Questions

Q1.

A particle of mass 3 kg is moving with velocity (3**i** + 5**j**) m s^{-1} when it receives an impulse (–4**i** + 3**j**) N s.

Find

(a) the speed of the particle immediately after receiving the impulse,

(5)

(b) the kinetic energy gained by the particle as a result of the impulse.

(3)

(Total for question = 8 marks)

Q2.

A ball of mass 0.5 kg is moving with velocity (**2**i – 3**j**) m s^{-1} when it receives an impulse (4**i** + 5**j**) N s. Find the gain in kinetic energy of the ball due to the impulse.

(Total for question = 6 marks)

Q3.

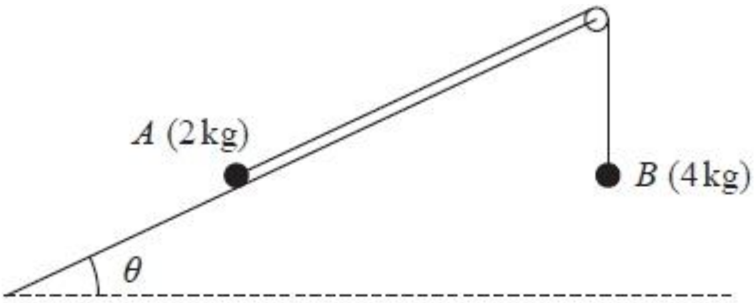


Figure 1

A particle *A* of mass 2 kg is attached to one end of a light inextensible string. A particle *B* of mass 4 kg is attached to the other end of the string. The string passes over a small smooth pulley. The pulley is fixed at the top of a fixed rough plane, which is inclined to the horizontal at an angle θ, where tan $\tan\theta = \frac{3}{4}$. Initially the particles are held at rest with *A* on the plane, *B* hanging freely below the pulley and the string taut, as shown in Figure 1. The part of the string from *A* to the pulley lies along a line of greatest slope of the plane.

The coefficient of friction between *A* and the plane is $\frac{1}{5}$.

At time $t = 0$, the particles are released from rest, with *A* more than 1.5 m from the pulley and *B* more than 1.5 m above the ground.

At time $t = T$ seconds, the speed of *B* is v m s^{-1} and *B* is 1.5 m below its initial position.

(a) Find the total potential energy lost by the system in the interval $0 \le t \le T$.

(3)

(b) Find the work done against friction in the interval $0 \le t \le T$.

(3)

(c) Use the work-energy principle to find the value of v.

(3)

(Total for question = 9 marks)

Q4.

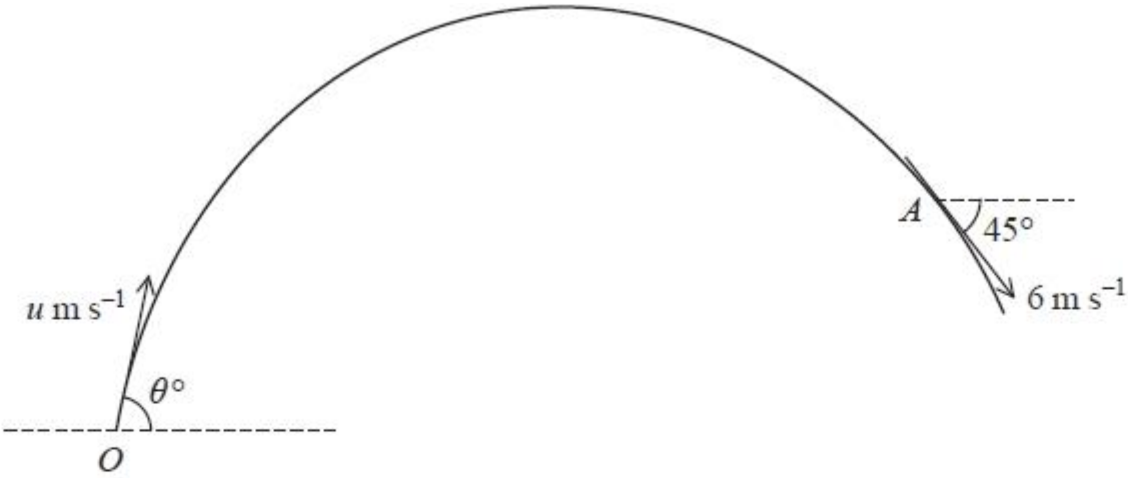


Figure 4

At time t = 0, a particle P of mass 0.7 kg is projected with speed u m s^{-1} from a fixed point O at an angle $\theta°$ to the horizontal. The particle moves freely under gravity. At time t = 2 seconds, P passes through the point A with speed 6 m s^{-1} and is moving downwards at 45° to the horizontal, as shown in Figure 4.

Find

(a) the value of θ,

(6)

(b) the kinetic energy of P as it reaches the highest point of its path.

(3)

For an interval of T seconds, the speed, v m s^{-1}, of P is such that $v \leq 6$

(c) Find the value of T.

(5)

(Total for question = 14 marks)

Q5.

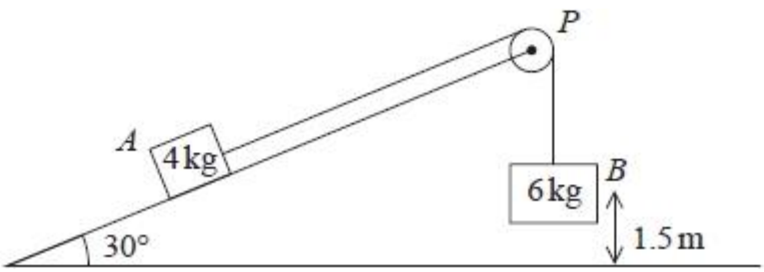


Figure 3

Two blocks, *A* and *B*, of masses 4 kg and 6 kg respectively, are connected by a light inextensible string. Block *A* is held at rest on a fixed rough ramp that is inclined at an angle of 30° to the horizontal. The string passes over a small smooth pulley, *P*, which is fixed at the top of the ramp. Block *B* hangs vertically below *P*, 1.5 m above the ground, as shown in Figure 3. Block *A* is more than 1.5 m from *P*. The blocks are released from rest with the string taut so that *A* moves up the ramp and the section of the string from *A* to *P* is parallel to a line of greatest slope of the ramp. The coefficient of friction between *A* and the ramp is $\frac{1}{\sqrt{3}}$

The blocks are modelled as particles and air resistance is ignored.

(a) Find the work done against friction as *A* moves 1.5 m up the ramp.

(4)

(b) Find the potential energy lost by the system as *A* moves 1.5 m up the ramp.

(3)

(c) Use the work-energy principle to find the speed of *B* at the instant immediately before it hits the ground.

(3)

(Total for question = 10 marks)

Q6.

A car of mass 800 kg pulls a trailer of mass 300 kg up a straight road which is inclined to the horizontal at an angle α, where $\sin \alpha = \frac{1}{14}$. The trailer is attached to the car by a light inextensible towbar which is parallel to the direction of motion of the car. The car's engine works at a constant rate of *P* kW. The non-gravitational resistances to motion are constant and of magnitude 600 N on the car and 200 N on the trailer.

At a given instant the car is moving at 10 m s^{-1} and is accelerating at 0.5 m s^{-2}

(a) Find the value of *P*.

(5)

When the car is moving up the road at 12 m s^{-1}, the towbar breaks. The trailer comes to instantaneous rest after moving a distance *d* metres up the road from the point where the towbar broke. The non-gravitational resistance to the motion of the trailer remains constant and of magnitude 200 N.

(b) Find, using the work-energy principle, the value of *d*.

(5)

(Total for question = 10 marks)

Q7.

A cyclist and his bicycle have a total mass of 75 kg. The cyclist is moving up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{21}$. The non-gravitational resistance to motion is modelled as a constant force of magnitude R newtons. The cyclist is working at a constant rate of 280 W and moving at a constant speed of 2 m s^{-1}.

(a) Find the value of R.

(4)

Later the cyclist cycles down the same road on the same bicycle. He is again working at a constant rate of 280 W and the resistance to motion is now modelled as a constant force of magnitude 60 N.

(b) Find the acceleration of the cyclist at the instant when his speed is 3.5 m s^{-1}.

(4)

(Total for question = 8 marks)

Q8.

A cyclist and his bicycle, with a combined mass of 75 kg, move along a straight horizontal road. The cyclist is working at a constant rate of 180 W. There is a constant resistance to the motion of the cyclist and his bicycle of magnitude R newtons. At the instant when the speed of the cyclist is 4 m s^{-1}, his acceleration is 0.2 m s^{-2}.

(a) Find the value of R.

(4)

Later, the cyclist moves up a straight road with a constant speed v m s^{-1}. The road is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{21}$. The cyclist is working at a rate of 180 W and the resistance to the motion of the cyclist and his bicycle from non-gravitational forces is again the same constant force of magnitude R newtons.

(b) Find the value of v.

(4)

(Total for question = 8 marks)

Q9.

A car of mass 900 kg is moving on a straight road that is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{49}$. When the car is moving up the road, with the engine of the car working at a constant rate of 10.8 kW, the car has a constant speed of v m s^{-1}. The resistance to the motion of the car from non-gravitational forces is modelled as a constant force of magnitude R newtons.

When the car is moving down the road, with the engine of the car working at a constant rate of 10.8 kW, the car has a constant speed of $2v$ m s^{-1}. The resistance to the motion of the car is still modelled as a constant force of magnitude R newtons.

Find

(i) the value of R,

(ii) the value of v.

(Total for question = 8 marks)

Q10.

A truck of mass 800 kg is moving on a straight road that is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{10}$. When the truck is moving up the road at a constant speed of 12 m s^{-1}, the engine of the truck is working at a constant rate of 15 kW. The resistance to the motion of the truck from non-gravitational forces is modelled as a constant force of magnitude R newtons.

(a) Find the value of R.

(4)

The truck now moves down the same road. The resistance to the motion of the truck is now modelled as a constant force of magnitude 500 N. The engine of the truck is again working at a constant rate of 15 kW.

(b) Find the acceleration of the truck at the instant when it is moving at 12 m s^{-1}.

(3)

(Total for question = 7 marks)

Q11.

A van has mass 750 kg. The van is moving up a straight road at constant speed U m s^{-1} The road is inclined to the horizontal at an angle θ, where $\sin\theta = \frac{1}{15}$

The resistance to the motion of the van from non-gravitational forces is modelled as a single force of magnitude 30 U newtons. The engine of the van is working at a constant rate of 16 kW.

