

Exercise walk-through

3.2

Work energy and power (full A.3)

International Baccalaureate · IB Diploma · Physics · SL

Mechanical Energy · 3.1

Reasoning

Define the system and useful output before calculating efficiency. Doubling speed quadruples kinetic energy at constant mass. Power describes transfer per time, not total energy. Measure a lifting height and load, time the lift, and record electrical input with suitable instruments. Repeat trials and account for heating or friction as transfers, not missing energy.

Power against resistance

- 1 Set the model** A car travels steadily at 25 m/s against 600 N of resistance. Input power is 20 kW.
- 2 Calculate** Useful power $P = Fv = 600(25) = 15000 \text{ W}$. Efficiency $= 15/20 = 0.75 = 75\%$.

Decision

At constant speed kinetic energy is unchanged. The engine transfers energy to the surroundings through resistance.

Exercises 2.1·2.3

2.1 A 30 N force pulls a sled 8.0 m along a rope at 40° to the horizontal. Calculate the work done. [2]

2.2 A 4.0 kg ball moves at 6.0 m/s. Calculate its kinetic energy, and its momentum. [3]

2.3 A spring ($k = 250 \text{ N/m}$) is compressed 0.12 m. Calculate the elastic energy stored. [2]

Exercises 2.1·2.3

2.1 A 30 N force pulls a sled 8.0 m along a rope at 40° to the horizontal. Calculate the work done. [2]

$$\mathbf{2.1} \quad W = 30 \times 8.0 \times \cos 40^\circ = 183.8 \approx 180 \text{ J.}$$

2.2 A 4.0 kg ball moves at 6.0 m/s. Calculate its kinetic energy, and its momentum. [3]

$$\mathbf{2.2} \quad E_k = \frac{1}{2} \times 4.0 \times 36 = 72 \text{ J}; p = 4.0 \times 6.0 = 24 \text{ kg} \cdot \text{m/s. Check: } p^2/2m = 576/8 = 72 \text{ J } \checkmark.$$

2.3 A spring ($k = 250 \text{ N/m}$) is compressed 0.12 m. Calculate the elastic energy stored. [2]

$$\mathbf{2.3} \quad E_H = \frac{1}{2} \times 250 \times 0.0144 = 1.8 \text{ J.}$$

Exercises 2.4·3.1

2.4 A crane lifts a 250 kg beam 12 m at a steady 0.50 m/s. Calculate the useful power ($g = 9.8 \text{ m/s}^2$). [3]

2.5 A motor takes 1500 W and delivers 1050 W. Calculate the efficiency as a percentage. [2]

3.1 A 0.20 kg ball is dropped from 15 m onto a spring ($k = 400 \text{ N/m}$) and compresses it with no energy loss. Calculate the ball's speed at 5.0 m above the spring, the maximum compression, and state the energy assumption. [6]

Exercises 2.4·3.1

2.4 A crane lifts a 250 kg beam 12 m at a steady 0.50 m/s. Calculate the useful power ($g = 9.8 \text{ m/s}^2$). [3]

2.4 Force = $mg = 2450 \text{ N}$; $P = Fv = 2450 \times 0.50 = 1225 \approx 1.2 \text{ kW}$.

2.5 A motor takes 1500 W and delivers 1050 W. Calculate the efficiency as a percentage. [2]

2.5 $\eta = 1050/1500 = 0.70 = 70\%$.

3.1 A 0.20 kg ball is dropped from 15 m onto a spring ($k = 400 \text{ N/m}$) and compresses it with no energy loss. Calculate the ball's speed at 5.0 m above the spring, the maximum compression, and state the energy assumption. [6]

3.1 From 15 m to 5.0 m: $\Delta E_p = 0.20 \times 9.8 \times 10.0 = 19.6 \text{ J}$ lost $\rightarrow E_k = 19.6 \text{ J}$;
 $v = \sqrt{2 \times 19.6/0.20} = 14 \text{ m/s}$. At maximum compression all $mg(15 + x)$ goes into $\frac{1}{2}kx^2$:
 $1.96(15 + x) = 200x^2 \rightarrow x = 0.39 \text{ m}$. Assumption: no air resistance – mechanical energy conserved.

Exercises 3.2-3.3

3.2 A 900 kg car accelerates from 12 m/s to 28 m/s in 9.0 s against 500 N of resistance. Calculate the change in kinetic energy, the work done against resistance (take 180 m travelled), and the minimum average engine power. [6]

3.3 Fuel A releases 45 MJ/kg and Fuel B releases 50 MJ/kg but costs 20 % more per kilogram. Explain, using energy density, which fuel gives more energy per unit cost and what else a buyer should consider. [3]

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3.2 $\Delta E_k = \frac{1}{2} \times 900 \times (784 - 144) = 2.88 \times 10^5 \text{ J}$; work against resistance = $500 \times 180 = 9.0 \times 10^4 \text{ J}$; total energy = $3.78 \times 10^5 \text{ J}$ over 9.0 s $\rightarrow P = 4.2 \times 10^4 \text{ W} = 42 \text{ kW}$ minimum.

3.3 Fuel A releases 45 MJ/kg and Fuel B releases 50 MJ/kg but costs 20 % more per kilogram. Explain, using energy density, which fuel gives more energy per unit cost and what else a buyer should consider. [3]

3.3 Per unit cost, B gives $50/1.2 \approx 41.7 \text{ MJ}$ against A's 45 MJ – A delivers more energy per unit cost; buyers must also weigh storage safety, availability and engine compatibility, not energy density alone.