

1. A car of mass 1000 kg is moving at a constant speed of 16 m s^{-1} up a straight road inclined at an angle θ to the horizontal. The rate of working of the engine of the car is 20 kW and the resistance to motion from non-gravitational forces is modelled as a constant force of magnitude 550 N.

(a) Show that $\sin \theta = \frac{1}{14}$.

(5)

When the car is travelling up the road at 16 m s^{-1} , the engine is switched off. The car comes to rest, without braking, having moved a distance y metres from the point where the engine was switched off. The resistance to motion from non-gravitational forces is again modelled as a constant force of magnitude 550 N.

- (b) Find the value of y .

(4)

(Total 9 marks)

2. 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 $a \text{ m s}^{-2}$.

- (b) Find the value of a .

(4)

(Total 8 marks)

3. 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 $U \text{ ms}^{-1}$. 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)

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 car of mass 800 kg is moving at a constant speed of 15 m s^{-1} down a straight road inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{24}$. The resistance to motion from non-gravitational forces is modelled as a constant force of magnitude 900 N.

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

(4)

When the car is travelling down the road at 15 m s^{-1} , the engine is switched off. The car comes to rest in time T seconds after the engine is switched off. The resistance to motion from non-gravitational forces is again modelled as a constant force of magnitude 900 N .

(b) Find the value of T .

(4)

(Total 8 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)

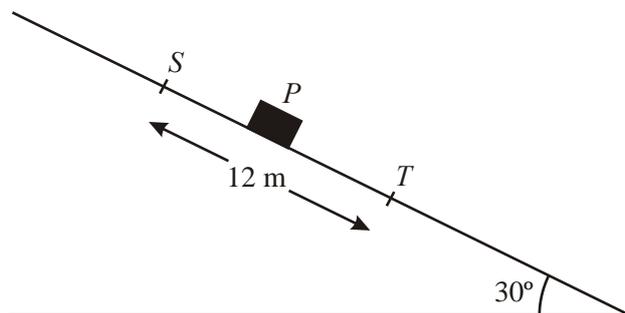
The car now moves up a hill inclined at α to the horizontal, where $\sin \alpha = \frac{1}{28}$. The resistance to motion of the car from non-gravitational forces remains of magnitude 600 N . The engine of the car now works at a rate of 30 kW .

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

(4)

(Total 6 marks)

7.



A small package P is modelled as a particle of mass 0.6 kg. The package slides down a rough plane from a point S to a point T , where $ST = 12$ m. The plane is inclined at an angle of 30° to the horizontal and ST is a line of greatest slope of the plane, as shown in the diagram. The speed of P at S is 10 m s^{-1} and the speed of P at T is 9 m s^{-1} . Calculate

- (a) the total loss of energy of P in moving from S to T ,

(4)

- (b) the coefficient of friction between P and the plane.

(5)

(Total 9 marks)

8. The resistance to the motion of a cyclist is modelled as kv^2 N, where k is a constant and $v \text{ m s}^{-1}$ 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.

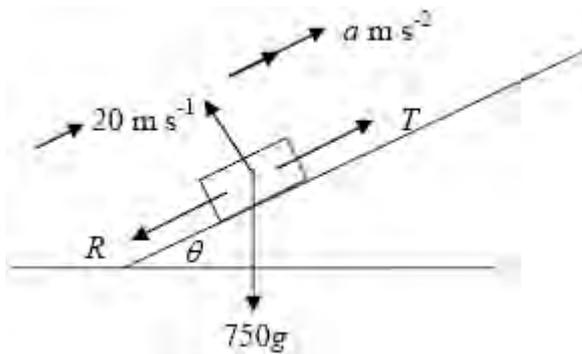
(6)

(Total 9 marks)

- 1 (a) $20000 = 16F$ ($F = 1250$)
 $\square F = 550 + 1000 \times 9.8 \sin \theta$ M1A1
 ft their F M1A1ft
 Leading to $\sin \theta = \frac{1}{14}$ * cso A1 5
- (b) N2L $\square 550 + 1000 \times 9.8 \times \sin \theta = 1000a$
 $(550 + 1000 \times 9.8 \times \frac{1}{14} = 1000a)$ M1A1
 or $1250 = 1000a$
 $(a = (-)1.25)$
 $v^2 = u^2 + 2as \Rightarrow 16^2 = 2 \times 1.25 \times y$ M1
 $y \approx 102$ accept 102.4, 100 A1 4
- Alternative
 Work-Energy $\frac{1}{2} \times 1000 \times 16^2 - 1000 \times 9.8 \times \frac{1}{14} y = 550y$ M1 M1 A1
 $y \approx 102$ accept 102.4, 100 A1 4

