5.3 Work, energy and power

Name: _____ Class: _____ Date: _____ **Total: 31 marks**

KEY WORDS kinetic energy • power

Work, energy and power

Objective

Use the work-energy principle and conservation of mechanical energy on slopes, with power $P = Fv$ for constant-rate engines, and close projectile problems by energy (objectives 1.2, 3.1).

1 Key knowledge and worked examples

Energy bookkeeping. KE $= \frac{1}{2}mv^2$; PE $= mgh$; work by a force $= Fs$ along the motion (resistance does $-Rs$ over the SLOPE distance; gravity $\pm mg\,d\sin\alpha$). Power: $P = Fv$ – at maximum constant speed F balances all resistance; otherwise $F - R - mg\sin\alpha = ma$. A perpendicular impact fixes a velocity's DIRECTION, then energy gives the height.

Worked example – car and projectile (WME02 June 2025 Q4, Q7). (i) 750 kg car on a slope $\sin\alpha = \frac{1}{7}$, resistance 200 N, engine 20 kW: constant speed $\frac{20000}{V} = 1050 + 200$ gives $V = 16$; at 10: $2000 - 1250 = 750a$ gives $a = 1$; engine off: $37500 = 1250d$ gives $d = 30$ m. (ii) Stone at 20 m s^{-1} ($g = 10$), 11 m up with components V and $2V$: $200 = 2.5V^2 + 110$ gives $V = 6$; hitting a 60° plane perpendicularly (velocity 30° below horizontal, speed $12/\cos 30° = 8\sqrt{3}$): $200 = 96 + 10H$ gives $H = 10$ m.

2 Practice

2.1 A crate of mass 20 kg is pushed 5 m up a slope at 30° to the horizontal against a frictional force of 15 N. Find the total work done against gravity and friction. [3]

2.2 An engine works at 8 kW pulling a 1200 kg car along a level road with total resistance 500 N. Find the maximum constant speed and the acceleration at 8 m s^{-1}. [4]

2.3 A ball is projected at 15 m s^{-1} and reaches its highest point. Using energy (g = 9.8), find the height risen. [2]

3 Exam-style questions

3.1 *(Edexcel IAL WME02 June 2025 Q4.)* A rough plane is inclined at α to the horizontal, where $\sin\alpha = \frac{1}{7}$. A car of mass 750 kg moves up a line of greatest slope of the plane. The total non-gravitational resistance to the car's motion is 200 N and the engine works at a constant rate of 20 kW. (a) Find the constant speed at which the car can move up the plane. (b) Find the acceleration of the car at an instant when it is moving up the plane at 10 m s^{-1}. (c) At the instant the car is moving at 10 m s^{-1} at the point A, the engine is switched off and the resistance remains 200 N. The car comes to rest at the point B. Use the work-energy principle to find the distance AB. [12]

3.2 *(Edexcel IAL WME02 June 2025 Q7.)* A small stone is projected from a point O on horizontal ground with speed 20 $\mathrm{m\,s^{-1}}$ at an angle α above the horizontal. The stone is modelled as a particle moving freely under gravity with $g = 10\ \mathrm{m\,s^{-2}}$. When the stone is 11 m above the ground, the magnitude of the vertical component of its velocity is $V\ \mathrm{m\,s^{-1}}$ and the magnitude of the horizontal component is $2V\ \mathrm{m\,s^{-1}}$. (a) Using conservation of mechanical energy, show that $V = 6$. (b) The stone hits a fixed plane, inclined at 60° to the horizontal, at the point A, the first point of contact, perpendicularly to the plane. Find the height of A above the ground (2 s.f.). [10]

Solutions

2.1 Gravity: $20(9.8)(5\sin 30^\circ) = 490$ J; friction: $15(5) = 75$ J; total 565 J.

2.2 Maximum speed: $\frac{8000}{500} = 16\ \mathrm{m\,s^{-1}}$. At 8: driving force = 1000 N, so $1000 - 500 = 1200a$ and $a = 0.417\ \mathrm{m\,s^{-2}}$ (0.42).

2.3 $\frac{1}{2}(15)^2 = 9.8h$: $h = \frac{112.5}{9.8} = 11.5$ m.

3.1 (a) At constant speed the driving force $F = \frac{P}{V}$ balances resistance plus gravity: $\frac{20000}{V} = 750(9.8)\frac{1}{7} + 200 = 1050 + 200 = 1250$, so $V = 16\ \mathrm{m\,s^{-1}}$. (b) $\frac{20000}{10} - 1250 = 750a$: $2000 - 1250 = 750a$, $a = 1\ \mathrm{m\,s^{-2}}$. (c) Work-energy: KE lost = work against gravity + friction: $\frac{1}{2}(750)(10^2) = 750(9.8)(d\frac{1}{7}) + 200d$, i.e. $37500 = 1050d + 200d = 1250d$, so $AB = 30$ m.

3.2 (a) Energy from O to the 11 m point: $\frac{1}{2}m(20)^2 = \frac{1}{2}m(V^2 + (2V)^2) + m(10)(11)$: $200 = \frac{5}{2}V^2 + 110$, so $V^2 = 36$ and $V = 6$ ✓ (components 6 and 12, speed$^2 = 180$). (b) Perpendicular to the 60° plane, the velocity makes 30° with the horizontal (below it), so with horizontal component 12 the speed is $\frac{12}{\cos 30^\circ} = 8\sqrt{3}$ and speed$^2 = 192$. Energy from O to A: $200 = \frac{1}{2}(192) + 10H = 96 + 10H$, so $H = 10.4$, i.e. 10 m (2 s.f.).

Local review guidance: $\frac{P}{V}$ for the driving force with all three slope terms present; work-energy with resistance over the slope distance and gravity over the height; perpendicular impact converted to a velocity direction before any energy statement. This is authored classroom guidance.