1. A car of mass 750 kg is moving up a straight road inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{15}$. The resistance to motion of the car from non-gravitational forces has constant magnitude R newtons. The power developed by the car's engine is 15 kW and the car is moving at a constant speed of 20 m s^{-1}.

(a) Show that $R = 260$.

(4)

The power developed by the car's engine is now increased to 18 kW. The magnitude of the resistance to motion from non-gravitational forces remains at 260 N. At the instant when the car is moving up the road at 20 m s^{-1} the car's acceleration is a m s^{-2}.

(b) Find the value of a.

(4)
(Total 8 marks)

2. A cyclist and her bicycle have a total mass of 70 kg. She cycles along a straight horizontal road with constant speed 3.5 ms^{-1}. She is working at a constant rate of 490 W.

(a) Find the magnitude of the resistance to motion.

(4)

The cyclist now cycles down a straight road which is inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{14}$, at a constant speed U ms^{-1}. The magnitude of the non-gravitational resistance to motion is modelled as $40U$ newtons. She is now working at a constant rate of 24 W.

(b) Find the value of U.

(7)
(Total 11 marks)

3. A truck of mass of 300 kg moves along a straight horizontal road with a constant speed of 10 m s^{-1}. The resistance to motion of the truck has magnitude 120 N.

(a) Find the rate at which the engine of the truck is working.

(2)

On another occasion the truck moves at a constant speed up a hill inclined at θ to the horizontal, where $\sin\theta = \frac{1}{14}$. The resistance to motion of the truck from non-gravitational forces remains of magnitude 120 N. The rate at which the engine works is the same as in part (a).

(b) Find the speed of the truck.

(4)
(Total 6 marks)

4. A car of mass 1500 kg is moving up a straight road, which is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{14}$. The resistance to the motion of the car from non-gravitational forces is constant and is modelled as a single constant force of magnitude 650 N. The car's engine is working at a rate of 30 kW.

Find the acceleration of the car at the instant when its speed is 15 m s^{-1}.

(Total 5 marks)

5. A lorry of mass 2000 kg is moving down a straight road inclined at angle α to the horizontal, where $\sin\alpha = \frac{1}{25}$. The resistance to motion is modelled as a constant force of magnitude 1600 N. The lorry is moving at a constant speed of 14 m s^{-1}.

Find, in kW, the rate at which the lorry's engine is working.

(Total 6 marks)

6. A car of mass 1200 kg moves along a straight horizontal road with a constant speed of 24 m s^{-1}. The resistance to motion of the car has magnitude 600 N.

(a) Find, in kW, the rate at which the engine of the car is working.

(2)

The car now moves up a hill inclined at α to the horizontal, where $\sin \alpha = \frac{1}{28}$ The resistance to motion of the car from non-gravitational forces remains of magnitude 600 N. The engine of the car now works at a rate of 30 kW.

(b) Find the acceleration of the car when its speed is 20 m s^{-1}.

(4)
(Total 6 marks)

7. A car of mass 1000 kg is moving along a straight horizontal road. The resistance to motion is modelled as a constant force of magnitude R newtons. The engine of the car is working at a rate of 12 kW. When the car is moving with speed 15 m s^{-1}, the acceleration of the car is 0.2 m s^{-2}.

(a) Show that $R = 600$.

(4)

The car now moves with constant speed U m s^{-1} downhill on a straight road inclined at θ to the horizontal, where $\sin\theta = \frac{1}{40}$. The engine of the car is now working at a rate of 7 kW. The resistance to motion from non-gravitational forces remains of magnitude R newtons.

(b) Calculate the value of U.

(5)
(Total 9 marks)

8. A car of mass 1200 kg moves along a straight horizontal road. The resistance to motion of the car from non-gravitational forces is of constant magnitude 600 N. The car moves with constant speed and the engine of the car is working at a rate of 21 kW.

(a) Find the speed of the car.

(3)

The car moves up a hill inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{14}$.