Find the value of U.

(Total for question = 5 marks)

Q12.

A cyclist and his bicycle have a total mass of 75 kg. The cyclist is moving down a straight road that is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{15}$

The cyclist is working at a constant rate of 56 W. The magnitude of the resistance to motion is modelled as a constant force of magnitude 40 N. At the instant when the speed of the cyclist is V m s^{-1}, his acceleration is $\frac{1}{3}$ m s^{-2}

Find the value of V.

(5)

(Total for question = 5 marks)

Q13.

A truck of weight 9000 N is travelling up a hill on a straight road that is inclined at an angle θ to the horizontal, where

$\sin\theta = \frac{1}{15}$

When the truck travels up the hill with the engine working at 3P watts, the truck is moving at a constant speed of 12 m s^{-1}

Later on, the truck travels down the hill along the same road, with the engine working at P watts. At the instant when the speed of the truck is 12 m s^{-1}, the acceleration of the truck is $\frac{g}{20}$

The resistance to motion of the truck from non-gravitational forces is a constant force of magnitude R newtons in all circumstances.

Find (i) the value of P,

(ii) the value of R.

(Total for question = 9 marks)

Q14.

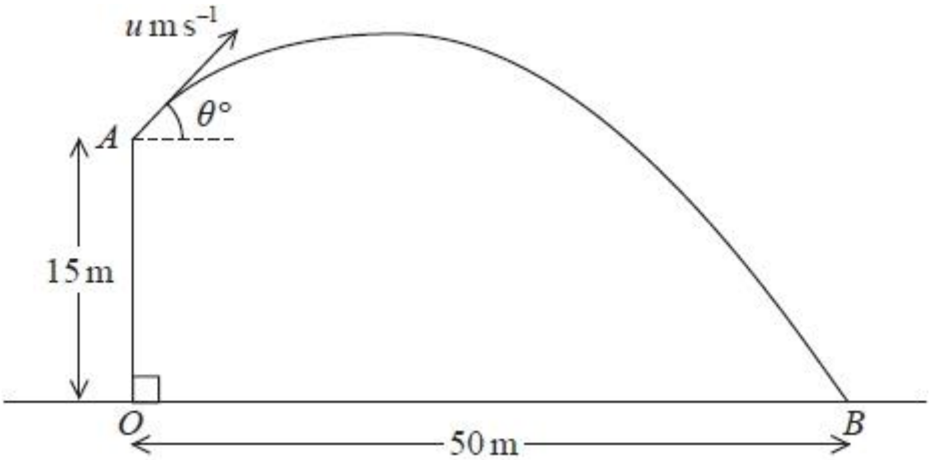


Figure 4

A small ball is thrown from the point *A* with speed u m s^{-1} at an angle $\theta°$ above the horizontal. The point is vertically above the point *O*, which is on horizontal ground, such that *AO* is 15 m.

The ball takes 3 seconds to travel from *A* to *B*, where *B* is on the ground and *OB* = 50 m, as shown in Figure 4. By modelling the motion of the ball as that of a particle moving freely under gravity,

find

(a) (i) the value of θ,

(ii) the value of u,

(6)

(b) the speed of the ball as it hits the ground at *B*,

(3)

(c) the direction of motion of the ball as it hits the ground at *B*.

(2)

(Total for question = 11 marks)

Q15.

A particle *P* is projected from a fixed point *A* with speed 12 m s^{-1} at an angle α above the horizontal and moves freely under gravity. As *P* passes through the point *B* on its path, *P* is moving with speed 8 m s^{-1} at an angle β below the horizontal.

(a) By considering energy, find the vertical distance between *A* and *B*.

(4)

Particle *P* takes 1.5 seconds to travel from *A* to *B*.

(b) Find the size of angle α.

(3)

(c) Find the size of angle β.

(3)

(d) Find the length of time for which the speed of *P* is less than 8 m s^{-1}.

(4)

(Total for question = 14 marks)

Q16.

A car of mass 900 kg is travelling up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{25}$. The car is travelling at a constant speed of 14 m s^{-1} and the resistance to motion from non-gravitational forces has a constant magnitude of 800 N. The car takes 10 seconds to travel from *A* to *B*, where *A* and *B* are two points on the road.

(a) Find the work done by the engine of the car as the car travels from *A* to *B*.

(4)

When the car is at *B* and travelling at a speed of 14ms^{-1} the rate of working of the engine of the car is suddenly increased to *P* kW, resulting in an initial acceleration of the car of 0.7 m s^{-2}. The resistance to motion from non-gravitational forces still has a constant magnitude of 800 N.

(b) Find the value of *P*.

(4)

(Total for question = 8 marks)

Q17.

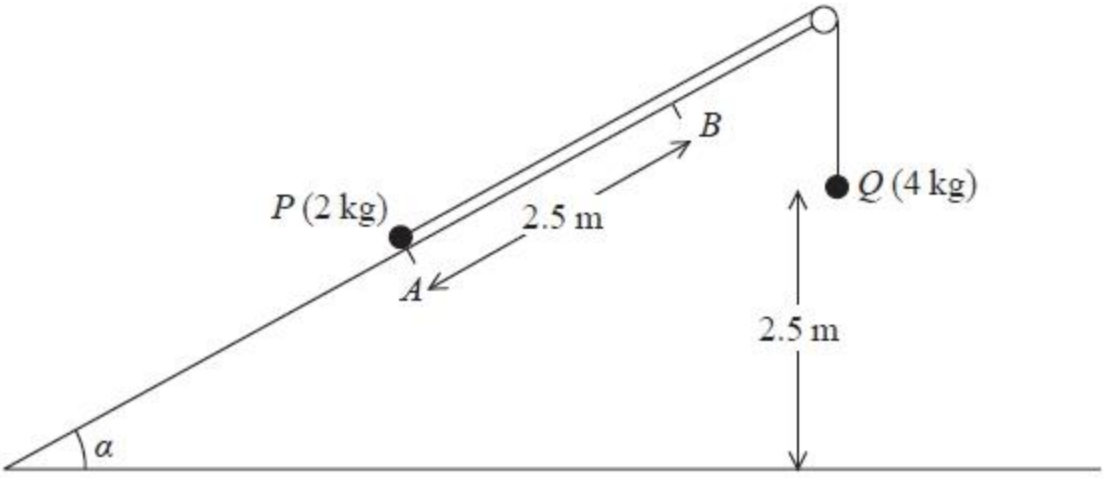


Figure 1

Two particles *P* and *Q*, of mass 2 kg and 4 kg respectively, are connected by a light inextensible string. Initially *P* is held at rest at the point *A* on a rough fixed plane inclined at α to the horizontal ground, where $\sin\alpha = \frac{3}{5}$. The string passes over a small smooth pulley fixed at the top of the plane. The particle *Q* hangs freely below the pulley and 2.5 m above the ground, as shown in Figure 1. The part of the string from *P* to the pulley lies along a line of greatest slope of the plane. The system is released from rest with the string taut. At the instant when *Q* hits the ground, *P* is at the point *B* on the plane. The coefficient of friction between *P* and the plane is $\frac{1}{4}$.

(a) Find the work done against friction as *P* moves from *A* to *B*.

(4)

(b) Find the total potential energy lost by the system as *P* moves from *A* to *B*.

(3)

(c) Find, using the work-energy principle, the speed of *P* as it passes through *B*.

(4)

(Total for question = 11 marks)

Q18.

A truck of mass 1800 kg is moving along a straight horizontal road. The engine of the truck is working at a constant rate of 10 kW. The non-gravitational resistance to motion is modelled as a constant force of magnitude R newtons. At the instant when the truck is moving with speed 15 m s^{-1}, the acceleration of the truck is 0.25 m s^{-2}.

(a) Find the value of R. **(4)**

The truck now moves up a straight road at a constant speed V m s^{-1}. The road is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{14}$. The non-gravitational resistance to motion is now modelled as a constant force of magnitude $30V$ newtons. The engine of the truck is now working at a constant rate of 12 kW.

(b) Find the value of V. **(6)**

(Total for question = 10 marks)

Q19.

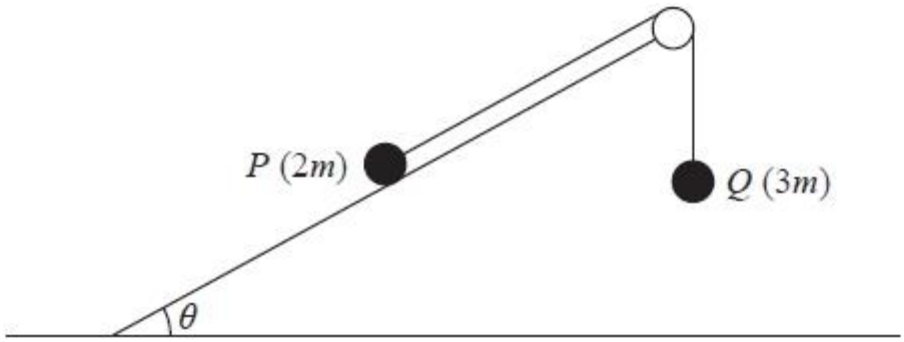


Figure 1

Two particles P and Q, of mass $2m$ and $3m$ respectively, are connected by a light inextensible string. Initially P is held at rest on a fixed rough plane inclined at θ to the horizontal ground, where $\sin\theta = \frac{2}{5}$. The string passes over a small smooth pulley fixed at the top of the plane. The particle Q hangs freely below the pulley, as shown in Figure 1. The part of the string from P to the pulley lies along a line of greatest slope of the plane. At time $t = 0$ the system is released from rest with the string taut. When P moves the friction between P and the plane is modelled as a constant force of magnitude $\frac{3}{5}mg$. At the instant when each particle has moved a distance d, they are both moving with speed v, particle P has not reached the pulley and Q has not reached the ground.

(a) Show that the total potential energy lost by the system when each particle has moved a distance d is $\frac{11}{5}mgd$. **(3)**

(b) Use the work-energy principle to find v^2 in terms of g and d. **(4)**

When $t = T$ seconds, $d = 1.5$ m.

(c) Find the value of T.

(2)

(Total for question = 9 marks)

Q20.

A car of mass 1200 kg moves up a straight road. The road is inclined to the horizontal at an angle α where $\sin \alpha = \frac{1}{15}$. The car is moving up the road with constant speed 10 m s^{-1} and the engine of the car is working at a constant rate of 11760 watts. The non-gravitational resistance to motion has a constant magnitude of R newtons.

