Exercise walk-through

Work ▪ 3.2

eXercise

You must be able to

- define **work** 功 as $W = Fd\cos\theta$
- explain how the **angle** 角度 between force and displacement makes work positive, negative, or zero
- calculate the work done by a constant force
- find the work done by a variable force from the **area** under a force-position graph

Method — The work formula

$W = Fd\cos\theta$, where θ is the angle between the force and the displacement. Work is a scalar, measured in joules.

Method — The sign of work

- $\theta < 90^\circ \rightarrow$ **positive** work (energy added)
- $\theta = 90^\circ \rightarrow$ **zero** work (e.g. the normal force on a box sliding along a flat floor)
- $\theta > 90^\circ \rightarrow$ **negative** work (e.g. friction opposing motion)

Method — Variable force

The work done by a changing force is the **area under the force-versus-position graph**.

Practice 2.1 ▪ 1 mark

A 30 N force pushes a box 4.0 m in the direction of the force. Find the work done.

Solution 2.1

Method: Variable force

Worked steps

$W = Fd = 30 \times 4.0 = 120$ J **B1**.

Practice 2.2 ▪ 2 marks

State the work done by the normal force on a box sliding along a flat floor, and why.

Solution 2.2

Method: The sign of work

Worked steps

zero B1 — the normal force is perpendicular to the motion ($\theta = 90^\circ$, $\cos 90^\circ = 0$) B1.

Practice 2.3 ▪ 2 marks

A 50 N force drags a crate 10 m at 37° above the horizontal ($\cos 37^\circ \approx 0.80$). Find the work done.

Solution 2.3

Worked steps

$W = 50 \times 10 \times 0.80 = 400$ J **M1** **A1**.

Practice 2.4 ▪ 1 mark

A force-position graph is a rectangle 10 N tall and 3.0 m wide. Find the work done.

Solution 2.4

Method: Variable force

Worked steps

area $= 10 \times 3.0 = 30$ J B1.

Exam-style 3.1 ▪ 1 mark

The work done by a force is zero when the angle between the force and the displacement is

A $0°$

B $45°$

C $90°$

D $180°$

Solution 3.1

Method: The work formula

A 0°

B 45°

C 90° ✓

D 180°

Worked steps

C.

Exam-style 3.2 ▪ 1 mark

Friction acting on a sliding object does

A positive work

B negative work

C zero work

D undefined work

Solution 3.2

Method: The sign of work

A positive work

B negative work ✓

C zero work

D undefined work

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

A child pulls a sled with a 40 N force at 30° above the horizontal for 20 m ($\cos 30^\circ \approx 0.87$).

(a) Find the work done by the pull.

(b) Explain why the vertical component of the pull does no work here.

Solution 3.3

Worked steps

(a) $W = 40 \times 20 \times \cos 30^\circ = 800 \times 0.87 = 696$ J M1 A1. (b) the sled moves horizontally, so the vertical component is perpendicular to the displacement and does no work B1.