3.2 Further Mechanics: Work, Energy and Power: 30-minute Pack

Total Marks

AQA 7367 · Calculator allowed · about 30 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

Formulae and modelling assumptions used in this worksheet

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Unless a question states otherwise, take g = 9.8 m s^-2 and model each object as a particle. Strings and ropes are light and inextensible, and any pulleys or engines are treated as smooth or ideal unless stated. Key results used across this worksheet: work done by a constant force F acting through a displacement s at angle theta to the direction of motion is W = F*s*cos(theta); kinetic energy is KE = (1/2)*m*v^2; gravitational potential energy relative to a reference level is GPE = m*g*h; the work-energy principle states that the total work done by all the forces acting on a particle equals the change in its kinetic energy; power is the rate of doing work, so for a force F moving its point of application at speed v in the direction of F, P = F*v, and the work done over a time interval is W = integral of P with respect to t; for a force that varies with displacement, F(x), the work done as the point of application moves from x = a to x = b is W = integral from a to b of F(x) dx.

1 A metal ball of mass 4 kg is released from rest at a height of 3 m above the surface of soft sand. It penetrates a distance of 0.1 m into the sand before coming to rest. The sand exerts a constant resisting force on the ball. Take g = 9.8 m/s^2.

(a) Find the speed of the ball as it hits the sand, to 3 significant figures. **(2)**

(b) Use the work-energy principle for the whole motion to find the magnitude of the resisting force, to 3 significant figures. **(3)**

(Total for Question 1 is 5 marks)

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2 A particle of mass 2 kg is released from rest at the top of a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 12/13$. The length of the plane is 8 m and the coefficient of friction between the particle and the plane is 0.15. At the bottom of the plane the particle moves onto a rough horizontal surface for which the coefficient of friction is 0.2. Take $g = 9.8$ m/s^2.

(a) Find the work done against friction as the particle moves down the plane, to 3 significant figures. **(3)**

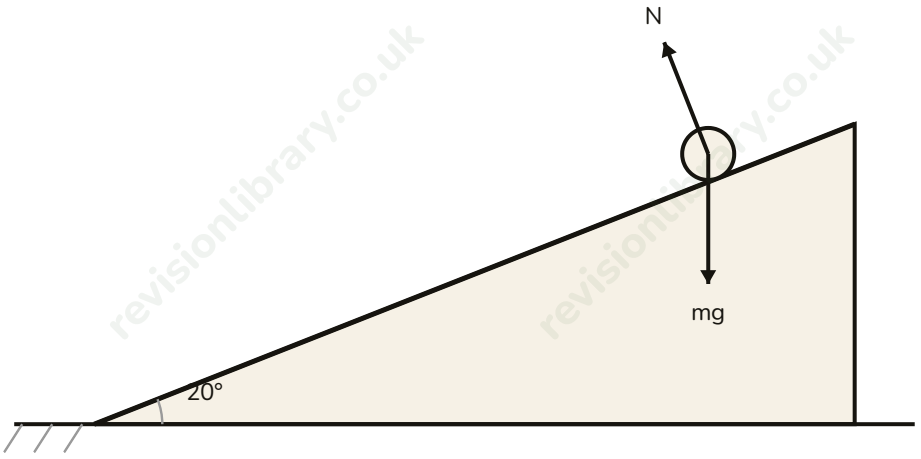
(b) Use the work-energy principle to find the speed of the particle at the bottom of the plane, to 3 significant figures. **(3)**

(c) Find the distance the particle travels along the horizontal surface before coming to rest, to 3 significant figures. **(3)**

(Total for Question 2 is 9 marks)

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3 A small block of mass 1.5 kg is released from rest at the top of a smooth incline of length 6 m, inclined at 20 degrees to the horizontal, and slides down to the bottom of the incline.



released from rest at the top; incline length 6 m

(a) Use energy methods to find the speed of the block at the bottom of the incline. **(3)**