(a) Find the value of R.

(4)

The rate of working of the car is now increased to 50 kW. At the instant when the speed of the car is V m s^{-1}, the magnitude of the non-gravitational resistance to the motion of the car is 700 N and the acceleration of the car is 1.5 m s^{-2}.

(b) Find the value of V.

(6)

(Total for question = 10 marks)

Q21.

A ball of mass 0.6kg is projected vertically upwards with speed 22.4 m s^{-1} from a point which is 1.5m above horizontal ground. The ball moves freely under gravity until it reaches the ground. The ground is soft and the ball sinks 2.5cm into the ground before coming to rest. The ball is modelled as a particle and the ground is assumed to exert a constant resistive force of magnitude R newtons on the ball. Using the work-energy principle, find, to 3 significant figures, the value of R.

(5)

(Total for question = 5 marks)

Q22.

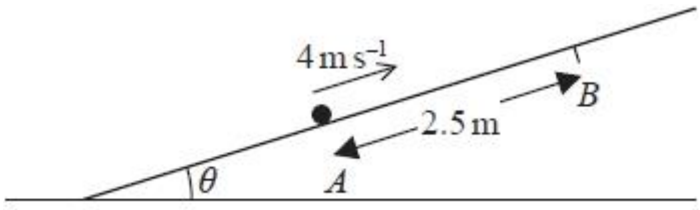


Figure 1

A rough straight ramp is fixed to horizontal ground. The ramp is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{7}$. The points A and B are on a line of greatest slope of the ramp with AB = 2.5 m and B above A, as shown in Figure 1. A package of mass 2 kg is projected up the ramp from A with speed 4 m s^{-1} and first comes to instantaneous rest at B. The coefficient of friction between the package and the ramp is μ. The package is modelled as a particle.

Use the work-energy principle to find the value of μ.

(6)

(Total for question = 6 marks)

Q23.

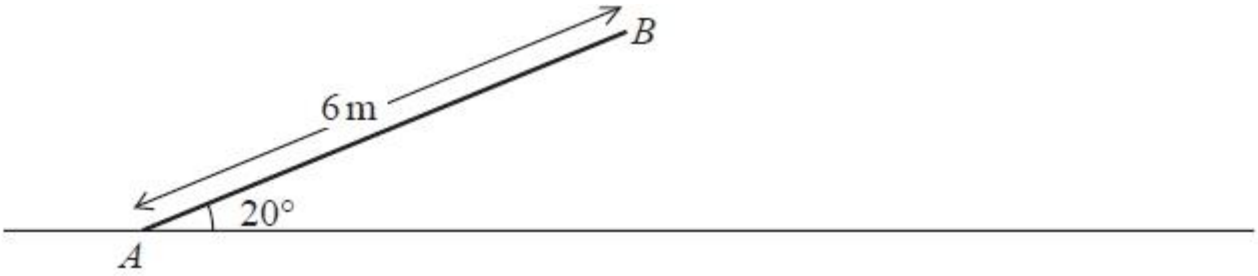


Figure 3

A rough ramp *AB* is fixed to horizontal ground at *A*. The ramp is inclined at 20° to the ground. The line *AB* is a line of greatest slope of the ramp and *AB* = 6 m. The point *B* is at the top of the ramp, as shown in Figure 3. A particle *P* of mass 3 kg is projected with speed 15 m s^{-1} from *A* towards *B*. At the instant *P* reaches the point *B* the speed of *P* is 10 m s^{-1}. The force due to friction is modelled as a constant force of magnitude *F* newtons.

(a) Use the work-energy principle to find the value of *F*.

(6)

After leaving the ramp at *B*, the particle *P* moves freely under gravity until it hits the horizontal ground at the point *C*. The speed of *P* as it hits the ground at *C* is *w* m s^{-1}.

Find

(b) (i) the value of *w*,

(ii) the direction of motion of *P* as it hits the ground at *C*,

(5)

(c) the greatest height of *P* above the ground as *P* moves from *A* to *C*.

(4)

(Total for question = 15 marks)

Q24.

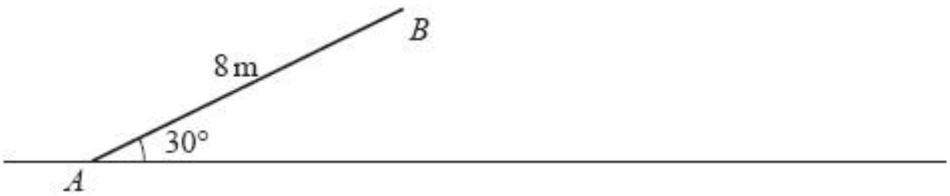


Figure 2

A smooth straight ramp is fixed to horizontal ground. The ramp has length 8 m and is inclined at 30° to the ground, as shown in Figure 2. A particle *P* of mass 0.7 kg is projected from a point *A* at the bottom of the ramp, up a line of greatest slope of the ramp, with speed u m s^{-1}. As *P* reaches the point *B* at the top of the ramp, *P* has speed 4.2 m s^{-1}.

(a) By considering energy, find the value of u.

(4)

After leaving the ramp at *B*, the particle *P* moves freely under gravity until it hits the ground at a point *C*. Immediately before hitting the ground at *C*, particle *P* is moving at θ° below the horizontal with speed w m s^{-1}.

Find

(b) (i) the value of w,

(ii) the value of θ,

(4)

(c) the horizontal distance from *B* to *C*.

(5)

(Total for question = 13 marks)

Examiner's Report

Q1.

In part (a) most marks were lost because candidates only found the vector form for **v** and failed to find the speed. More marks were lost in part (a) because of this than in part (b) which, on the whole, was quite well done, with most candidates appreciating the need to find the difference in the two kinetic energies. Interestingly, many of those who had not found the speed in part (a) went on to successfully find it and use it in part (b). A few candidates lost the final 3 marks by working in vectors, although many who started in this way managed to correct themselves and produce an appropriate solution.

Q2.

This proved to be an accessible start to the paper for the vast majority of the students, with many achieving full marks. Very few students misquoted the impulse − momentum formula. The most common reason for losing marks was a sign error or an algebraic slip in finding the velocity of the ball after receiving the impulse. In attempting to find the gain in kinetic energy, a small number of students substituted the velocities in the wrong order or attempted to square vectors in order to find the kinetic energy. A few students used the incorrect formula $\frac{1}{2}mv$ for kinetic energy.

Q3.

This individual parts of this question were answered well, although it was common for all marks to be lost on at least one part. In part (a) there were many correct solutions, usually delivered succinctly, but common mistakes were to include KE, include resolving for both particles or to add the GPE terms. This was also the question most likely to be penalised for over specifying the final answer as 41.16.

Part (b) was generally answered well done. It was unusual to see a mistake in writing down the friction, although this was not always explicitly stated. The most common mistakes here were to resolve the 1.5 again and some candidates also included the weight.

Part (c) tended to have more mistakes, with candidates either only including the KE of one particle or double counting energy terms, especially when attempting to use their answers from (a) and (b). It was also not uncommon for the answers to (a) and (b) to be added.

Q4.

Most candidates started part (a) by considering the horizontal and vertical components of the initial velocity. The equation for the horizontal component was usually correct, but there was commonly a sign error in the equation for the vertical velocity using an upward component of 6sin45 at *A* rather than −6sin45. Most candidates used their equations correctly to find θ.

Parts (b) and (c) do not require the candidate to have values for u and θ, so full marks in the rest of the question were available to those candidates who were not successful in completing part (a).

In part (b) many candidates used the horizontal component of speed correctly and reached the correct answer. The most common error was to assume that the kinetic energy at the highest point would be zero.

There are several approaches to part (c). All of them require the candidate to realise that the speed of *P* will also be 6 m s^{-1} at a point on the upward path of *P*. Many candidates found a correct approach and reached the correct answer if they avoided arithmetic and algebraic slips. Some candidates gave a range of values for t as the final answer, e.g. $1.13 < t < 2$ rather than find the value of T. The most common error was to confuse the speed and the vertical component of the speed.

Q5.

(a) The majority of candidates understood exactly what they needed to do and they obtained the correct answer. Some candidates gave the answer as an exact fraction, which was not appropriate having substituted a value for *g*. Some candidates started by finding a correct expression for the maximum friction, but then they included a weight component when finding the work done against the friction. There were also a few trig errors.

(b) The method for finding the change in potential energy of an individual block was generally well understood and when a negative answer was reached, almost all candidates realised that they needed to give a positive answer. Although the question asks for the potential energy lost by the system, several candidates only considered the change in potential energy for one of the blocks.

(c) Many candidates did appreciate that they could use their results from (a) and (b), although some preferred to start afresh. There were several sign errors in forming the work-energy equation, although the most common error was to try to work with only one of the blocks. If only one block is considered then it is also necessary to consider the work done by the tension in the string, but this was usually overlooked. It was extremely rare for the instruction to use a work-energy approach to be ignored.

Q6.

(a) This was a good source of marks for many students. A clearly labelled diagram helped to avoid confusion between masses and forces. Almost all students understood the relationship between the driving force and the rate of work of the engine. Most students formed a combined equation of motion for the car and the trailer, but the alternative using separate equations was seen. The most common errors in the equation of motion were confusion between weight and resistance, and omission of one or more terms from the equation. At the very end, some students did not express their final answer in kilowatts, and several made errors in dividing by 1000.

(b) This part of the question did not depend on a correct solution to (a) and there were several fully correct solutions. The common errors were to quote a dimensionally incorrect equation, usually by using an incorrect expression for the kinetic energy, or by using 200 rather than 200*d*. The gain in potential energy was often included twice, once as gain in potential energy, and once as work done against the weight. Some students tried to write down an equation for the system as a whole, not just for the trailer. The final mark was often lost for given the answer to more than three significant figures.

Q7.

Students were generally successful when answering this question, although in part (a) some simply found the driving force, some tried to use energy and a few had sin/cos errors. In part (b) common errors were omission of the component of the weight from the equation of motion, using 140 for the driving force or leaving out the acceleration. Some still ignore the instructions regarding use of $g = 9.8$ and gave answers as fractions (e.g. $a = \frac{11}{15}$) which lost the final A mark.

Q8.

Part (a) was a standard scenario and all but a small number scored full marks. The second part was also done well, but sometimes spoiled by the over-accuracy of the final answer and/or sign errors in the equation of motion.

Q9.

