

Exercise walk-through

6.1

Rotational Kinetic Energy

AP Physics C: Mechanics

Rotational kinetic energy

Energy of spin

$$K_{rot} = \frac{1}{2} I \omega^2$$

A rolling body has **both**: $K = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2$.

A **flywheel** stores energy in its spin – and $K \propto \omega^2$.

Torque and work

$$W = \int \tau d\theta, \quad P = \tau \omega$$

Area under a τ - θ graph; $W_{net} = \Delta K_{rot}$.

$\tau = 15$, $\Delta\theta = 8$: $W = 120$ J; at $\omega = 20$,
 $P = 300$ W.

The whole energy toolkit, translated

kinetic energy

$$\frac{1}{2}mv^2 \longrightarrow \frac{1}{2}I\omega^2$$

work

$$W = \int F dx \longrightarrow W = \int \tau d\theta$$

power

$$P = Fv \longrightarrow P = \tau\omega$$

momentum

$$\vec{p} = m\vec{v} \longrightarrow \vec{L} = I\vec{\omega}$$

the substitution

$$F \rightarrow \tau, \quad x \rightarrow \theta, \quad v \rightarrow \omega, \quad m \rightarrow I$$

There is nothing new to learn in rotational energy – only a dictionary. Every translational result you already have comes across intact.

Exercises 2.1-2.3

2.1 A wheel with $I = 2 \text{ kg m}^2$ spins at 3 rad s^{-1} . Find its rotational KE. [2]

2.2 If a spinning object's angular speed triples, by what factor does its rotational KE change? [1]

2.3 State the two terms in the total kinetic energy of a rolling object. [2]

Exercises 2.1-2.3

2.1 A wheel with $I = 2 \text{ kg m}^2$ spins at 3 rad s^{-1} . Find its rotational KE. [2]

2.1

- $K = \frac{1}{2}I\omega^2 = \frac{1}{2}(2)(3)^2 = 9 \text{ J}$

2.2 If a spinning object's angular speed triples, by what factor does its rotational KE change? [1]

2.2

- Nine times (ω is squared)

2.3 State the two terms in the total kinetic energy of a rolling object. [2]

2.3

- Translational $\frac{1}{2}mv^2$ and rotational $\frac{1}{2}I\omega^2$

Exercises 2.4·3.1

2.4 A flywheel stores 18 J of rotational KE at $I = 4 \text{ kg m}^2$. Find its angular speed. [2]

3.1 Rotational kinetic energy is [1]

☐

A $\frac{1}{2}mv^2$

B $\frac{1}{2}I\omega^2$

C $I\omega$

D $\frac{1}{2}kx^2$

Exercises 2.4·3.1

2.4 A flywheel stores 18 J of rotational KE at $I = 4 \text{ kg m}^2$. Find its angular speed. [2]

2.4

- $\omega = \sqrt{2K/I} = \sqrt{2(18)/4} = \sqrt{9} = 3 \text{ rad s}^{-1}$

3.1 Rotational kinetic energy is [1]

☐

A $\frac{1}{2}mv^2$

B $\frac{1}{2}I\omega^2$

C $I\omega$

D $\frac{1}{2}kx^2$

3.1 B

- $K = \frac{1}{2}I\omega^2$

Exercise 3.2

3.2 A rolling ball's total kinetic energy is

[1]

☐

A only $\frac{1}{2}mv^2$

B only $\frac{1}{2}I\omega^2$

C $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

D zero

Exercise 3.2

3.2 A rolling ball's total kinetic energy is

[1]

☐

A only $\frac{1}{2}mv^2$

B only $\frac{1}{2}I\omega^2$

C $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

D zero

3.2 C

- a rolling object has both terms

Exercise 3.3 (a)

3.3 A solid disc has $I = 0.8 \text{ kg m}^2$ and spins at 5 rad s^{-1} .

(a) Find its rotational kinetic energy.

[2]

Exercise 3.3 (a)

3.3 A solid disc has $I = 0.8 \text{ kg m}^2$ and spins at 5 rad s^{-1} .

(a) Find its rotational kinetic energy.

[2]

(a)

- $K = \frac{1}{2}(0.8)(5)^2 = 10 \text{ J}$

Exercise 3.3 (b)

3.3 A solid disc has $I = 0.8 \text{ kg m}^2$ and spins at 5 rad s^{-1} .

(b) State its energy if the spin rate doubles.

[1]

Exercise 3.3 (b)

3.3 A solid disc has $I = 0.8 \text{ kg m}^2$ and spins at 5 rad s^{-1} .

(b) State its energy if the spin rate doubles.

[1]

(b)

- Four times, 40 J

Exercise 3.4 (a)

3.4 A rolling wheel has translational $\text{KE} = 12 \text{ J}$ and rotational $\text{KE} = 6 \text{ J}$.

(a) Find the total kinetic energy.

[1]

Exercise 3.4 (a)

3.4 A rolling wheel has translational $KE = 12 \text{ J}$ and rotational $KE = 6 \text{ J}$.

(a) Find the total kinetic energy.

[1]

(a)

- $12 + 6 = 18 \text{ J}$

Exercise 3.4 (b)

3.4 A rolling wheel has translational $KE = 12 \text{ J}$ and rotational $KE = 6 \text{ J}$.

(b) State the fraction stored in rotation.

[1]

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[1]

(b)

- $6/18 = \frac{1}{3}$