore$ $500 - 100 = k \times 10$ i.e. k = 40	M1 A1
	On section BC: resultant force = $F_1 - 40v_1$	A1 f.t.
	No acceleration and $5000 = F_1v_1$	M1
	$\Rightarrow \frac{5000}{v_1} = 40v_1$	A1 f.t.
	i.e. $v_1 = 11.2\text{ms}^{-1}$ (3 SF)	A1 cao
		[11]
b)	On section CD resultant force = $F_2 - 40v_2 + 500\sin\theta$	B1
	no acceleration and $5000 = F_2v_2$	M1
	$\Rightarrow \frac{5000}{v_2} - 40v_2 + 100 = 0$	A1
	$2v_2^2 - 5v_2 - 250 = 0$	M1
	$(2v_2 - 25)(v_2 + 10) = 0$ $\therefore v_2 = 12.5\text{ ms}^{-1}$	A1 cao
		[5]

19.	On level road resultant force = F – 2000	M1 A1
	Newton II $\Rightarrow$ $F - 2000 = 1500 \times 1.5$	M1
	$\therefore$ F = 4250N	A1
	P = Fv	M1
	$\therefore$ Power = $4250 \times 12 = 51000$ W	A1 c.a.o.
	Power = 51 kW	A1 f.t.
		[7]

WORK, ENERGY AND POWER

20.a) When on level road resultant force = F – 2100 — M1 A1
Steady speed $\therefore$ F = 2100

P = Fv — B1
$\therefore 65000 = 2100 \times v$ — M1
i.e. v = 30.95 i.e. v = 31.0 ms^{-1}(3 SF) — A1 cao
[5]

b) Total mass now 1800 kg — B1
$\therefore$ Frictional forces = $\frac{1800}{1400} \times 2100 = 2700$ — M1 A1
$\therefore$Resultant force up hill = $F_1 - 2700 - 1800g\sin\theta$ — M1 A1
Steady speed $\therefore F_1 = 3876$ — A1 c.a.o.

P = Fv $\Rightarrow$ 65000 = 3876v — M1
$\Rightarrow$ v = 16.8 ms^{-1} (3 SF) — A1 c.a.o.
[8]

21.a) Resultant force = $4 \times 15 \times 10^4 - R$ — M1 A1
Steady speed $\therefore$no acceleration — B1
$\therefore R = 6 \times 10^5$ N — A1 f.t.
[4]

b) Total power of 4 engines $= 4 \times 15 \times 10^4 \times 200$ — M1
$= 1.2 \times 10^8$ — A1 f.t.
[2]

c) Resistance = kv — B1
$6 \times 10^5 = k \times 200 \quad \Rightarrow R = 3000v$ — M1 A1 f.t.
thrust of engines = $\frac{1.2 \times 10^8}{150} = 8 \times 10^5$ — M1 A1 f.t.
and resistance = $3000 \times 150 = 4.5 \times 10^5$ — B1 f.t.

$\therefore$ when climbing resultant force $= 8 \times 10^5 - 4.5 \times 10^5 - 70 \times 10^3 g\sin 30$ — M1
$= 7000$ — A1 cao
Newton II $\Rightarrow 7000 = 70 \times 10^3 a$ — M1
i.e. a = 0.1 ms^{-2} — A1 c.a.o.
[10]

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22. D – R = Ma — M1 A1
P = Dv = v(R + ma) — M1 A1
[4]

WORK, ENERGY AND POWER

23. a) Momentum = $0.3(2\mathbf{i} - 4\mathbf{j})$	M1
$\lvert\text{Momentum}\rvert = 0.3\sqrt{2^2 + 4^2} = 1.34$ Ns	M1 A1
	[3]
b) k.e. $= \frac{1}{2} \times 0.3\ \lvert 2\mathbf{i} - 4\mathbf{j}\rvert^2$ J	M1
$= \frac{1}{2} \times 0.3 \times (4 + 16)$ J	M1
$= 3$ J	A1
	[3]

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24. $0.4g - T = 0.4a$	M1 A1
$T - 0.3g = 0.3a$	A1
Adding: $a = \dfrac{0.1g}{0.7} = 1.4\ \text{ms}^{-2}$	M1 A1
After 1.5 s from rest, each particle is moving with speed $2.1\ \text{ms}^{-1}$	M1 A1
k.e. of system $= \frac{1}{2} \times 0.7 \times 2.1^2 = 1.5435$ J	M1 A1
	[9]