Most candidates showed a good understanding of the methods required here and many correct solutions were seen. The most common error was a sign error in the equation for the motion down the road and there were some algebra slips in solving the simultaneous equations. A few candidates made an error in converting 10.8 kW to 10800W, and there were some incorrect equations for the relationship between power, driving force and velocity.

Q10.

This question proved to be a very straight forward opening for most candidates. It was clear that almost all were very familiar with the topic and knew exactly what to do in both parts. It was rare for marks to be dropped in either part, although sign errors did occur, particularly in part (b). A small number of candidates dropped marks through giving a final to more than 3 significant figures, but this was rare.

Q11.

The majority of candidates understood how to use the rate of working to find the driving force provided by the engine. Errors in setting up the equation of motion were rare, but there were some slips in the algebra and arithmetic in the course of rearranging this as a quadratic in U.

Most candidates used their calculators to solve the resulting equation and while this could score full marks, any slip in producing the equation led to the final 2 marks being lost. Some candidates took the precaution of showing the solution using the quadratic formula, but that formula needs to be used correctly to score the method mark.

Many candidates did not score the final A mark due to giving their answer to more than 3 significant figures, following the use of $g = 9.8$.

Q12.

This proved to be a very accessible question for the majority of candidates, with many scoring full marks. The most common error was to assume that the cyclist was moving up the road rather than down, resulting in a sign error in the equation of motion.

The solution of this question involves substituting a value for g, so a final answer expressed as an exact fraction is not appropriate.

Q13.

Most candidates understood the relationship between power, driving force and speed. They were able to form a pair of simultaneous equations and solve to find the values of *P* and *R*. Apart from sign errors in the equations, most errors were due to a confusion between mass and weight. Some candidates consistently worked through with a mass of 9000 kg. Several students worked with the correct weight, 9000 N, but then used $9000\times\frac{g}{20}$ in place of $\frac{9000}{g}\times\frac{g}{20}$ in the equation for the motion down the hill.

Q14.

Part (a) was a relatively straight forward projectiles question, and most candidates handled it well. The most common error seen was not using -15 for the vertical displacement, leading to the answers for part (a) and (b and c) being reversed. Several candidates did not realise the time to land was given as 3s, which made their work extremely complicated, attempting to produce equations at a general time, which they were unable to solve to find u and θ.

In part (b) by far the most popular successful approach was to find horizontal and vertical components and then use Pythagoras, with a minority attempting to use energy. Whilst most knew the horizontal component from (a), it was not uncommon for the initial speed to be used in the vertical equation, rather a component of it. A significant number of candidates found a vertical component but then failed to use Pythagoras to find the speed.

In part (c), whilst most candidates knew what was required, very few gained the final mark. Although earlier in the question candidates were often confused over what was speed and what was a component of speed, most could identifiably be seen to attempt to use what they thought were horizontal and vertical components correctly. However, either due to earlier mistakes, or premature rounding, the correct answer was rarely reached, with 49.7 being a common answer.

Those who did reach 49.8, rarely included the description of "below" the horizontal, or drew a clear diagram to indicate this direction.

Q15.

Throughout this question marks were lost by not giving answers to an appropriate degree of accuracy. The first part was usually well done, although there were some students who failed to follow the instruction in the question and did not use an energy method and lost all of the marks as a result. In part (b), those who used equations involving angles α and β found it difficult to eliminate β. The third proved to be a problem for many, with the direction of the vertical component of velocity causing problems. In part (d), a correct strategy eluded most but for those who did make progress, the most popular choice of method was Alt 2 on the markscheme.

Q16.

Most candidates demonstrated a good understanding of work and power, but many lost at least one accuracy mark through giving answers to more than three significant figures or by giving an answer for P in watts rather than in kilowatts.

In part (a) some candidates considered only the work done against the resistance to motion or only the work done to increase the potential energy. Another common error involved using 10 m or 14 m as the distance travelled.

Q17.

Most candidates scored some marks in part (a) of this question. A few used $\sin\alpha$ in place of $\cos\alpha$, but the most common error was to find the total work done, rather than just the work done against friction.

The wording in part (b) refers to the whole system, but many candidates considered only the potential energy gained by P. Some candidates who did consider both particles had them both gaining or both losing potential energy – this suggests a very limited understanding of the physical model described in the question.

Again in part (c), many candidates considered just one particle rather than the whole system. It was only in rare cases that a candidate considering only one particle found the tension in the string and included the work done by the tension in their work-energy equation. Some candidates did achieve a "correct" answer by using an incorrect method and making sign errors – they scored no marks.

A few candidates ignored the instruction to use the work-energy principle and attempted to find the speed of P using equations for motion with constant acceleration. Some of these obtained the correct answer but scored no marks because they had not used the method required.

Q18.

Almost all got full marks in part (a) with the most common answer being 217, although many gave it as 650/3 or 216.7. A few lost the last A mark for truncating the answer to 216.6. The second part was also done well, with most arriving at an answer of 8. However, many did not show their method for solving the quadratic equation and just gave 8 as the answer, presumably after using their calculator. This is fine if they get the correct answer but it should be noted that if the answer is incorrect then the method mark is also automatically lost. However, many simplified the equation to $V^2 + 42V - 400 = 0$ and factorised it. There were very few who had the correct equation but failed to solve it correctly and use of $12/V$ instead of $12000/V$ was rarely seen.

Q19.

In part (a) many used a correct method with full working. However, a few tried to work out the tension in the string and include that in their formula or to include kinetic energy. In contrast, candidates found the second part much more demanding. Many realised that they needed to include KE, PE and work done against friction (by multiplying 3/5 mg by d) but a common error was to omit the KE of one of the particles or just to write $\frac{1}{2}mv^2$ without indicating which mass they were using. Many didn't realise that they could use their answer from part (a) and gave two separate terms to calculate the loss in PE. If they had the correct number of terms, then they usually went on to get full marks in part (b) although there were the occasional sign errors. Most gave the answer as a fraction although a few stated it as $0.64gd$. Many candidates did not score any marks for part (c) as it was common to see use of $s = vt$ or to use an acceleration of g. However, some did pick up the M mark for using their incorrect answer from part (a) in a correct equation.

Q20.

Most students made a confident start to this paper, with the majority giving a fully correct solution to part (a)

Part (b) presented more of a challenge. There were a number of fully correct solutions, but some students omitted the component of the weight from their equation of motion, some used the value of *R* obtained in part (a) rather than the value given in the rubric for part (b) and some made sign errors in their equation. Some students made slips in converting 50 kW to watts, and some gave more than 3 significant figures in their final answer.

Q21.

This question requires students to use the work-energy principle. "Correct" answers acquired solely through the use of *suvat* equations scored no marks. It is possible to answer this question by direct application of a work-energy equation for the motion from the instant of projection to the instant when the ball comes to rest. Many students engaged in unnecessary work using *suvat* equations to find additional values such as the maximum height reached or the speed of impact with the ground. Most students did notice the different units in 1.5 m and 2.5 cm and dealt with this correctly. The most common error in the work-energy equation was to leave out the GPE lost in the final 2.5 cm of the motion. Some students who worked from the maximum height included a KE term which should not have been there as the ball is starting and finishing at rest.

Q22.

The majority of candidates understood how to find the magnitude of the force due to the friction between the package and the ramp, but far fewer went on to find the work done against the friction as the package moved up the ramp. Most candidates used correct expressions for the loss in kinetic energy and the gain in gravitational potential energy, but many of the work-energy equations involved the friction, not the work done against friction, making them dimensionally incorrect. There is still a significant minority of candidates who include both the gain in potential energy and the work done against the weight.

The question asked candidates to "use the work-energy principle", so solutions using the *suvat* equations were not accepted.

Q23.

(a) Many candidates found the value of *F* correctly. The most common error was to state that the work done against friction was *F*, rather than 6*F*. There were also some sign errors and some candidates omitted a term from the work–energy equation, or counted the change in gravitational potential energy twice. Some candidates lost the final mark due to giving an overspecified answer.

(b) Several candidates gave a fully correct solution. The most popular approach was to consider the horizontal and vertical components of the velocity at *C*, but the use of energy was a common alternative. Some candidates were confused between the speed of 10 ms^{-1} and its horizontal and vertical components. The statements about the direction of motion of *P* at *C* were not always clear; here again, a diagram can be very useful.

(c) Most candidates used *suvat* equations to solve this problem. There were many correct solutions, but a few candidates found the additional height above *B* and went no further.

Q24.

In part (a), the majority used energy as instructed and correctly obtained $u = 9.8$ but some had signs confused in their energy equation and some ignored energy altogether (which received no credit). For part (b)(i), many started completely from scratch and treated it as a projectile question, with a significant number splitting the motion, firstly to the maximum height and then from there to the ground. This obviously introduced lots of potential errors in components and distances used and in combining the final vertical and horizontal components to get the final velocity. Very few realised, due to conservation of energy, that w had to be the same as u. Most of those who obtained $w = 9.8$ did so from projectile methods. Some tried to use *suvat* incorrectly. Following on from difficulties in finding w, many struggled to find the correct angle in part (b)(ii). Many students understood how to do part (c), but were hampered because of earlier errors. A time was often found in part (b) and used in part (c), usually correctly, but in both part (b) and part (c) there was a significant number who used 9.8 as the initial speed of projection.

Mark Scheme

Q1.

Question Number	Scheme	Marks
a	Impulse-momentum equation: $(-4\mathbf{i}+3\mathbf{j}) = 3(\mathbf{v} - (3\mathbf{i}+5\mathbf{j}))$	M1A1
	$\mathbf{v} = \frac{5}{3}\mathbf{i}+6\mathbf{j}$	A1
	Find the magnitude: speed$=\sqrt{\left(\frac{5}{3}\right)^2+6^2} = 6.23$ (m s^{-1}) (6.2 or better)	M1A1 (5)
b	Gain in KE $=\frac{m}{2}\left(\lvert\mathbf{v}\rvert^2-\lvert\mathbf{u}\rvert^2\right)=\frac{3}{2}\left((\text{their } 6.23)^2-(3^2+5^2)\right)$	**M1A1 ft**
	$=7.17$ (J) (7.2 or better) (must be +ve)	A1 (3)
		[8]
	Notes	
a	First M1 for $\pm(-4\mathbf{i}+3\mathbf{j}) = 3(\mathbf{v} - (3\mathbf{i}+5\mathbf{j}))$ (M0 if 3 omitted or wrong mass used or term omitted) First A1 for a correct equation Second A1 for a correct **v** Second M1 for finding the magnitude of their **v** Third A1 for $\frac{\sqrt{349}}{3}$, 6.2 or better.	
b	M1 for $\pm\frac{3}{2}((\mathit{their}6.23)^2 - (3^2+5^2))$ (M0 if 3 omitted or wrong mass used or term omitted) Also M0 for $\pm\frac{3}{2}\left\{(\frac{5}{3}\mathbf{i}+6\mathbf{j})^2 - (3\mathbf{i}+5\mathbf{j})^2\right\}$ unless it becomes $\pm\frac{3}{2}\left\{((\frac{5}{3})^2+6^2)-(3^2+5^2)\right\}$ First **A1ft** on their **v** for a correct expression Second A1 for 43/6 oe, 7.2 or better.	

