3.2 Further Mechanics: Work, Energy and Power: Test Pack

Total Marks

AQA 7367 · Calculator allowed · about 65 minutes

Name: _____ Date: ____ / ____ / _____

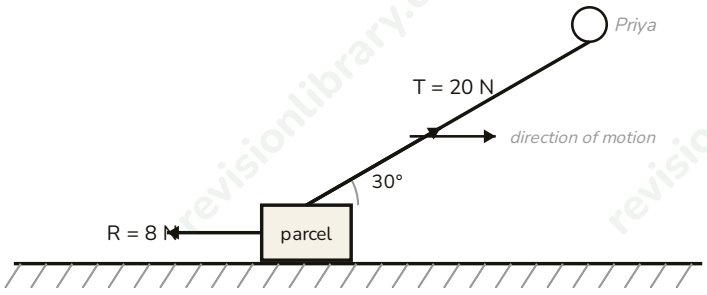
Answer ALL questions. Show all your working.

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 courier, Priya, pulls a parcel of mass 4 kg across a horizontal warehouse floor using a rope inclined at 30 degrees to the horizontal. The tension in the rope is a constant 20 N, and a constant resistance to motion of 8 N acts on the parcel as it slides. The parcel starts from rest.



(a) Given that the parcel moves a distance of 5 m across the floor, calculate the work done by the tension in the rope. **(2)**

(b) Using the work-energy principle, find the speed of the parcel after it has moved this 5 m distance. **(4)**

(Total for Question 1 is 6 marks)

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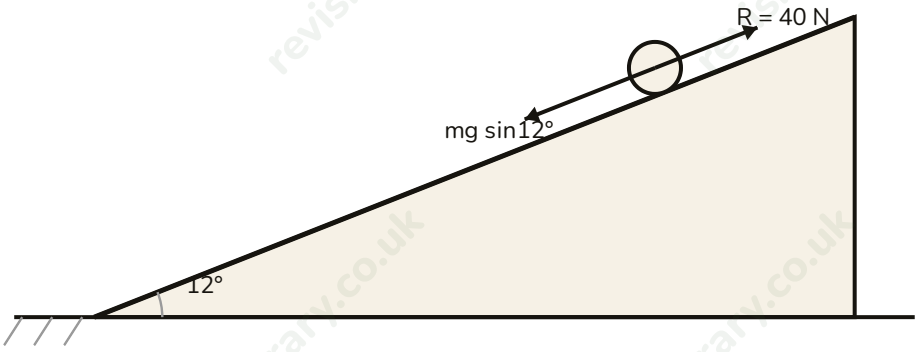
2 A car of mass 1200 kg experiences a resultant driving force of 900 N while moving at a constant speed of 18 m/s along a horizontal road.

(a) Calculate the power developed by the engine. **(3)**

(Total for Question 2 is 3 marks)

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3 A skier, Aisha, of mass 65 kg starts from rest at the top of a slope inclined at 12 degrees to the horizontal and skis down a distance of 150 m measured along the slope. The resistance to motion, from friction and air resistance combined, has constant magnitude 40 N.



skier starts from rest at the top

(a) Use the work-energy principle to find Aisha's speed at the bottom of the slope. **(5)**

(b) State one physical factor, other than air resistance and friction, that this model does not take into account and that could affect the accuracy of the calculated speed. **(1)**

(Total for Question 3 is 6 marks)

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4 A car of mass 1500 kg has an engine working at a constant rate of 60 kW. The resistance to motion is a constant 800 N whatever the speed. Take $g = 9.8\ m/s^2$.

(a) Find the maximum speed of the car on a straight horizontal road, in m/s to 3 significant figures. **(3)**

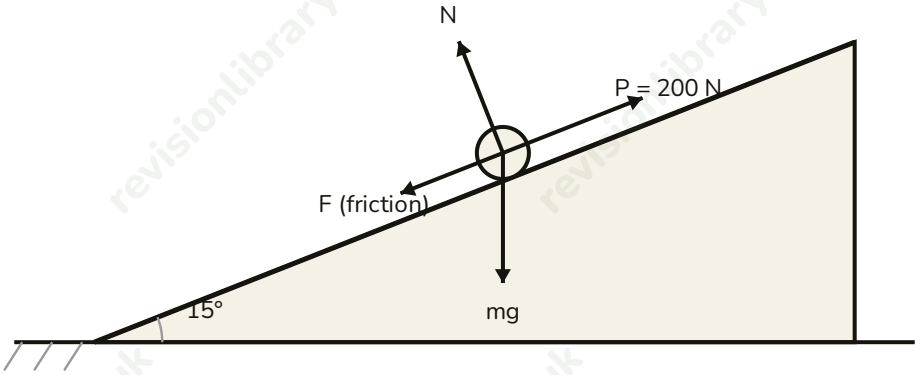
(b) Find the acceleration of the car on the horizontal road when its speed is 9 m/s, to 2 significant figures. **(3)**