The car's engine continues to work at 21 kW and the resistance to motion from non-gravitational forces remains of magnitude 600 N.

(b) Find the constant speed at which the car can move up the hill.

(4)
(Total 7 marks)

9. A car of mass 1000 kg is towing a trailer of mass 1500 kg along a straight horizontal road. The tow-bar joining the car to the trailer is modelled as a light rod parallel to the road. The total resistance to motion of the car is modelled as having constant magnitude 750 N. The total resistance to motion of the trailer is modelled as of magnitude *R* newtons, where *R* is a constant. When the engine of the car is working at a rate of 50 kW, the car and the trailer travel at a constant speed of 25 m s^{-1}.

(a) Show that $R = 1250$.

(3)

When travelling at 25 m s^{-1} the driver of the car disengages the engine and applies the brakes. The brakes provide a constant braking force of magnitude 1500 N to the car. The resisting forces of magnitude 750 N and 1250 N are assumed to remain unchanged. Calculate

(b) the deceleration of the car while braking,

(3)

(c) the thrust in the tow-bar while braking,

(2)

(d) the work done, in kJ, by the braking force in bringing the car and the trailer to rest.

(4)

(e) Suggest how the modelling assumption that the resistances to motion are constant could be refined to be more realistic.

(1)
(Total 13 marks)

10. A lorry of mass 1500 kg moves along a straight horizontal road. The resistance to the motion of the lorry has magnitude 750 N and the lorry's engine is working at a rate of 36 kW.

(a) Find the acceleration of the lorry when its speed is 20 m s^{-1}.

(4)

The lorry comes to a hill inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{10}$. The magnitude of the resistance to motion from non-gravitational forces remains 750 N.

The lorry moves up the hill at a constant speed of 20 m s^{-1}.

(b) Find the rate at which the lorry's engine is now working.

(3)
(Total 7 marks)

11. A car of mass 400 kg is moving up a straight road inclined at an angle θ to the horizontal, where $\sin \theta = \frac{1}{14}$. The resistance to motion of the car from non-gravitational forces is modelled as a constant force of magnitude R newtons. When the car is moving at a constant speed of 20 m s^{-1}, the power developed by the car's engine is 10 kW.

Find the value of R.

(Total 5 marks)

12. A girl and her bicycle have a combined mass of 64 kg. She cycles up a straight stretch of road which is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{14}$. She cycles at a constant speed of 5 m s^{-1}. When she is cycling at this speed, the resistance to motion from non-gravitational forces has magnitude 20 N.

(a) Find the rate at which the cyclist is working.

(4)

She now turns round and comes down the same road. Her initial speed is 5 m s^{-1}, and the resistance to motion is modelled as remaining constant with magnitude 20 N. She free-wheels down the road for a distance of 80 m. Using this model,

(b) find the speed of the cyclist when she has travelled a distance of 80 m.

(5)

The cyclist again moves down the same road, but this time she pedals down the road. The resistance is now modelled as having magnitude proportional to the speed of the cyclist. Her initial speed is again 5 m s^{-1} when the resistance to motion has magnitude 20 N.

(c) Find the magnitude of the resistance to motion when the speed of the cyclist is 8 m s^{-1}.

(1)

The cyclist works at a constant rate of 200 W.

(d) Find the magnitude of her acceleration when her speed is 8 m s^{-1}.

(4)
(Total 14 marks)

13. A car of mass 1000 kg is moving along a straight horizontal road with a constant acceleration of f m s^{-2}. The resistance to motion is modelled as a constant force of magnitude 1200 N. When the car is travelling at 12 m s^{-1}, the power generated by the engine of the car is 24 kW.

(a) Calculate the value of f.

(4)

When the car is travelling at 14 m s^{-1}, the engine is switched off and the car comes to rest, without braking, in a distance of d metres. Assuming the same model for resistance,

(b) use the work-energy principle to calculate the value of d.