Q2.

Q	Scheme	Marks	Notes
	Impulse- momentum equation	M1	Must be subtracting velocities (or equivalent). Dimensionally correct.
	$4\mathbf{i}+5\mathbf{j}=\frac{1}{2}(\mathbf{v}-(2\mathbf{i}-3\mathbf{j}))$	A1	Correct unsimplified equation.
	$\mathbf{v}=10\mathbf{i}+7\mathbf{j}$	A1	Seen or implied
	KE Gain	M1	Dimensionally correct. Condone $\pm$ Must be difference of two KE terms.
	$=\frac{1}{2}0.5(10^2+7^2-(2^2+(-3)^2))$	A1ft	Correct unsimplified expression Follow their v . Condone $\pm$
	$=34$ J	A1	CSO
		(6)	

Q3.

Question Number	Scheme	Marks
a	PE lost $= 4g \times 1.5 - 2g \times 1.5 \sin\theta$ $\left(= 6g - 3g \times \frac{3}{5}\right)$ $= \frac{21g}{5} = 41.2$ (J) or 41 (J)	M1A1 A1 cao **(3)**
b	Friction $= \frac{1}{5} \times 2g\cos\theta$ Work done against friction $= 1.5 \times$ their F $= \frac{12g}{25} = 4.70$ (J) or 4.7(J)	B1 M1 A1 cao **(3)**
c	Work-energy equation: gain in KE $= \frac{21g}{5} - \frac{12g}{25} = \frac{1}{2} \times 4v^2 + \frac{1}{2} \times 2v^2$ $\Rightarrow \left(v^2 = \frac{31g}{25}\right)$ $v = 3.49$ or 3.5	M1A1ft A1 **(3)** **Total 9**

Notes	
a	
M1	Attempt at a difference in 2 dimensionally correct GPE terms. Distance up slope must be resolved.
A1	Correct expression for change in GPE. Trig need not be substituted.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f. Must be positive, since question asks for energy lost, but condone dropping of minus without justification, if subtracted the wrong way.
b	
B1	Correct expression for friction. Allow in terms of μ, as long as they state $\mu = 1/5$.
M1	Dimensionally correct attempt at WD with their friction. Must have found a friction.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f.
c	
M1	Work energy equation with change in GPE, WD and 2 KE terms (possibly combined).
A1ft	Correct equation. Follow through their (dimensionally correct) GPE and WD terms.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f.

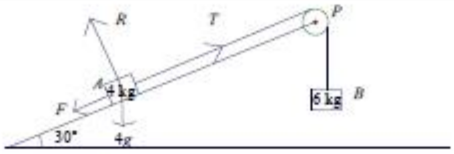
Q4.

Question Number	Scheme	Marks	Notes
a	Equate horizontal components of speeds:	M1	
	$u\cos\theta° = 6\cos 45°\left(=3\sqrt{2}\right)$ (4.24....)	A1	Correct unsimplified
	Use suvat for vertical speeds: $u\sin\theta° - 2g = -6\sin 45°$	M1	Condone sign errors
	$\left(u\sin\theta = 2g - 3\sqrt{2}\right)$	A1	Correct unsimplified
	Divide to find $\tan\theta$: $\tan\theta = \dfrac{2g - 6\sin 45}{6\cos 45}$	DM1	Dependent on previous 2 Ms. Follow their components.
	$\left(= \dfrac{2g-3\sqrt{2}}{3\sqrt{2}} = 3.61..\right) \Rightarrow \quad \theta = 74.6 \ (75)$	A1	$(u = 15.93....)$
		(6)	
b	At max height, speed $= u\cos\theta (= 3\sqrt{2}$ (m s^{-1}))	B1	
	KE $= \dfrac{1}{2}\times 0.7\times\left(3\sqrt{2}\right)^2$ (J)	M1	Correct for their v at the top, $v \neq 0$
	$= 6.3$ (J)	A1	accept awrt 6.30. CSO
		(3)	
c	When P is moving upwards at 6 m s^{-1}	M1	Use suvat to find first time $v = 6$
	$u\sin\theta - gt = 3\sqrt{2}$	A1	
	$2g - 3\sqrt{2} - gt = 3\sqrt{2}$	M1	Solve for t
	$t = \dfrac{2g - 6\sqrt{2}}{g} = 1.13....$	A1	Sensitive to premature approximation. Allow 1.14.
	$T = 2 - 1.13 = 0.87$	A1	CAO accept awrt 0.87
		(5)	
		[14]	

Alt c	$6\sin 45 = 0 + gt$	M1A1	find time from top to A:
	$T = 2t = \dfrac{\frac{12\sqrt{2}}{2}}{g} = 0.87$	M1 A1 A1	Correct strategy Correct unsimplified
		(5)	
Alt c	: $u\sin\theta = gt$ (their u, θ)	M1	Time to top
	$t = 1.567....$	A1	
	$T = 2(2 - 1.567...)$	M1A1	
	$= 0.87$	A1	
		(5)	
Alt c	Vertical speed at A = - (vertical speed at B) = $= \sqrt{36 - \left(3\sqrt{2}\right)^2} = 3\sqrt{2}$	M1 A1	Or use the 45° angle
	Use $v = u + at$ for $A \rightarrow B$	M1	Correct use for their values
	$-3\sqrt{2} = 3\sqrt{2} - gT$	A1	
	$T = 0.87$	A1	
		(5)	

Alt d	$v^2 = \left(3\sqrt{2}\right)^2 + (u\sin\theta - gt)^2 \leq 36$	M1	Form expression for v^2. Inequality not needed at this stage
		A1	Correct inequality for v^2.
	$-\sqrt{18} \leq u\sin\theta - gt \leq \sqrt{18}$	M1	
	$\dfrac{u\sin\theta - \sqrt{18}}{g} \leq t \leq \dfrac{u\sin\theta + \sqrt{18}}{g}$	A1	
	$T = \dfrac{u\sin\theta + \sqrt{18}}{g} - \dfrac{u\sin\theta - \sqrt{18}}{g} = \dfrac{2\sqrt{18}}{g} = 0.866$	A1	
		(5)	

Q5.

Q	Scheme	Marks	Notes
(a)			
	$R = 4g\cos 30°$	B1	
	$F = \frac{1}{\sqrt{3}}R\left(=2g\right)$	M1	Use of $F = \mu R$
	Work done $= 1.5F$	M1	Independent. Correct method for work done seen or implied. Allow without a value for F found
	$= 3g$ or 29.4 (J) or 29 (J)	A1	Not $\frac{147}{5}$
		(4)	
(b)	PE lost by B $-$ PE gained by A	M1	Dimensionally correct. Condone sin/cos confusion and sign errors.
	$= 6g\times 1.5 - 4g\times 1.5\sin 30°$	A1	Correct unsimplified expression. Allow $\pm\left(6g\times 1.5 - 4g\times 1.5\sin 30°\right)$
	$= 6g$ or 58.8 (J) or 59 (J)	A1	
		(3)	
(c)	Work energy equation	M1	Q asks for work-energy. Need all terms. Dimensionally correct. Condone sign errors.
	$\frac{1}{2}\times 4v^2 + \frac{1}{2}\times 6v^2 + 3g = 6g$	A1ft	Correct unsimplified equation. Follow their (a) and (b). $\frac{1}{2}\times 10v^2 + \text{their}(a) = \text{their}(b)$ or starting afresh
	$5v^2 = 3g \Rightarrow v = \sqrt{\frac{3g}{5}}$ or 2.42 $\left(\text{m s}^{-1}\right)$ or 2.4 $\left(\text{m s}^{-1}\right)$	A1	not $\frac{7\sqrt{3}}{5}$
		(3)	
		[10]	

Q6.

Q	Scheme	Marks	Notes
(a)	$F = \frac{1000P}{10}$	M1	Use of $P = Fv$
	Equation of motion	M1	All terms required. Dimensionally correct. Accept separate equations for the car and the trailer.
	$F - 300g\sin\alpha - 800g\sin\alpha - 200 - 600$ $= 1100 \times 0.5$	A1	Unsimplified equation(s) with at most one error
		A1	Correct unsimplified equation in F (or P)
	$P = 21.2$	A1	Accept 21. Max. 3 sf
		(5)	
(b)	Work-energy equation for the trailer	M1	The Q requires work-energy. Equation for the trailer, with all terms dimensionally correct. Condone sign errors
	$200d = \frac{1}{2}.300.12^2 - 300dg\sin\alpha$	A1	Unsimplified equation with at most one error
		A1	Correct unsimplified equation
	Solve for d	DM1	Dependent on the previous M1
	$d = 52.7\ (\text{m})$ or $53\ (\text{m})$	A1	Max 3 sf
		(5)	
		[10]	

Q7.

Question Number	Scheme	Marks
a	Use of $P = Fv$: $280 = F \times 2$ oe	M1
	Equation of motion: $F - 75g\sin\theta = R$	M1 A1
	$140 - 75 \times 9.8 \times \frac{1}{21} = R$	
	$R = 105$ (or 110)	A1
		(4)
	Notes	
	First M1 for $280 = F \times 2$ oe Second M1 for resolving parallel to the plane with $a = 0$ with usual rules	
	First A1 for a correct equation as shown	
	Second A1 for 105 or 110	
b	Equation of motion: $75g\sin\theta + \frac{280}{3.5} - 60 = 75a$ or $-75a$	M1A2
	$a = 0.73$ (m s^{-2}) (0.733) or -0.73 (- 0.733)	A1
		(4)
		[8]
	Notes	
	First M1 for resolving parallel to the plane with $a \neq 0$ with usual rules First A1and Second A1 for a correct equation. Deduct 1 mark for each incorrect term. (A1A0 or A0A0) (Use of 280/2 is an A error) Third A1 for 0.73 or 0.733 (allow negative answers)	

Q8.

