5.2 Work done and energy transfer

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

KEY WORDS force

Objective

Use $W = Fs$ with the distance along the line of action, tell the energy-transfer story, and link frictional work to temperature rise. Original questions for spec statement 4.5.2.

1 Key knowledge and worked examples

A force does **work** when it causes a displacement:

$$W = Fs$$

- W work done in J; F force in N; s distance **moved along the line of action of the force** in m.
- **1 joule = 1 newton-metre**: 1 J is 1 N moving something 1 m. Convert freely: 240 N · m = 240 J.

Build an explanation that fits the question; identify the force, the energy transfer and any heating:

1. work is done **by the force** on the object;
2. energy is transferred **from** the agent (chemical store of a person, kinetic store of a vehicle) **to** the object;
3. work done **against friction** raises the object's (and surface's) **temperature** – energy dissipates to thermal stores.

Worked example. A child pushes a baby walker 2.8 m along the floor with a horizontal force of 25 N.

- The force and the movement are both horizontal – the distance is along the line of action.

$$W = Fs = 25\ \text{N} \times 2.8\ \text{m} = 70\ \text{J}$$

Worked example (vertical). A crane lifts a 250 kg beam 12 m at steady speed (g = 9.8 N/kg).

- Steady lift means the crane's force equals the weight: $F = mg = 250 \times 9.8 = 2450$ N.

$$W = Fs = 2450 \times 12 = 29\,400\ \text{J} \approx 29\ \text{kJ}$$

- The energy transfers to the beam's gravitational potential store (see topic 1).

Watch the wording: a force at right angles to the motion (a vertical normal force under a horizontally-moving box) does **no** work along that path – s must lie along the force's line of action.

2 Practice

2.1 A box is dragged 8.0 m by a 60 N force along its direction. Calculate the work done. [2]

2.2 A 50 N force does 350 J of work. Calculate the distance moved along its line of action. [2]

2.3 State what happens to the energy when work is done against friction, and give the units equivalence for one joule. [2]

3 Exam-style questions

3.1 A child pulls a toy car 4.5 m across a carpet with a horizontal force of 2.0 N.

(a) Calculate the work done by the child. [3]

(b) The same pull moves the car the same distance on a smoother floor where friction is smaller. Compare the work done by the pull and the energy dissipated by friction. [2]

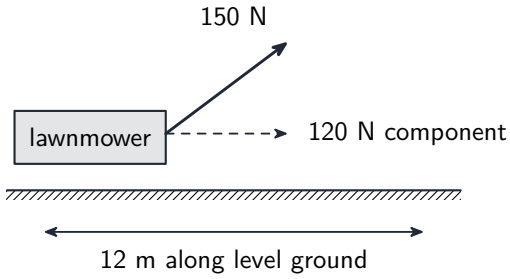
(c) The child then pushes with 2.0 N at right angles to the car's motion while it coasts 4.5 m. Explain why this force does no work on the car. [2]

3.2 A gardener pushes a lawnmower with a force of 150 N at an angle along a 12 m stretch of level ground (the force's component along the motion is 120 N).

(a) Explain which distance enters $W = Fs$ here. [1]

(b) Calculate the work done by the 150 N force along the 12 m stretch. [2]

(c) Over the 12 m the frictional force totals 100 N opposing the motion. Calculate the work done against friction and explain the associated energy transfer. [3]



Solutions

2.1

$$W = Fs = 60 \times 8.0 = \mathbf{480}\ \text{J}$$

(substitution 1, answer with unit 1)

2.2 Rearrange first: $s = W/F$ (C1).

$$s = \frac{350}{50} = \mathbf{7.0}\ \text{m}$$

2.3 The object's (and surface's) temperature rises – energy transfers to thermal stores; 1 J = 1 N · m.

3.1 (a) Force parallel to the motion.

$$W = Fs = 2.0 \times 4.5 = \mathbf{9.0}\ \text{J}$$

(C1 substitution, A1 answer, A1 unit) (b) The work done by the pull is unchanged because force and distance are unchanged. Less energy is dissipated by friction to thermal stores, so more of the input can increase the car's kinetic energy. (c) The force is at right angles to the displacement, and s must be along the line of action of the force – there is no component of this force along the motion, so no work is done on the car by it.

3.2 (a) Only the component of the force along the motion counts: use 120 N over 12 m. (b)

$$W = F_s s = 120 \times 12 = \mathbf{1440}\ \text{J}$$

(C1, A1) (c) Work against friction = 100 × 12 = **1200** J (C1); this energy transfers to the thermal stores of the blade, grass and surroundings – their temperature rises; with a level path and no other energy transfers, the remaining 240 J increases the mower's kinetic energy.