(c) The car now climbs a straight road inclined at an angle α to the horizontal where $\sin \alpha = 1/20$. The engine power and the resistance are unchanged. Find the maximum speed up the hill, to 3 significant figures. **(3)**

(Total for Question 4 is 9 marks)

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5 A warehouse worker, Tomasz, pushes a crate of mass 25 kg up a rough plane inclined at 15 degrees to the horizontal, using a constant force of 200 N acting parallel to the plane. The coefficient of friction between the crate and the plane is 0.3. The crate starts from rest and moves a distance of 4 m up the plane.



crate moves up the rough plane

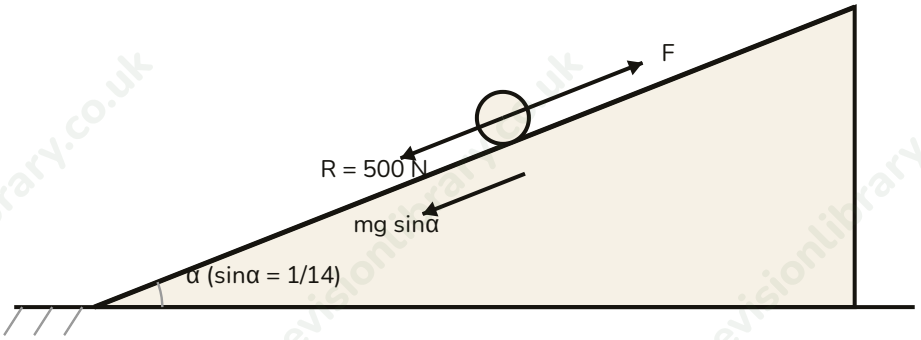
(a) Show that the frictional force acting on the crate has magnitude awrt 71.0 N. **(3)**

(b) Use the work-energy principle to find the speed of the crate after it has moved the 4 m distance up the plane. **(5)**

(Total for Question 5 is 8 marks)

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6 A car of mass 900 kg experiences a constant resistance to motion of magnitude 500 N, and its engine works at a constant power of 20 kW.



car of mass 900 kg

(a) Find the maximum speed of the car on a horizontal road. **(3)**

(b) The car now travels up a straight road inclined at angle α to the horizontal, where sin(α) = 1/14. At an instant when the car's speed is 25 m/s, the engine still works at the same power of 20 kW and the resistance to motion is still 500 N. Find the acceleration of the car at this instant. **(6)**

(Total for Question 6 is 9 marks)

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7 A particle of mass 3 kg moves in a straight line along the x-axis under the action of a single force F newtons, where F = (18 - 2x) and x is the displacement in metres from the particle's starting point, for $0 \leq x \leq 9$. The particle starts at x = 0 with speed 2 m/s.

(a) Find the work done by F as the particle moves from x = 0 to x = 5. **(4)**

(b) Find the speed of the particle when x = 5. **(3)**

(c) Explain, without further calculation, why the particle's speed is increasing throughout its motion from x = 0 to x = 9. **(2)**

(Total for Question 7 is 9 marks)

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Mark scheme · 3.2 Further Mechanics: Work, Energy and Power: Test Pack

Question 1

(a) uses W = F*s*cos(θ) = 20*5*cos(30 degrees) **M1**

(a) 86.6 J, awrt **A1**

(a) Answer: W = 86.6 J (awrt)

(b) work done against resistance = R*s = 8*5 = 40 (J) **M1**

(b) applies the work-energy principle: (1/2)*4*v^2 - 0 = (work done by tension) - (work done against resistance), ft (a) **M1**