Question Number	Scheme	Marks
a	Use of $P = Fv$: $F = \dfrac{180}{4}$	B1
	Equation of motion: $F - R = 75 \times 0.2$	M1
	Equation in R: $\dfrac{180}{4} - R = 75 \times 0.2 \ (45 - R = 15)$	**DM1**
	$R = 30$	A1
		(4)
b	Equation of motion: $D - 75g\sin\theta - R = 0$	M1
	$\dfrac{180}{v} - 75 \times g \times \dfrac{1}{21} -$ their $R = 0$	A2 **ft**
	$v = 2.77$ or 2.8	A1
		(4)
		[8]
	Notes	
	(a) B1 for $F = \dfrac{180}{4}$ seen First M1 for equation of motion with usual rules, F does not need to be substituted Second M1, dependent on first M1, for an equation in R only with usual rules A1 for $R = 30$	
	(b) M1 for equation of motion with usual rules but none of D, $\sin\theta$ nor R need to be substituted A2 **ft** for a correct equation, in v only, ft on their R A1A0 if one error Third A1 for 2.77 or 2.8 (**Only** answers)	

Q9.

Q	Scheme	Marks	Notes
	Either equation of motion	M1	All terms required.
	Motion up the road: $F_U = R + 900g\sin\theta$	A1	One equation correct unsimplified
	Motion down the road: $F_D = R - 900g\sin\theta$	A1	Both equations correct unsimplified
	Use of $P = Fv$ to form at least one equation in R and v	M1	
	$\frac{10800}{v} = R + 900g\sin\theta$ $\frac{10800}{2v} = R - 900g\sin\theta$	A1	Correct unsimplified $(90g\sin\theta = 180)$
	$\left.\begin{array}{l}\frac{10800}{v} = R + 900g\sin\theta \\ \frac{10800}{2v} = R - 900g\sin\theta\end{array}\right\} \Rightarrow \frac{10800}{2v} = 1800g \times \frac{1}{49}$	DM1	Solve simultaneous equations, both containing R and v, for R or v Dependent on 2 preceding M marks
	$v = 15$ only	A1	One correct value
	$R = 540$ only	A1	Both values correct
	Alternative working: $2(R - 900g\sin\theta) = R + 900g\sin\theta$		
	$\Rightarrow R = 540\ ,\ v = 15$		
		(8)	
		[8]	

Q10.

Question Number	Scheme	Marks
a	Equation of motion: $F = R + 800g\sin\theta$ $= R + 80g$ Use of $P = Fv$: $F = \frac{15000}{12}(=1250)$ $R(=1250 - 80g) = 470\text{N}$ or 466	M1 A1 B1 A1 cao **(4)**
b	Equation of motion: $\frac{15000}{12} + 80g - 500 = 800a$ $a = 1.9$ (m s^{-2}) or $a = 1.92$	M1A1 A1 cao **(3)**
		Total 7

Notes	
(a)	
M1	Equation of motion with Driving Force, Resistance and resolved Weight.
A1	Correct equation
B1	Use of $P = Fv$. Might be on diagram.
A1cao	470 N (466 N). **Must be 2 or 3 s.f.**
(b)	
M1	Equation of motion with Driving Force, Resistance, resolved Weight and ma.
A1	Correct equation, including correct driving force.
A1cao	$a = 1.92$ (m s^{-2}) or 1.9 (m s^{-2}) Accept -1.92. **Must be 2 or 3 s.f., but do not penalise if lost in (a).**

Q11.

Q	Scheme	Marks	Notes
	Use of $F = \frac{16000}{U}$	M1	$\frac{16}{U}$ scores M0
	Equation of motion.	M1	All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion.
	$F - 30U - 750g\sin\theta = 0$	A1	Correct unsimplified equation in F or their F
	$\Rightarrow \frac{16000}{U} - 30U - 490 = 0$ $30U^2 + 490U - 16000 = 0$	DM1	Form and solve a quadratic equation in U Horizontal form seen or implied. Dependent on the two preceding M marks Need to see working if solving an incorrect quadratic or obtain an incorrect answer.
	$U = 16.3$ or $U = 16$ only	A1	Max 3 sf
		(5)	
		[5]	

Q12.

Question Number	Scheme	Marks
	Use of $56 = FV$	B1
	Equation of motion	M1
	$F + 75g\sin\alpha - 40 = 75 \times \frac{1}{3}$	A1
	$\left(\frac{56}{V} = 65 - 49 = 16\right)$	A1
	$V = \frac{56}{16} = 3.5$	A1
		[5]
	Notes	
B1		
M1	Require all terms. Dimensionally correct.(Omission of g is an accuracy error.) Condone sine / cosine confusion and sign errors	
A1	Unsimplified equation with at most one error. In F or in V. Two signs inconsistent is 2 errors.	
A1	Correct unsimplified equation. In F or in V.	
A1	Max 3 s.f.. Not $\frac{7}{2}$ Not $3\frac{1}{2}$	

Q13.

Question Number	Solution	Marks	Notes
	Driving force $=\dfrac{3P}{12}$	B1	Use of $P = Fv$ Allow for $\dfrac{P}{12}$ in second equation if not awarded here
	Motion up the hill $F - R - W\sin\theta = 0$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\dfrac{3P}{12} - R - \dfrac{9000}{15} = 0$ $\left(\dfrac{3P}{12} - R = 600\right)$	A1	Correct substituted equation Any equivalent form
	Motion down the hill $F + W\sin\theta - R = \dfrac{9000}{9.8} \times \dfrac{9.8}{20}$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\dfrac{P}{12} + \dfrac{9000}{15} - R = 450$ $\left(\dfrac{P}{12} - R = -150\right)$	A1 A1	Substituted equation with at most one error. Any equivalent form. Correct substituted equation. Any equivalent form.
	Solve for P or R	DM1	Dependent on both preceding M marks
	$\left(\dfrac{2P}{12} = 750\right) \Rightarrow P = 4500$	A1	One correct
	$R = 525\ (530)$	A1	Both correct
		(9)	
SC1	Misread mass = 9000kg Gives equations $\dfrac{P}{4} = R + 5880$ $\dfrac{P}{12} = R - 1470$ Solutions: $P = 44100, R = 5145$		B1 M1A0 M1A1ftA0 M1A1ftA1ft Total 7/9
SC2	Use of mass = weight = 9000 Gives equations $\dfrac{P}{4} = R + 600$ $\dfrac{P}{12} = R + 3810$ Solutions: $P = -19260, R = -5415$		B1 M1A1 M1A1A0 M1A0A0 Total 6/9
		[9]	

Q14.

Note: If they have a sign error on the 15, their values for (a) and (b,c) will be swapped around. Apply follow through as per the mark scheme, for their values.

Question Number	Scheme	Marks
a	$\leftrightarrow$: $3u\cos\theta = 50$	B1
	$\updownarrow$: $3u\sin\theta - 4.9\times 9 = -15 \quad (3u\sin\theta = 29.1)$	M1A1
	Solve for u or θ : $\tan\theta = \dfrac{29.1}{50}$, $\theta = 30.2$ or 30	M1A1
	$u = 19.3$ or 19	A1
		(6)
b	Conservation of energy: $\frac{1}{2}mv^2 = \frac{1}{2}m\times 19.3^2 + 15mg$ follow their u	M1A1ft
	$v = 25.8$ (m s^{-1}) or 26	A1
b alt	Use of Pythagoras on horizontal and vertical components:	
	$\rightarrow \dfrac{50}{3} \quad \uparrow \dfrac{29.1}{3} - 3\times 9.8 (= -19.7)$	
	$v = \sqrt{\left(\dfrac{50}{3}\right)^2 + \text{"}19.7\text{"}^2}$	M1A1ft
	$v = 25.8$ (m s^{-1}) or 26	A1
		(3)
c	Use of trig to find direction: angle $= \cos^{-1}\left(\dfrac{\frac{\text{"}50\text{"}}{3}}{\text{"}25.8\text{"}}\right)$ or $\tan^{-1}\left(\dfrac{\text{"}19.7\text{"}}{\frac{\text{"}50\text{"}}{3}}\right)$	M1
	Downwards at 49.8° to the horizontal/ground $(50°)$	A1
		(2) **Total 11**

Notes	
a	
B1	$3u\cos\theta = 50$
M1	Use of $s = ut + \frac{1}{2}at^2$ for vertical motion. Condone sign errors.
A1	Fully correct equation
M1	Solve equations for either θ or u.
A1	$\theta = 30.2$ or 30 (question states degrees, so radians score A0)
A1	$u = 19.3$ or 19 (N.B. Only penalise more than 3 s.f. once per question) (Note: If they get sin/cos the wrong way round, they will still get the correct value, but score A0)
b	
M1	Conservation of energy from start to finish. Must have 2 K.E. and 1 GPE.
A1ft	Correct equation. Follow through their u.
A1cao	$v = 25.8$ or 26
alt	
M1	Use SUVAT to find vertical component of velocity at B and use Pythagoras to find speed.
A1ft	Correct (unsimplified) components. Follow through values of u and θ if used. Condone slip in processing a correct expression for vertical component before putting into Pythagoras.
A1	$v = 25.8$ or 26
c	
M1	Use their components/speed, with cos or tan to find angle.
A1	50° (49.8°) below horizontal o.e. **Must specify downwards/below/o.e. Allow a clear diagram included in, or explicitly referred to in (c)**

Q15.

