

Rotational energy, rolling and angular momentum

AP Physics 1 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems cover rotational kinetic energy, rolling without slipping and conservation of angular momentum. You will compare sliding with rolling, analyse skaters and turntables and extract physics from graphs, in the style of AP Physics 1 unit 6.

Start with single-formula problems, then move to collisions, ramps and experiments. Use $g = 9.81 \text{ m/s}^2$, show I and ω for both states and keep units in every line.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 6

Problem 1 Spinning flywheel energy (easy)

A flywheel has rotational inertia 0.50 kg m^2 and spins at 40 rad/s .

1. Calculate its rotational kinetic energy.
2. Calculate the new energy if the angular speed doubles.

Problem 2 Revolutions per minute (easy)

A grinding wheel with $I = 0.20 \text{ kg m}^2$ turns at 120 rpm .

1. Convert 120 rpm to rad/s .
2. Calculate its rotational kinetic energy.

Problem 3 Angular momentum of a turntable (easy)

A turntable with $I = 0.40 \text{ kg m}^2$ spins at 15 rad/s .

1. Calculate its angular momentum and state the unit.
2. Calculate its angular momentum if the speed falls to 10 rad/s .

Problem 4 Rolling wheel (easy)

A bicycle wheel of radius 0.35 m rolls without slipping at 7.0 m/s .

1. Calculate its angular speed.
2. Calculate how many revolutions it makes each second.

Problem 5 A skater pulls in her arms (easy)

A skater spins with $I = 3.0 \text{ kg m}^2$ at 2.0 rad/s . She pulls in her arms so that I becomes 1.5 kg m^2 . Assume no external torque.

1. Calculate her new angular speed.
2. State what quantity is conserved and why.

Problem 6 Work done by a torque (easy)

A constant torque of 4.0 N m acts on a wheel through an angle of 5.0 rad. The wheel starts from rest and has $I = 0.40 \text{ kg m}^2$.

1. Calculate the work done.
2. Calculate the final angular speed.

Problem 7 Skater's energy (medium)

A skater spins at 3.0 rad/s with $I = 2.4 \text{ kg m}^2$, then pulls in her arms so that $I = 0.80 \text{ kg m}^2$.

1. Calculate her new angular speed.
2. Calculate her kinetic energy before and after.
3. Explain where the extra energy comes from.

Problem 8 Rolling ball (medium)

A solid ball ($I = (2/5)mR^2$) of mass 0.50 kg rolls without slipping at 3.0 m/s.

1. Calculate its translational kinetic energy.
2. Calculate its rotational kinetic energy.
3. Calculate the fraction of its total kinetic energy that is rotational.

Problem 9 Rolling down a ramp (medium)

Wanjiru in Nairobi releases a solid disk and a hoop from rest at the top of a ramp 1.5 m high. Both roll without slipping.

1. Calculate the speed of the disk at the bottom.
2. Calculate the speed of the hoop.
3. State which reaches the bottom first.

Problem 10 Motor and a disk (medium)

A motor applies a constant torque of 2.5 N m to a disk with $I = 0.25 \text{ kg m}^2$, starting from rest.

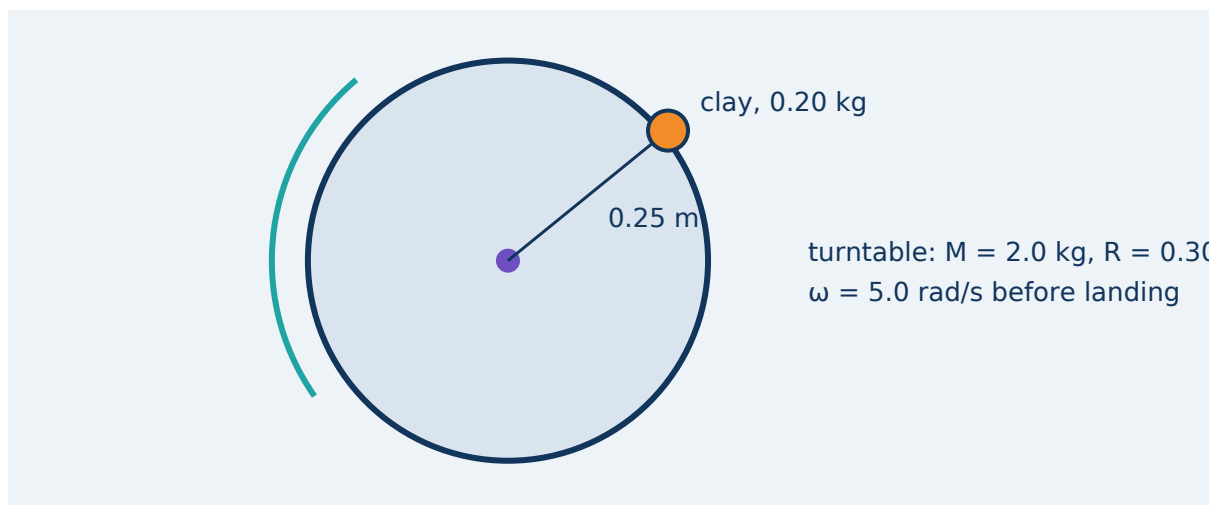
1. Calculate its angular speed after 8.0 s.
2. Calculate its kinetic energy then and the average power over the 8.0 s.
3. Calculate the motor's power at 8.0 s using $P = \tau\omega$.