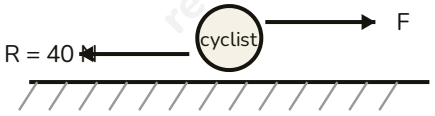
(b) Show, by resolving forces along the incline and using a suvat equation, that the same speed at the bottom is obtained as in part (a). **(3)**

(Total for Question 3 is 6 marks)

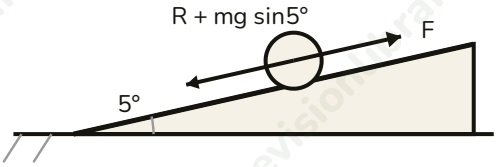
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4 A cyclist, Owen, and his cycle have a combined mass of 80 kg. Cycling along a horizontal road at a constant speed of 6 m/s, Owen experiences a constant resistance to motion of 40 N.

(a) horizontal road



(b) incline at 5°



(a) Calculate the power that Owen develops while cycling at this constant speed on the horizontal road. **(2)**

(b) Owen then rides up a hill inclined at 5 degrees to the horizontal, continuing to develop the same constant power as in part (a) and experiencing the same resistance of 40 N. Find the new constant speed at which Owen travels up the hill. **(5)**

(Total for Question 4 is 7 marks)

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Mark scheme · 3.2 Further Mechanics: Work, Energy and Power: 30-minute Pack

Question 1

(a) conservation of energy (or $v^2 = 2gh$)	**M1**
(a) $v = \sqrt{2 \times 9.8 \times 3} = 7.67$ m/s	**A1**
(a) Answer: 7.67 m/s	
(b) loss of GPE over the whole descent = work done against the resistance	**M1**
(b) $4(9.8)(3 + 0.1) = R \times 0.1$	**A1**
(b) R = 1220 N	**A1**
(b) Answer: 1220 N	

Question 2

(a) friction = $\mu R = \mu mg \cos \alpha$	**M1**
(a) work = friction x distance	**M1**
(a) 9.05 J	**A1**
(a) Answer: 9.05 J	
(b) KE gained = loss in GPE - work done against friction	**M1**
(b) $(1/2)2v^2 = 2(9.8)(8)(12/13) - 9.046$	**A1**
(b) v = 11.6 m/s	**A1**
(b) Answer: 11.6 m/s	
(c) work done against friction = initial KE	**M1**
(c) $0.2 \times 2 \times 9.8 \times s = (1/2)2(11.649)^2$	**M1**
(c) s = 34.6 m	**A1**
(c) Answer: 34.6 m	

Question 3

(a) vertical height dropped, h = 6*sin(20 degrees) = 2.05 (m), awrt	**M1**
(a) equates GPE lost to KE gained: $m*g*h = (1/2)*m*v^2$	**M1**
(a) v = 6.34 m/s, awrt, cao	**A1**
(a) Answer: v = awrt 6.34 m/s	
(b) resolves along the incline: m*a = m*g*sin(20 degrees), giving a = g*sin(20 degrees)	**M1**
(b) uses $v^2 = u^2 + 2*a*s$ with u = 0, a = 3.35 (m/s^2, awrt), s = 6	**M1**
(b) v = 6.34 m/s (awrt), matching part (a), cso	**A1**
(b) Answer: v = awrt 6.34 m/s, matching part (a) (shown)	

Question 4

(a) uses P = F*v = 40*6, with F = R at constant speed	**M1**
(a) P = 240 W, cao	**A1**
(a) Answer: P = 240 W	
(b) resolves along the slope at constant speed: driving force = R + m*g*sin(5 degrees)	**M1**
(b) m*g*sin(5 degrees) = 68.3 N, awrt	**A1**
(b) total resisting force = 40 + 68.3 = 108 (N), ft	**M1**
(b) uses P = F*v with the constant power P = 240 W from (a), ft	**M1**
(b) v = 2.22 m/s, awrt, cao	**A1**
(b) Answer: v = awrt 2.22 m/s	

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