Question Number	Scheme	Marks
a	Energy: $\frac{1}{2}m \times 144 = \frac{1}{2}m \times 64 + mgh$	M1A2
	$h = 4.1$ or 4.08 (m)	A1
	N.B. If they find an h, using a non-energy method, they score nothing in (a) BUT it can be used in (b), (c) and (d) without penalty.	(4)
b	Vertical distance: $h = 12\sin\alpha \times 1.5 - \frac{g}{2} \times 1.5^2$ (their h)	M1A1ft
	$(\sin\alpha = 0.839)$ $\alpha = 57.1°$ $(57°)$ (0.996 rads)	A1
		(3)
	Alt: Use $12\cos\alpha = 8\cos\beta$ and $-8\sin\beta = 12\sin\alpha - 1.5g$	
	and eliminate β to give equation in ONE trig ratio for α	M1A1ft
	$(\sin\alpha = 0.839)$ $\alpha = 57.1°$ $(57°)$ (0.996 rads)	A1
		(3)
c	Horizontal cpts: $12\cos\alpha = 8\cos\beta$ (with their α for the A mark)	M1A1ft
	$\beta = 35.4°$ $(35°)$ (0.617 or 0.62 rads)	A1
	Alt: $\tan\beta = \frac{12\sin\alpha - 1.5g}{12\cos\alpha}(= -0.709....)$ M1A1ft	
	$\beta = 35.4°$ $(35°)$ (0.617 rads or 0.62 rads) A1	
		(3)
	Alt: $h = \frac{(12\sin\alpha - 8\sin\beta)}{2} \times 1.5$ M1A1ft	
	$\beta = 35.4°$ $(35°)$ (0.617 rads or 0.62 rads) A1	
	Alt: $-8\sin\beta = 12\sin\alpha - (9.8 \times 1.5)$ M1A1ft	
	$\beta = 35.4°$ $(35°)$ (0.617 rads or 0.62 rads) A1	
d	Correct strategy e.g. $2(1.5 - T)$ where T = time to max height	M1
	Correct equations e.g. Time to max height: $T = \frac{12\sin\alpha}{g} = 1.028$ $t = 2\left(1.5 - \frac{12\sin\alpha}{g}\right)$	DM1A1
	Correct answer: $t = 0.94$ or 0.945 (s)	A1
	Alt 1: Time between the two points when $v = 8$ M1	
	$0 = 8\sin\beta t - \frac{1}{2}gt^2\left(= t\left(8\sin\beta - \frac{1}{2}gt\right)\right)$ DM1A1	
	$t = 0.94$, 0.945 A1	
	Alt 2: Find the difference between the two times when $h = 4.08$ M1	
	$h = 12\sin\alpha t - \frac{1}{2}gt^2$ for their h, α DM1A1	

	$t=1.5-0.555=0.94$ or 0.945 (s)	A1	
			(4)
	Alt 3: Use $v=u+at$ (vert) between the two points	M1	
	$8\sin\beta=-8\sin\beta+gt$	**D**M1A1	
	$t=\dfrac{16\sin\beta}{g}=0.94,\ 0.945$	A1	[14]
	Notes		
	(a) M1 for an energy equation with correct no. of terms etc. (M0 if no energy equation used) First A1 and Second A1 for a correct equation. Third A1 for 4.1 or 4.08 (m)		
	(b) M1 for a complete method to find an equation in $\sin\alpha$ only, using their h. (**N.B**. This equation could be obtained by getting two equations in α and β, which don't require h, and eliminating β, see above) First A1**ft** for a correct equation, ft on their h (if used) Second A1 for $57°$, $57.1°$, 1.0 ,1.00 rad		

	(c) M1 for a complete method to find equation in α and β only **Either** by equating horizontal velocity components: $12\cos\alpha=8\cos\beta$ **Or** by finding the vertical velocity component at B, v_V, and then using $\tan\beta=\dfrac{\lvert v_V\rvert}{12\cos\alpha}$ or $\sin\beta=\dfrac{\lvert v_V\rvert}{8}$. First A1**ft** for a correct equation. **N.B.** v_V can be found in a number of ways: $v=u+at$: $v_V=12\sin\alpha-1.5g$ $v^2=u^2+2as$: $v_V=\sqrt{(12\sin\alpha)^2-2g\times \text{their}h}$ $s=vt-\frac{1}{2}at^2 : h=1.5v_V+\frac{1}{2}g\times1.5^2 \Rightarrow v_V=\dfrac{h-\frac{1}{2}g\times1.5^2}{1.5}=\dfrac{2h}{3}-\dfrac{3g}{4}$ $s=(\frac{u+v}{2})t : h=(\frac{12\sin\alpha+v_V}{2})\times1.5 \Rightarrow v_V=\frac{4h}{3}-12\sin\alpha$ Second A1 for $\beta=35.4°$ $(35°)$ (0.617 rads or 0.62 rads)	
	(d) First M1 for a strategy to solve the problem Second **D**M1, dependent on first M, for attempt to set up an equation based on the strategy First A1 for a correct equation in t. Second A1 for 0.94 or 0.945	

Q16.

Question Number	Scheme	Marks	Notes
a	Resolving parallel to the plane	M1	Condone trig confusion
	$D = 900g\sin\theta + 800$	A1	
	$\frac{900}{25}g + 800(= 1152.8)$ (N)		
	Work done : Their $D \times$ distance $= 1152.8 \times 14 \times 10$	M1	Independent. For use of 14 x 10 x their D
	$= 161392 = 161$ kJ (160)	A1	Accept 161000 (J), 160000 (J) Ignore incorrect units.
		(4)	
	Alternative using energy:		
	Work done $= 900gd\sin\theta + 800d$ M1A1		Allow with incorrect d
	Use of $d = 14 \times 10$ M1		Independent – allow in an incorrect expression
	$= 161392 = 161$ kJ (160) A1		

b	Equation of motion	M1	All terms required. Condone trig confusion and sign errors. Allow with $900a$
	$D - 900g\sin\theta - 800 = 900 \times 0.7$	A1	Correct unsimplified with $a = 0.7$ used Accept with their 1152.8 arising from a 2 term expression in (a).
	$(D - 1152.8 = 900 \times 0.7)$		
	$D = 1782.8$ (N)		
	Use of $P = Fv$ $P = 14 \times \frac{\text{their } D}{1000}$	M1	Independent Treat missing 1000 as misread, so allow for $14 \times \text{their}D$ Allow for $\frac{1000P}{14}$ (or $\frac{P}{14}$) in their equation of motion
	$P = 25.0$ (25)	A1	CAO
		(4)	
		[8]	

Q17.

Question Number	Scheme	Marks	
a	Resolve perpendicular to the plane: $R = 2g\cos\alpha$	B1	
	Use $F = \mu R$: $F = \frac{1}{4}\times 2g\times\frac{4}{5}\left(=\frac{2g}{5}\right)$	M1	with $\frac{1}{4}$ and their R (3.92)
	Work done: WD $= 2.5\times F$	DM1	For their F
	$= 2.5\times\frac{2g}{5} = 9.8\,(\text{J})$	A1	Accept g
	If a candidate has found the total work done but you can see the correct terms/processes for finding the work done against friction, give B1M1DM1A0 (3/4)		
		(4)	
b	Change in PE : $\pm(4g\times 2.5 - 2g\times 2.5\sin\alpha)$	M1	Requires one gaining and one losing Condone trig confusion
	$=\pm(4g\times 2.5 - 2g\times 1.5)$	A1	$\pm$ (correct unsimplified)
	PE lost $= 7g = 68.6$ (J)	A1	or 69 (J) Accept $7g$
		(3)	

c	KE gained + WD = loss in GPE	M1	The question requires the use of work-energy. Alternative methods score 0/4. Requires all terms but condone sign errors (must be considering both particles)
	$\frac{1}{2}\times 4v^2 + \frac{1}{2}\times 2v^2 + (\text{their (a)}) = (\text{their (b)})$	A2	Correct unsimplified. -1 each error
	$3v^2 = 6g$		
	$v = \sqrt{2g} = 4.43\,(\text{m s}^{-1})$	A1	or 4.4. Accept $\sqrt{2g}$
		(4)	
		[11]	
	Alt 4(c)		
	Equations of motion for each particle leading to $T = \frac{12g}{5} = 23.52$ followed by a W-E equation for P: $2.5T = \frac{1}{2}\times 2v^2 + 2g\times 2.5\sin\alpha + (a)$ M1A2		Equations of motion for each particle leading to $T = \frac{12g}{5} = 23.52$ followed by a W-E equation for Q: $\frac{1}{2}\times 4v^2 + 2.5T = 4g\times 2.5$
	$v = \sqrt{2g} = 4.43\,(\text{m s}^{-1})$ A1		
	Use of $\alpha = 36.9$ gives correct answers to 3 sf		
	Use of $\alpha = 37$ gives correct answers to 2 sf and more than this is not justified, so A0 if they give 3 sf in this case.		

Q18.

Question Number	Scheme	Marks
a	$F = \dfrac{10000}{15}$	B1
	Use of "$F = ma$": $F - R = 1800 \times 0.25 (= 450)$ with their F	M1A1**ft**
	$R = \dfrac{10000}{15}$ - 450 = 220 or better , 650/3 oe (216.6..)	A1 (4)
b	$F = \dfrac{12000}{V}$	B1
	Moving at constant speed: $D = mg\sin\theta + 30V$	M1
	$\dfrac{12000}{V} = 1800g \times \dfrac{1}{14} + 30V$	A2
	Quadratic in V: $30V^2 + 1260V - 12000 = 0$	
	Solve for V: $V^2 + 42V - 400 = 0 = (V + 50)(V - 8)$	M1
	$V = 8$	A1 (6)
		[10]
	Notes	
a	B1 for $(F) = \frac{10000}{15}$ seen or implied. B0 for $\frac{10}{15}$ M1 for resolving horizontally First A1 ft for a correct equation with their F Second A1 for 650/3 oe, 220 or better i.e. 217, 216.7, ..	
b	B1 for (D) = 12000/V seen or implied. B0 for 12/V First M1 for resolving parallel to the plane with $a = 0$ but neither D nor $\sin q$ need to be substituted. First A1 and Second A1 for an equation in V only, A1A0 if one error. Second M1 for solving a 3-term quadratic in V by attempting to factorise or use the formula; this M mark can be implied by a correct answer but an incorrect answer scores M0A0. Third A1 for $V = 8$	
	N.B. Penalise use of kW ONCE per question	

Q19.

