

Exercise walk-through

3.5

Power

AP Physics C: Mechanics

Average and instantaneous power

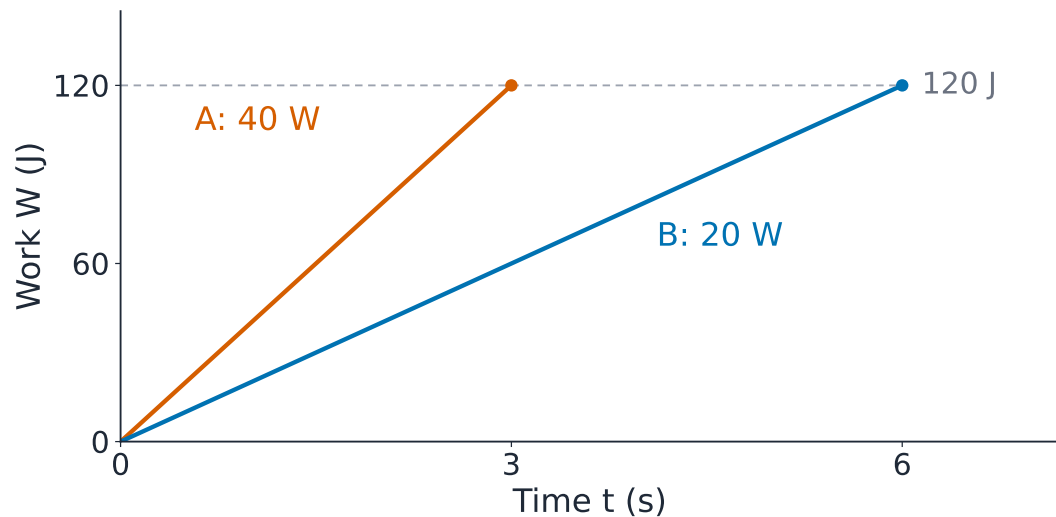
$$P_{\text{avg}} = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t}$$

$$P_{\text{inst}} = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$$

Power is energy transfer or conversion per unit time, measured in **watts** (J/s).

On a work–time graph, a secant gives interval-average power and a tangent gives instantaneous power. They agree on a straight line, but not on every curve.

Power from work–time slopes



Original example: $P = \Delta W / \Delta t = dW / dt$ on each straight segment.
The same 120 J in less time requires greater constant power.

For these straight segments, each slope is constant: average and instantaneous power agree within the segment.

Steady lifting: original attempt

Lift a 50 kg load steadily upward at 2.0 m/s, with $g = 9.8 \text{ m/s}^2$ and negligible losses.

Find the lifting force and power. Predict the power at twice the speed.

Does lifting to the same height then require twice the work? Explain the difference between energy and rate.

Steady lifting: worked check

$$F = mg = (50 \text{ kg})(9.8 \text{ m/s}^2) = 490 \text{ N}$$

$$P = Fv = (490 \text{ N})(2.0 \text{ m/s}) = 980 \text{ W}$$

At 4.0 m/s, ideal power doubles to 1960 W. For the same final height, ideal work remains mgh ; the transfer occurs in half the time.

Steady speed and negligible losses are assumptions, not consequences of the word “lift”.

Car climbing a hill: original attempt

A 1200 kg car travels steadily at 15 m/s along a road rising 1.0 m for each 20 m of road distance.

Using $g = 9.8 \text{ m/s}^2$, calculate vertical speed, then power against gravity.

What additional information would be needed to find engine input power including losses?

Exercises 2.1-2.3

2.1 A motor does 900 J of work in 3 s. Find its power. [2]

2.2 A 20 N force moves an object at 5 m s^{-1} . Find the power. [2]

2.3 State the unit of power and what it equals. [1]

Exercises 2.1-2.3

2.1 A motor does 900 J of work in 3 s. Find its power. [2]

2.1

- $P = W/t = 900/3 = 300 \text{ W}$

2.2 A 20 N force moves an object at 5 m s^{-1} . Find the power. [2]

2.2

- $P = Fv = 20 \times 5 = 100 \text{ W}$

2.3 State the unit of power and what it equals. [1]

2.3

- The watt; $1 \text{ W} = 1 \text{ J s}^{-1}$

Exercises 2.4·3.1

2.4 Two motors do the same work; motor A takes less time. Which has the greater power? [1]

3.1 Power is defined as [1]

☐

A force times distance

B the rate of doing work

C work times time

D energy times speed

Exercises 2.4-3.1

2.4 Two motors do the same work; motor A takes less time. Which has the greater power? [1]

2.4

- Motor A (same work in less time means more power)

3.1 Power is defined as [1]

☐

A force times distance

B the rate of doing work

C work times time

D energy times speed

3.1 B

- power is the rate of doing work

Exercise 3.2

3.2 A car engine provides 3000 N of force at 20 m s^{-1} . Its power output is [1]

☐

A 150 W

B $6.0 \times 10^4 \text{ W}$

C 3000 W

D 20 W

Exercise 3.2

3.2 A car engine provides 3000 N of force at 20 m s^{-1} . Its power output is [1]

☐

A 150 W

B $6.0 \times 10^4 \text{ W}$

C 3000 W

D 20 W

3.2 B

- $P = Fv = 3000 \times 20 = 6.0 \times 10^4 \text{ W}$

Exercise 3.3 (a)

3.3 A crane lifts a 500 kg load at a steady 0.4 m s^{-1} ($g = 10 \text{ m s}^{-2}$).

(a) Find the upward force needed.

[1]

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3.3 A crane lifts a 500 kg load at a steady 0.4 m s^{-1} ($g = 10 \text{ m s}^{-2}$).

(a) Find the upward force needed.

[1]

(a)

- $F = mg = 5000 \text{ N}$

Exercise 3.3 (b)

3.3 A crane lifts a 500 kg load at a steady 0.4 m s^{-1} ($g = 10 \text{ m s}^{-2}$).

(b) Find the power output of the crane.

[2]

Exercise 3.3 (b)

3.3 A crane lifts a 500 kg load at a steady 0.4 m s^{-1} ($g = 10 \text{ m s}^{-2}$).

(b) Find the power output of the crane.

[2]

(b)

- $P = Fv = 5000 \times 0.4 = 2000 \text{ W}$

Exercise 3.4 (a)

3.4 A pump does 12 000 J of work in 40 s.

(a) Find its power.

[2]

Exercise 3.4 (a)

3.4 A pump does 12 000 J of work in 40 s.

(a) Find its power.

[2]

(a)

- $P = 12000/40 = 300 \text{ W}$

Exercise 3.4 (b)

3.4 A pump does 12 000 J of work in 40 s.

(b) State how much energy it uses in one minute at this rate.

[1]

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3.4 A pump does 12 000 J of work in 40 s.

(b) State how much energy it uses in one minute at this rate.

[1]

(b)

- $300 \times 60 = 18\,000 \text{ J}$