(b) 2*v^2 = 86.6 - 40 = 46.6 (or unsimplified equivalent), ft (a) **A1**

(b) v = 4.83 m/s, awrt, cao **A1**

(b) Answer: v = awrt 4.83 m/s

Question 2

(a) uses P = F*v **M1**

(a) P = 16200 (W), cao **A1**

(a) states the answer as 16.2 kW (or 16200 W), oe **A1**

(a) Answer: P = 16200 W = 16.2 kW

Question 3

(a) work done by gravity = m*g*sin(12 degrees)*150 **M1**

(a) work done by gravity = 19900 J, awrt **A1**

(a) work done against resistance = 40*150 = 6000 (J) **M1**

(a) applies the work-energy principle: (1/2)*65*v^2 - 0 = (their gravity work) - 6000, ft **M1**

(a) v = 20.7 m/s, awrt, cao **A1**

(a) Answer: v = awrt 20.7 m/s

(b) any valid modelling limitation, e.g. the slope may not be uniform (constant angle) throughout its length; Aisha is treated as a single particle rather than an extended body; her mass, posture or technique may change during the descent; the model assumes she stays in contact with the slope throughout (oe) **B1**

(b) Answer: For example: the slope may not have a constant angle of 12 degrees along its whole length (the model assumes a uniform incline).

Question 4

(a) at maximum speed the driving force equals the resistance: F = R **M1**

(a) uses P = Fv **M1**

(a) v = 60000/800 = 75.0 m/s **A1**

(a) Answer: 75.0 m/s

(b) driving force = 60000/9 **M1**

(b) applies F = ma: driving force - resistance = ma **M1**

(b) a = 3.9 m/s^2 **A1**

(b) Answer: 3.9 m/s^2

(c) resolves along the slope: F = R + mg sin α **M1**

(c) uses P = Fv **M1**

(c) v = 60000/(800 + 1500(9.8)/20) = 39.1 m/s **A1**

(c) Answer: 39.1 m/s

Question 5

(a) normal reaction N = m*g*cos(15 degrees), value awrt 237 N **M1**

(a) friction = μ*N = 0.3*N **M1**

(a) friction = 71.0 N, cso **A1**

(a) Answer: Friction = awrt 71.0 N (shown)

(b) work done by the applied force = 200*4 = 800 (J) **M1**

(b) work done against gravity = m*g*sin(15 degrees)*4, value awrt 254 J **M1**

(b) work done against friction = 71.0*4, ft (a), value awrt 284 J **M1**

(b) applies the work-energy principle: (1/2)*25*v^2 - 0 = 800 - (their gravity work) - (their friction work) **M1**

(b) v = 4.58 m/s, awrt, cao **A1**

(b) Answer: v = awrt 4.58 m/s

Question 6

(a) at maximum speed, the resultant force is zero, so the driving force equals the resistance, F = R **M1**

(a) uses P = F*v_{max}, i.e. 20000 = 500*v_{max} **M1**

(a) v_{max} = 40 m/s, cao **A1**

(a) Answer: v_{max} = 40 m/s

(b) uses P = F*v to find the driving force at this instant, F = 20000/25 **M1**

(b) F = 800 N, cao **A1**

(b) resolves along the slope: m*a = F - R - m*g*sin(α) **M1**

(b) m*g*sin(α) = 900*9.8*(1/14) = 630 N, cao **A1**

(b) substitutes: 900*a = 800 - 500 - 630 **M1**

(b) a = -0.367 m/s^2 (i.e. deceleration of 0.367 m/s^2), awrt, cao **A1**

(b) Answer: a = -0.367 m/s^2 (deceleration of awrt 0.367 m/s^2)

Question 7

(a) sets up W = integral from 0 to 5 of (18 - 2x) dx **M1**

(a) integrates correctly to 18x - x^2 (+ c) **M1**

(a) substitutes limits: (18*5 - 5^2) - (18*0 - 0^2) **M1**

(a) W = 65 J, cao **A1**

(a) Answer: W = 65 J

(b) applies the work-energy principle: (1/2)*3*v^2 - (1/2)*3*2^2 = 65, ft (a) **M1**

(b) rearranges to v^2 = (2*65 + 3*4)/3, oe **M1**

(b) v = 6.88 m/s, awrt, cao **A1**

(b) Answer: v = awrt 6.88 m/s

(c) F = 18 - 2x > 0 for all 0 ≤ x < 9, so the force (and hence the resultant force) acts in the direction of motion throughout, oe **B1**

(c) by the work-energy principle, a positive resultant force in the direction of motion does positive work, increasing the kinetic energy (and hence the speed) throughout, oe **B1**

(c) Answer: Since F = 18 - 2x is positive for all 0 ≤ x < 9, the force acts in the direction of motion throughout, so it does positive work and the kinetic energy (and hence the speed) increases throughout.

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