(3)

(c) Give a reason why the model used for the resistance to motion may not be realistic.

(1)
(Total 8 marks)

14. The resistance to the motion of a cyclist is modelled as kv^2 N, where k is a constant and v m s^{-1} is the speed of the cyclist. The total mass of the cyclist and his bicycle is 100 kg. The cyclist freewheels down a slope inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{20}$, at a constant speed of 3.5 m s^{-1}.

(a) Show that $k = 4$.

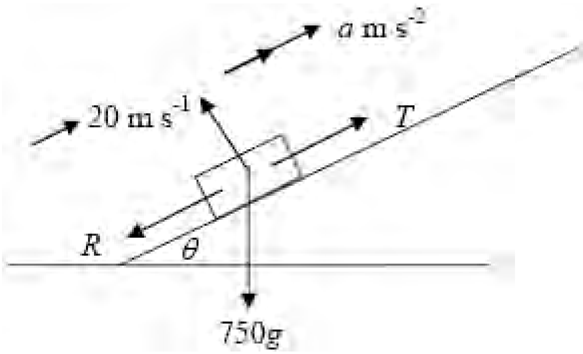
(3)

The cyclist ascends a slope inclined at an angle β to the horizontal, where $\sin \beta = \frac{1}{40}$, at a constant speed of 2 m s^{-1}.

(b) Find the rate at which the cyclist is working.

(6)
(Total 9 marks)

1. (a)



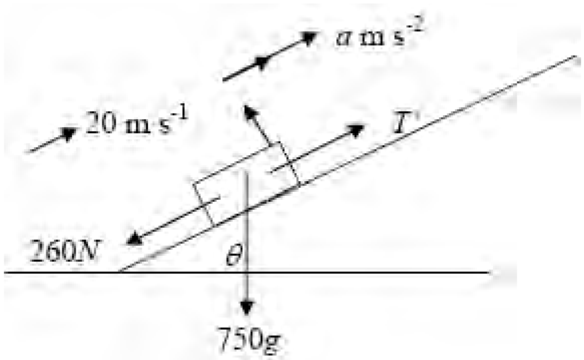
$T = \frac{15000}{20} = 750$ M1

R(parallel to road) $T = R + 750g\sin\theta$ M1 A1

$R = 750 - 750 \times 9.8 \times \frac{1}{15}$

$R = 260$ A1 4

(b)



$T' = \frac{18000}{20} = 900$ M1

$T' - 260 - 750g \times \sin\theta = 750a$ M1 A1

$a = \frac{900 - 260 - 750 \times 9.8 \times \frac{1}{15}}{750}$

$a = 0.2$ A1 4

[8]

2. (a) $\frac{490}{3.5} - R = 0$ B1 M1 A1

$R = 140$ N A1 4

(b) $\frac{24}{u} + 70g.\frac{1}{14} - 40u = 0$ B1

$40u^2 - 49u - 24 = 0$ M1 A2,1,0

$(5u - 8)(8u + 3) = 0$ DM1

$u = 1.6$ DM1 A1 7

[11]

3. (a) Constant v $\Rightarrow$ driving force = resistance

$\Rightarrow$ F = 120 (N) M1

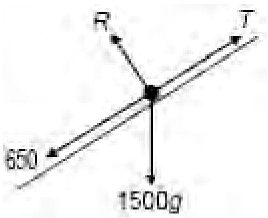
$\Rightarrow$ P = 120 × 10 = 1200W M1 2

(b) Resolving parallel to the slope, zero acceleration:

$\frac{P}{v} = 120 + 300g\sin\theta(= 330)$ M1A1A1

$\Rightarrow \text{v} = \frac{1200}{330} 3.6\left(\text{ms}^{-1}\right)$ A1 4

[6]



4. F = ma parallel to the slope, M1 *

$T - 1500g\sin\theta - 650 = 1500a$ A1

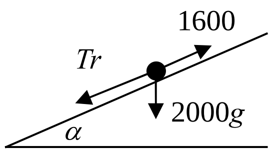
Tractive force, 30000 = T × 15 M1 *

$a = \frac{\frac{30000}{15} - 1500(9.8)(\frac{1}{14}) - 650}{1500}$ d * M1

0.2 (m s^{-2}) A1

[5]

5.