Question Number	Scheme	Marks
a	Loss in GPE : $3mgd - 2mg \times d\sin\theta = 3mgd - \frac{4}{5}mgd$	M1A1
	$d = \frac{11}{5}mgd$ ***Given answer***	A1 (3)
b	Must be using **work-energy** $\frac{1}{2}\times 2mv^2 + \frac{1}{2}\times 3mv^2 + \frac{3}{5}mgd = \frac{11}{5}mgd$	M1A2
	$v^2 = \frac{16}{25}gd$	A1 (4)
c	Use of $s = \frac{u+v}{2}t$ or equivalent: $1.5 = \frac{(0+\sqrt{\frac{24g}{25}})}{2}T$	M1
	$T = 0.98$ or 0.978 or $5\sqrt{30}/28$	A1 (2)
		[9]
	Notes	
a	M1 for $\pm(3mgd - 2mgd\sin q)$ (allow if cos used instead of sin) First A1 for a correct unsimplified expression in $\pm mgd$ Second A1 for given positive answer	
b	First M1 for a dimensionally correct work-energy equation, with all 4 terms as above, if they use the answer from (a), **OR**: $\frac{1}{2}$ ´ $2mv^2 + \frac{1}{2}$ ´ $3mv^2 + \frac{3}{5}mgd + 2mgd\sin q = 3mgd$ i.e. all 5 terms if they don't, but condone sign errors. (M0 if incorrect no. of terms) First A1 and Second A1 for a correct equation, A1A0 if one error. Third A1 for $\frac{16gd}{25}$ oe or $6.3d$ or $6.27d$	
c	M1 for a complete method to give an equation in T only. (M0 if they just assume a value for a e.g. $a = 0$ or g) A1 for 0.98 or 0.978 or $15/\sqrt{(24g)}$ oe	

Q20.

Question Number	Scheme	Marks	Notes
(a)	$F = \frac{11760}{10}$	B1	Seen or implied
	$R = F - 1200g\sin\alpha$	M1	Motion up the slope. Allow with F. Need all three terms but condone sign errors. Condone trig confusion
	$R = \frac{11760}{10} - 1200g\frac{1}{15}$	A1	Correct equation, correctly substituted.
	$R = 390$ (392)	A1	Max 3 s.f.
		(4)	
(b)	$F = \frac{50000}{V}$	B1	Seen or implied. Could be scored after incorrect work on an energy equation to find F
	$F - 1200g\sin\alpha - 700 = 1200 \times 1.5$	M1	Equation of motion. Must be using 700. Need all four terms but condone sign errors. Condone trig confusion
		A1	Equation in V or F (and α) with at most one error. Their F
	$\frac{50000}{V} - 1200g\frac{1}{15} - 700 = 1200 \times 1.5$	A1	Correct equation in V
	Solve for V	DM1	Dependent on previous M
	$V = 15$ (15.2)	A1	Max 3 s.f.
		(6)	
		10	

Q21.

Question Number	Scheme	Marks	Notes
	W.D against R: $0.025R$	B1	Seen or implied
	W.D. against R = KE Loss + PE Loss	M1	Work-energy equation. NB Q asks for work-energy. Need all relevant terms and no extras. Follow their WD. Condone 2.5 for 0.025. 1.5 for 1.525 is M0 - this is equivalent to leaving out a term in the work-energy equation.
	$0.025R = \frac{1}{2}\times 0.6\times 22.4^2 + 0.6g\times(1.5+0.025)$	A1	At most one error. Use of 2.5 for 0.025 is one error
		A1	Correct unsimplified. Follow their WD
	$R = 6380$ N	A1	Q asks for 3 s.f. - do not accept 6400
		5	
			Values you might see: KE $= 150.528$(J) Distance to top $= 25.6$(m) Top to ground $= 27.1$(m) Total distance from top $= 27.125$(m) v^2 at ground $= 531.16$ Change in GPE from top to stop $= 159.495$(J)

NB The Q asks for work-energy. Full marks can be scored for a solution which eventually uses work-energy. A candidate who does additional work with *suvat* equations scores no marks until they form a work-energy equation.

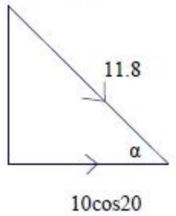
NB If working from the max height to the lowest point then the work-energy equation need not show the zero value for KE. Non-zero KE in this instance is M0 for an additional term.

WD	h	Marks	
$0.025R$	$1.5+2.5$	B1M1A1A0A0	One error 3/5
$0.25R$	$1.5+0.025$	B0M1A1A1A0	One error 3/5
$0.25R$	$1.5+2.5$	B0M1A1A0A0	Two errors 2/5

Q22.

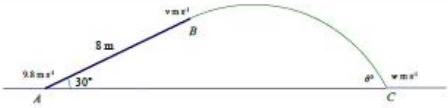
Question Number	Scheme	Marks
	Work energy equation KE lost = WD + PE gain	M1
	$\frac{1}{2}\times 2\times 16 = \text{WD} + 2g\times 2.5\sin\theta$	A1
	$(\text{WD} = 9)$	A1
	Use of $F = \mu\times 2g\cos\theta$	B1
	Use of Work done $= 2.5F$	B1
	$9 = 2.5\times\mu\times 2g\cos\theta \Rightarrow \mu = 0.19$	A1 (6) [6]
M1	Must be using work-energy. Require all terms. Dimensionally correct. Allow their WD, but must be WD, not F Condone sine/cosine confusion and sign errors	
A1	Unsimplified equation with at most one error	
A1	Correct unsimplified equation NB: $16 = WD + 7$ seen scores 3 marks	
B1	$(F = \mu\times 19.398...)$ Allow $\pm$ This mark is available if they use a *suvat* approach	
B1	Allow $\pm$	
A1	Or 0.186. Max 3 sf. Not $\frac{3\sqrt{3}}{28}$	

Q23.

Q	Scheme	Marks	Notes
a	Change in KE: $\frac{1}{2}\times3\times(15^2-10^2)\quad(=187.5)$ (J) Gain in GPE: $3g\times6\sin20\quad(=60.3....)$ (J) Work done against friction: $6F$	B1 B1 B1	One term correct unsimplified Two terms correct unsimplified All three terms correct unsimplified
	Work energy:	M1	Dimensionally correct. All terms needed. Condone sign errors and sin/cos confusion
	$187.5=6F+18g\sin20$	A1	Correct unsimplified equation
	$F=21.2\quad(21)$	A1	
		(6)	
b	Energy:	M1	Dimensionally correct. All terms needed. Condone sign errors and sin/cos confusion
	$\frac{1}{2}\times3\times100+3\times9.8\times6\sin20=\frac{1}{2}\times3\times w^2$	A1	Correct unsimplified equation
	$w=11.8\ (12)\ (\text{m s}^{-1})$	A1	
			
	Direction : $\cos\alpha=\frac{10\cos20}{11.84...}$	M1	Use trig. to find a relevant angle
	$37.5°\ (37°)$ below the horizontal	A1	
		(5)	
b alt	Find components and use Pythagoras:	M1	Condone sign errors and sin/cos confusion
	$w=\sqrt{\left((10\sin20)^2+12g\sin20\right)+(10\cos20)^2}$	A1	Correct unsimplified equation $(v_x=9.396...,\quad v_y=7.205...)$
	$w=11.8\ (12)\ (\text{m s}^{-1})$	A1	
	Direction : $\tan\alpha=\frac{\sqrt{(10\sin20)^2+12g\sin20}}{10\cos20}$	M1	Use trig. to find a relevant angle
	$37.5°\ (37°)$ below the horizontal	A1	
		(5)	

Q	Scheme	Marks	Notes
c	Use *suvat* to find height above *B*:	M1	Complete method
	$(10\sin20)^2=2g\times s\qquad(s=0.5968....)$	A1	Correct unsimplified equation in s
	Total height $=s+6\sin20$	DM1	Dependent on the preceding M1
	$=2.65\ (2.6)$ (m)	A1	
		(4)	
c alt	Vertical component of w (by trig or Pythagoras)	M1	
	$=7.205..$	A1	
	Max ht $=\frac{v^2}{2g}$	DM1	Dependent on the preceding M1
	$=\frac{7.205^2}{19.6}=2.65$	A1	
		(4)	
c alt	Conservation of energy:	M1	Using speed at max ht $=10\cos20°$ Need all terms. Condone sign error
	$\frac{1}{2}\times3\times(10\cos20°)^2+3gh=\frac{1}{2}\times3w^2$	A1	Correct unsimplified equation
	$h=\frac{w^2-100\cos^2 20°}{2g}$	DM1	Substitute for w and solve for h Dependent on the preceding M1
	$=2.65\ (2.6)$ (m)	A1	
		(4)	
		[15]	

Q24.

Question Number	Scheme	Marks
		
a	Energy: $\frac{1}{2}m\times 4.2^2 + mg\times 8\sin 30° = \frac{1}{2}m\times u^2$	M1A2
	$u^2 = 96.04 \Rightarrow u = 9.8$ or 9.80	A1 (4)
	Notes	
	M1 for energy equation with correct no. of terms (M0 if not using energy) First A1 and Second A1 for a correct equation. Deduct 1 mark for each incorrect term. (A1A0 or A0A0) Third A1 for $u = 9.8$ or 9.80 (49/5 is A0 because of rubric on qu paper)	
b (i) b(ii)	Their u or 9.8 $\tan\theta° = \frac{w_V}{w_H}$ or $\cos\theta° = \frac{w_H}{w}$ or $\sin\theta° = \frac{w_V}{w}$ where $w_H = 4.2\cos 30°$; $w_V = \sqrt{(4.2\sin 30)^2 + 2g\times 4}$; $w =$ their u $\theta = 68$ or 68.2	**B1 ft** M1 **A1 ft** A1
	Notes	(4)
	B1 **ft** for $w =$ their u or if they use energy again $w = 9.8$ (Do not award if it has come from use of $v^2 = u^2 + 2as$, without components, for a projectile, or any other incorrect method) M1 for a complete method to produce an equation in θ only, **ft** on their u value (**Allow** an inverted tan or cos/sin confusion) (M0 if they use $u = 0$ when finding w_V or don't resolve 4.2) First A1 **ft** for a correct equation in θ only, **ft** on their u or w value Second A1 for $\theta = 68$ or 68.2	

Question Number	Scheme	Marks
c	**<u>Find t</u>** **Either:** Vertical component of velocity at C: $4.2\sin 30° - gt = -w\sin\theta°$ Follow their w, θ	M1A1
	$t = 1.14$ (s) (8/7)	A1
	Or: Using vertical distance B to ground: $-4 = 4.2\sin 30°\times t - \frac{1}{2}gt^2$	M1 A1
	$t = 1.14$ (s) (8/7)	A1
	<u>Use horizontal motion:</u> **Either** : $4.2\cos 30°\times t$	M1
	$= 4.16$ (4.2) (m)	A1
	Or: (their u or w)cos(their θ)$\times t$	M1
	$= 4.16$ (4.2) (m)	A1 (5)
		[13]
	Notes	
	First M1 for a complete method to find the time with usual rules First A1 for a correct equation for their w and θ Second A1 for $t = 1.14$ or better Second M1 for horizontal motion equation with usual rules Third A1 for 4.2 or 4.16 (m)	