[9]

2. (a)



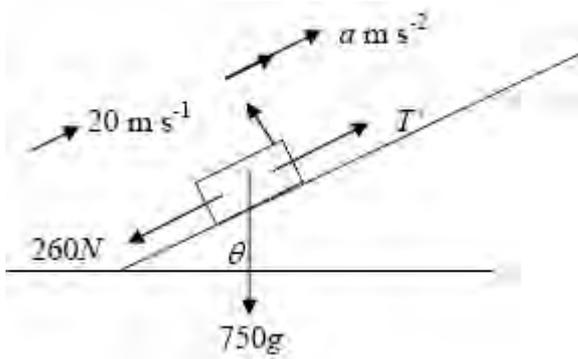
$$T = \frac{15000}{20} = 750 \quad \text{M1}$$

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

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

$$R = 260 \quad \text{A1} \quad 4$$

(b)



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

$$T' - 260 - 750g \times \sin \theta = 750a \quad \text{M1 A1}$$

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

$$a = 0.2 \quad \text{A1} \quad 4$$

[8]

3. (a)

$$\frac{490}{3.5} - R = 0$$

B1 M1 A1

$$R = 140 \text{ N}$$

A1 4

(b)

$$\frac{24}{u} + 70g \cdot \frac{1}{14} - 40u = 0 \quad \text{B1}$$

$$40u^2 - 49u - 24 = 0$$

M1 A2,1,0

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

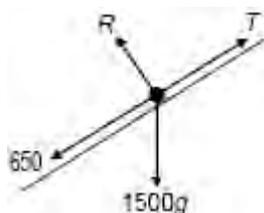
DM1

$$u = 1.6$$

DM1 A1 7

[11]

4.



F = ma parallel to the slope, M1 *

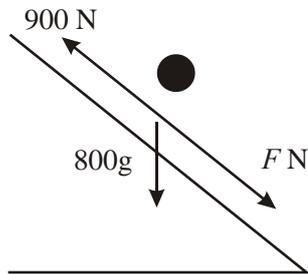
$$T - 1500g \sin \theta - 650 = 1500a \quad \text{A1}$$

Tractive force, $30000 = T \times 15$ M1 *

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

$$\underline{0.2} \text{ (m s}^{-2}\text{)} \quad \text{A1}$$

5. (a)



$$F + 800g \sin \alpha = 900$$

M1

$$F = 573 \frac{1}{3}$$

A1

$$W = 573 \frac{1}{3} \times 15 = 8600$$

M1

$$= 8.6 \text{ kW}$$

A1

4

NB. Going up hill is an error, not a Misread

(b) $N2L \ 800 \times 9.8 \times \frac{1}{24} - 900 = 800a (*)$

M1

$$a = -\frac{43}{60}$$

awrt -0.72

A1

$$0 = 15 - \frac{43}{60}T$$

M1

$$T \approx 21$$

accept 20.9

A1cso

4

(*) If they are using their F from (a) then they need to have scored the M1 in (a) in order to score the M1 here.

Alternative

$$\text{WD: } 573 \frac{1}{3} s = \frac{1}{2} \times 800 \times 15^2$$

$$s = 157$$

$$\text{Use of } v^2 = u^2 + 2as$$

$$a = 0.72$$

M1 for getting as far as an equation in a .

A1 finish as above

2nd Alternative

$Ft = \text{Change in momentum:}$

M1 Using the correct F

M1 Use of the method to form an equation

A1 Equation correct unsimplified but fully substituted

A1 $T \approx 21$

[8]

6. (a) $\frac{P}{24} = 600$ or $\frac{1000P}{24} = 600 \quad \Rightarrow P = 14.4 \text{ kW}$ M1 A1 2

(b) $\frac{30000}{20} - 1200 \times 9.8 \times \sin \alpha - 600 = 1200a$ M1 A2,1,0
 $\Rightarrow a = 0.4 \text{ m s}^{-2}$ A1 4

[6]