Resolve ↗: $T_r + \frac{2000g \times \sin\alpha}{(T_r = 816)}$ = 1600 M1A1A1

P = 816 × 14(W) ft their T_r M1A1ft

≈ 11(kW) accept 11.4 A1 cso 6

[6]

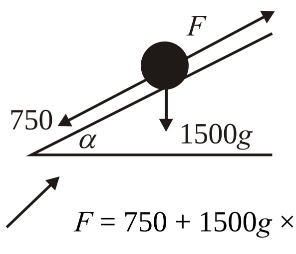
6.	(a)	$\frac{P}{24}=600$ or $\frac{1000P}{24}=600$ $\Rightarrow P=14.kW$		M1 A1	2
	(b)	$\frac{30000}{20}-1200\times 9.8\times \sin\alpha - 600 = 1200a$		M1 A2,1,0	
		$\Rightarrow a = 0.4$ m s^{-2}		A1	4
					[6]
7.	(a)	$T_r = \frac{12000}{15}$ (800)		M1	
		N2L $800 - R = 1000 \times 0.2$	ft their 800	M1 A1ft	
		$R = 600$ *	cso	A1	4
	(b)	$1000g \times \frac{1}{40} + T_r = R$		M1 A1	
		$T_r = \frac{7000}{U}$		M1	
		$U \approx 20$	accept 19.7		5
					[9]
8.	(a)	Driving force = $\frac{P}{v}$		B1	
		$\frac{21000}{v} = 600 \Rightarrow v = 35$ m s^{-1}		M1 A1	3
	(b)	$\frac{P}{v} = 600 + 1200.g.\frac{1}{14}$		M1 A1	
		(= 1440 N)			
		$\frac{21000}{v} = 1440 \Rightarrow v = \frac{21000}{1440} \approx 14.6$ or 15 m s^{-1}		M1 A1	4
					[7]
9.	(a)	50 000 = $F \times 25$ (F = 2000) *or equivalent*		M1	
		$\rightarrow F = R + 750$		M1	
		$R = 1250$ (*) *cso*		A1	3

	(b)	N2L $1500 + 2000 = 2500a$	M1 A1	
		ignore sign of a		
		$a = 1.4$ (ms^{-2})	A1	3
		cao		
	(c)	Trailer: $T + R = 1500 \times 1.4$ *or* Car: $T - 1500 - 750 = 1000 \times -1.4$	M1	
		$T = 850$ (N)	A1	2
	(d)	$25^2 = 2 \times 1.4 \times s$ ($s = 223.2$)	M1	
		$W = 1500 \times s$	M1 A1ft	
		ft their s		
		= 335 (kJ)	A1	4
		accept 330		
	(e)	Resistances <u>vary</u> with <u>speeds</u>	B1	1

[13]

10.	(a)	$F = \frac{36000}{20}$ (= 1800)	B1	
		N2L $\frac{3600}{20} - 750 = 1500a$	M1 A1ft	
		ft their F		
		$a = 0.7$ (m s^{-2})	A1	4

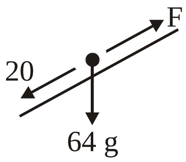
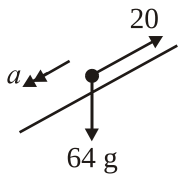
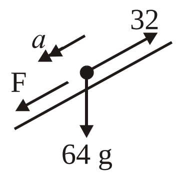
(b)



$F = 750 + 1500g \times \frac{1}{10}$ (= 2220)	M1 A1
$P = 2220 \times 20 = 44\ 400$	A1 3
Accept also 44 000, 44 kW, 44.4 kW	

