Unit 1 · Rotational Dynamics and Oscillatory Motion

HARDER PRACTICE QUESTIONS

Full marks 32

Write your answers on separate paper. Show your working. Take $g = 9.8\ \text{m/s}^2$.

1 Spot the error [3]

Find the mistake in the working and correct it.

A thin ring rolls without slipping from rest down a slope, through a height of 0.8 m. Prakriti writes:
"$Mgh = \tfrac{1}{2}Mv^2$, so $v = \sqrt{(2gh)} = \sqrt{(2 \times 9.8 \times 0.8)} = \mathbf{3.96\ m/s}$."

2 A real setting [4]

The numbers are made up.

A workshop in Bhaktapur keeps a flywheel, a solid disc of mass 50 kg and radius 0.4 m, turning at 2400 revolutions per minute as a store of energy.

i. Find its moment of inertia and its kinetic energy.
ii. For how long could this energy alone keep a 300 W machine running, if all of it could be used?

3 Predict, then explain [4]

Write your prediction first, then explain it.

A disc of moment of inertia 0.6 kg m^2 turns freely at 10 rad/s on a smooth axle. A second disc, of moment of inertia 0.2 kg m^2 and not turning, is dropped onto it on the same axle, and the two soon turn together.

i. Predict: is the kinetic energy the same afterwards?
ii. Find their common angular velocity.
iii. Find the kinetic energy before and after, and the fraction lost.

4 Show that [3]

Use $I = \dfrac{2}{3}MR^2$ for a hollow sphere about a diameter.

A thin hollow sphere rolls without slipping down a slope at an angle θ.

i. Show that two fifths of its kinetic energy is rotational.
ii. Show that its acceleration is $\dfrac{3}{5}g\sin\theta$.

5 Check the readings [4]

Answer from the data.

Sujan applies a steady torque to a wheel of moment of inertia 0.8 kg m^2, starting from rest, and reads its angular velocity every second:

Time (s)	0	1	2	3	4	5
ω (rad/s)	0	3.0	6.0	9.0	13.5	15.0

i. One reading doesn't fit. Which, and what should it be?
ii. Find the angular acceleration and the torque.
iii. Find the angle the wheel turns through in the 5 s.

6 Estimate it [3]

The moment of inertia is made up, but of the right size.

A skater in a fast spin turns about five times a second with her arms pulled in. Take her moment of inertia then as about 1 kg m^2. Estimate her rotational kinetic energy, and compare it with the energy a 50 kg student needs to climb one 1 m high step.

7 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Bibek wrote: “A heavier ring has a larger radius of gyration than a light ring of the same size. When a wheel rolls without slipping, the point touching the road moves forward at the speed of the car. A spanner gives the greatest torque when you push along its length, towards the nut.”

8 What if? [3]

A solid disc rolls from rest down a slope and reaches the bottom at a speed v. What would its speed at the bottom be if i. its mass were doubled, ii. its radius were halved, iii. the slope were twice as high? Give reasons.

9 Think [3]

A tightrope walker carries a long, heavy pole. Explain, using $\tau = I\alpha$, why the pole helps her keep her balance even though it adds to her weight.

10 Make your own [2]

Using two balls of 1 kg each and a light rod, describe two arrangements with the same mass in which one has four times the moment of inertia of the other about the rod’s middle. Show that it works.