7. (a) KE lost is $\frac{1}{2} \times 0.6 \times (10^2 - 9^2)$ (=5.7 J) B1
 PE lost is $0.6 \times 9.8 \times 12 \sin 30^\circ$ (= 35.28 J) B1
 Total loss in energy is 41.0 (J) M1 A1 4
accept 41

(b) $R = 0.6 \times 9.8 \times \cos 30^\circ$ (≈ 5.09) B1
 WE $40.98 = \mu \times 0.6 \times 9.8 \times \cos 30^\circ \times 12$ M1 A1ft
 $\mu \approx 0.67$ or 0.671 M1 A1 5
ft their (a)

[9]

Alternative for (b)

$$a = \frac{9^2 - 10^2}{2 \times 12} \left(= (-) \frac{19}{24} \right)$$

B1

awrt 0.79

N2L $mg \sin 30^\circ - \mu mg \cos 30^\circ = m \left(-\frac{19}{24} \right)$

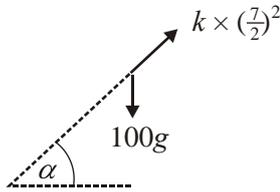
M1 A1ft

$$\mu \approx 0.67 \text{ or } 0.671$$

M1 A1 5

ft their a

8. (a)



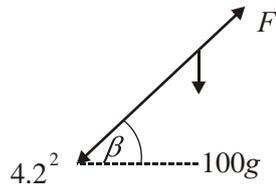
$$R (\swarrow), 100g \times \frac{1}{20} = k \times \left(\frac{7}{2} \right)^2$$

M1 A1

$$\Rightarrow k = 4 \text{ (T)}$$

A1 3

(b)



$$R (\nearrow), F - 100g \times \frac{1}{40} - 16 = 0$$

M1 A2

$$\Rightarrow F = 40.5 \text{ N}$$

A1

$$P = 40.5 \times 2$$

M1

$$= 81 \text{ W}$$

A1 6

[9]

1.
 - (a) This question was well answered with the great majority of candidates doing exactly what was required. The application of Newton's second law and resolution of the weight was usually correct and of course we always saw $\frac{1}{14}$. Candidates should be aware that in a 14 question like this, where an answer is given, their working needs to demonstrate clearly how the answer is derived. Some candidates omitted essential working and did not convince us that they had reached the required answer. Others did not attempt to simplify their working, which they evaluated using their calculator, obtaining a decimal answer, which they then told us was approximately equal to $\frac{1}{14}$.
 - (b) As usual, the more popular strategy in (b) seemed to be to use $F = ma$ and constant acceleration, rather than the work-energy principle. Some candidates repeated much of the working from part (a) to deduce that the total force acting parallel to the slope is 1250 N, others simply wrote it down as a straight forward deduction from the preceding work. For candidates who attempted to use the work-energy method, common errors included duplication of gravity or failure to include work done against resistance. Several candidates who used 550 N correctly in the first part went on to use 500 N in part (b) for no obvious reason.
2. 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.
3. 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.

4. 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

5. A significant number either misread the question or failed to appreciate that the car was moving downhill with resistive forces acting in the opposite direction. This led to a number of sign errors. Despite being asked to give the answer to (a) in kW, a number of candidates left the answer in Watts. Missing forces – usually the component of weight – was a common error. A few candidates appreciated that their working from (a) was relevant in (b), but the majority started afresh, often including forces in one part that they overlooked in the other. Some candidates appeared not to realise that the car was still moving down the hill in (b). Having found a value for the acceleration, most candidates used a valid method to find the value of T , although several did this in two stages, having failed to spot that they could use $v = u + at$. Some candidates lost marks carelessly here by misquoting formulae (e.g. $v^2 = u^2 + 2at$). Candidates need to be careful with signs – a few ended up with equations which gave a negative time and then ignored this to give a positive answer.

6. 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.

7. Energy and the work-energy principle are an area of weakness for many and, in part (a), it was quite common for candidates to find only the change in kinetic energy, ignoring the change in potential energy. No method was specified for part (b) and candidates were roughly evenly divided between those who used the work-energy principle, utilising their answer to part (a) and those who, essentially started again, using Newton's second law. If they had an incorrect answer to part (a), those using work-energy could gain 4 of the 5 marks in part (b). Errors of sign were often seen in the solutions of those who used Newton's second law. This often arose through uncertainty about the direction of the acceleration. A substantial minority of candidates treated the forces parallel to the plane as being in equilibrium, assuming that there was no acceleration.

8. No Report available for this question.