[7]

11.	$T = \dfrac{10000}{20}$ or equivalent		M1 A1	
	$T - R - 400\,g \sin \theta = 0$		M1 A1	
	$R = 220$		A1	5

12.	(a)			
		(↗): $F = 20 + 64g \sin \alpha$	M1 A1	
		$P = Fv = 64.8 \times 5 = 324$ W	M1 A1	4
	(b)			
		(↙): $64g \sin \alpha - 20 = 64a$	M1 A1	
		$a = 0.3875$ m s^{-2}	A1	
		$v^2 = 5^2 + 2 \times 0.3875 \times 80$	M1	
		$v = \sqrt{87} = 9.3$ m s^{-1} (2 sf)	A1	5
	(c)	$\frac{8}{5} \times 20 = 32$ N	B1	1
	(d)			
		$F = \frac{200}{8}$	B1	
		$\frac{200}{8} + 64g \sin \alpha - 32 = 64a$	M1 A1	
		$a = 0.59$ m s^{-2} (2 sf)	A1	4

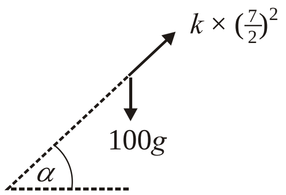
[14]

13.	(a)	$T_r = \dfrac{24000}{12}$ (= 2000)	M1	
		N2L: $T_r - 1200 = 1000 \times f$	M1 A1 ft	
		$f = 0.08$	A1	4

(b)	Work Energy $\frac{1}{2} \times 1000 \times 14^2 = 1200d$		M1 A1	
	$d = 81\frac{2}{3}$	awrt 81.7	A1	3
(c)	Resistances may *vary* with speed		B1	1

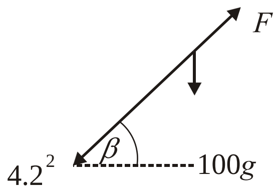
[8]

14. (a)



R (↙), $100g \times \frac{1}{20} = k \times \left(\frac{7}{2}\right)^2$	M1 A1	
$\Rightarrow k = 4$ (T)	A1	3

(b)



R (↗), $F - 100g \times \frac{1}{40} - 16 = 0$	M1 A2	
$\Rightarrow F = 40.5$ N	A1	
$P = 40.5 \times 2$	M1	
$= 81$ W	A1	6

[9]

1. This question produced a very good response with many candidates scoring full marks. The connection between power, driving force and velocity is clearly understood.

In part (a) the given answer ensured that those who were uncertain how to proceed could review their work and find the correct approach. Candidates should be reminded to use the notation introduced in a question (R) and to be careful not to omit any steps when deriving a given answer.

In part (b) the most common error was the omission of either the weight component or the resistance when applying Newton's second law parallel to the slope.

2. Very few students were unable to find the magnitude of the resistance to motion in (a) although some did produce some lengthy arguments before achieving the required solution. Others omitted to justify that the resistance had the same magnitude as the driving force.
In part (b) most candidates were able to attempt the equation of motion, although some failed to notice or to take correct account of the fact that this cyclist is moving down the road, rather than up, resulting in several sign errors. Most candidates were able to manipulate the equation, successfully incorporating $F = \frac{24}{u}$ (or equivalent) and going on to obtain and solve a quadratic equation.

3. Most candidates dealt with this question very well; a great proportion of candidates being able to score full marks for both parts. Part (a) was invariably correct, but a small number of candidates added a mass/weight to the resistance given in the question.

In part (b) the usual approach was to find the force of 330 N separately and then to substitute into $P = Fv$. Some candidates used the power from (a) as a force so scored nothing. Some wrote a correct equation for the total resistance to motion but forgot to include the 120 when they completed the calculation; a few included the 120 twice in some way - either adding or subtracting from 330.

A significant minority lost the final A mark through over-accuracy following the use of an approximate value for g or incorrect rounding.

annotation reference;**32.**This question was tackled confidently and successfully by the majority of candidates. The solution was often broken down into several small steps and only put together using Newton's second law right at the end. Sign errors were rare and resolving errors even more so. A few candidates muddled the driving force with the resultant force, or ignored the 650 N, and hence scored few marks. There were also some candidates confused about g, omitting it in the weight term and/or including it in the mass term

4. This was a straightforward question for many candidates. However, as usual, some were not sure how to deal with power and velocity in a question involving forces and the inclined plane. A surprising number of candidates felt that the lorry had to work against gravity when it was going down the hill. Too many candidates failed to realise that using 9.8 for gravity could not give answers to a high degree of accuracy. Only answers to 2 or 3 significant figures were accepted.

5. Most candidates scored full marks for this question. A few left the answer to part (a) in watts and some rounded their answer to 14 kW. In part (b) a few did not appreciate the difference between power and force and confused these when forming their equation using '$F = ma$'. Some forgot to include the force produced by the engine and others omitted the component of the weight down the plane.

6. The most common error here was a sign error in the $F=ma$ equation required in part (a) but most knew the Power equation and were able to get to the printed answer. In the second part there were some sign errors and some used Power = Nett force × speed but many candidates produced correct solutions. Sometimes answers were given to a greater degree of accuracy than could be accepted.

7. This proved to be an easy starter for most and full marks was often seen. A few dropped a mark for giving an overaccurate answer in part(b).

8. Part (a) was well done but later parts of the question proved very discriminating. In part (b), the quickest method is to consider the whole system, but many who gave only one equation used a mass of 1000 kg or 1500 kg. If the car or the trailer is considered separately, then a pair of equations is needed and this was very rarely seen. Another source of error was treating the tractive force of 2000 N as still applying to the system. Part (c) was not understood by the majority of candidates; thrust often being confused with impulse or linear momentum. Thrust, along with tension, does appear in the M1 specification and can be tested on the M2 paper. In part (d), many thought that the work done was just the change in kinetic energy or made the equivalent error of, having found the distance moved in coming to rest, multiplying by 3500 N instead of 1500 N. Candidates did not seem to be expecting to be asked the work done by a specific force in a situation where there were three forces acting. A few used ratios and correctly, as all three forces have been acting over the same distance, calculated $\frac{3}{7}$ of the energy loss. In part (e), the majority knew that, in practice, resistance varies with speed.

9. This proved to be a comfortable starting question for most candidates and full marks were common. A few try to remember formulae for standard questions of this type and these often made errors in applying them. Some candidates use a concept of an "effective accelerating force" and this frequently led to an error in sign resulting in the incorrect equation $F - 750 = \frac{3600}{20}$. In part (b), a substantial minority of candidates thought that the acceleration of part (a) still applied. Candidates who used the total force produced by engine and began by resolving the forces parallel to the plane were generally successful

10. This proved to be a very friendly starter with almost all candidates scoring full marks. The only errors that seemed to occur were those when candidates failed to take into account the weight component of the car, thus ending with an answer of 500 N. There were also the occasional slips when the factor of g was missed from the weight component.

11. (a) Most candidates were able to do this successfully.

(b) Those that attempted this part using energy often missed out a term or made sign errors.

(c) Almost all scored a mark here.

(d) Many only used the force of 25 in F = *ma* despite having often done (b) correctly. The other common error was to use 20 instead of 32 as the resistance. A number tried to use P = F*v* to do the question 'in one go' – this usually lead to sign errors in F even when all the terms were present.

12. This was tackled less successfully than most other questions on the paper. There were some who mistakenly used $P = (F - R)v$ to find the driving force and a greater number who correctly found this force as 2000 N but then incorrectly wrote 2000 $= ma$, ignoring the resistance to motion. A few gained no marks by ignoring the instructions and using Newton's Second Law. Part (c) was well answered, the majority commenting that resistances to motion were likely to vary with speed.

13. No Report available for this question.