Problem 11 Clay on a turntable (medium)

Mei in Singapore drops a 0.20 kg lump of clay onto a turntable ($M = 2.0 \text{ kg}$, $R = 0.30 \text{ m}$, a solid disk) spinning at 5.0 rad/s. The clay lands 0.25 m from the centre and sticks.

1. Calculate the rotational inertia of the turntable and of the clay.

2. Calculate the final angular speed.
3. Calculate the kinetic energy lost.



The clay lands on the turntable and sticks.

Problem 12 Angular momentum of a moving ball (medium)

A 0.20 kg ball moves at 5.0 m/s along a straight line that passes 0.40 m from a point O.

1. Calculate its angular momentum about O.
2. Explain why the value does not change as the ball travels along the line.

Problem 13 Storing energy in a flywheel (medium)

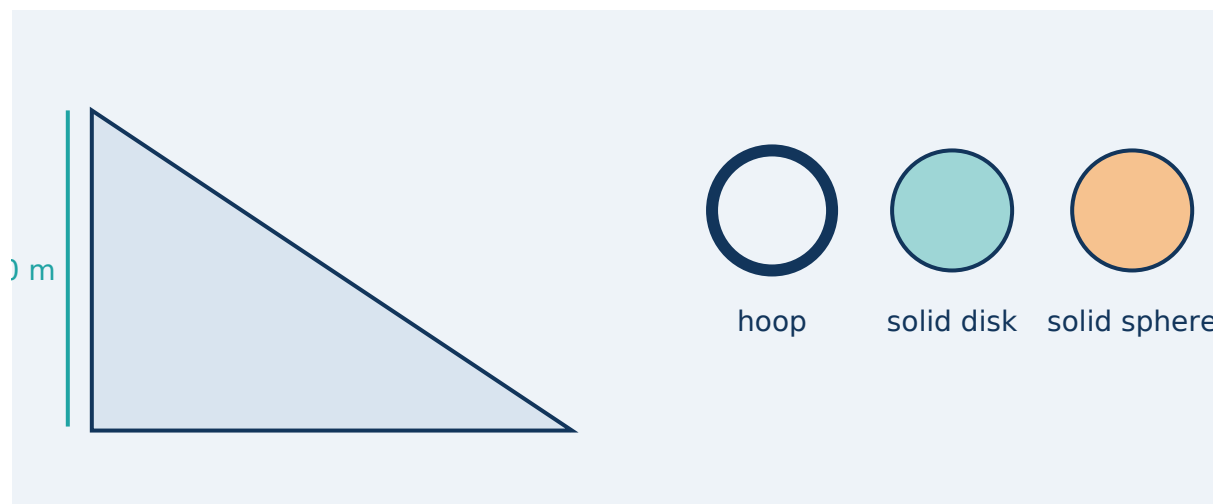
A flywheel of $I = 2.0 \text{ kg m}^2$ spins at 3000 rpm.

1. Calculate its angular speed in rad/s.
2. Calculate the energy stored.
3. Calculate how long it could run a 100 W lamp if all the energy were used.

Problem 14 Ranking rolling objects (medium)

A hoop, a solid disk and a solid sphere of equal mass and radius start from rest at the top of the ramp of height 0.50 m shown.

1. Write the speed at the bottom of each in terms of g and h .
2. Calculate the speeds.
3. Rank the objects by their finishing order.



Objects with the same mass and radius are released from rest at the top of the ramp.

Problem 15 Putty hits a rod (hard)

A uniform rod (mass 1.0 kg, length 0.60 m) lies on a frictionless horizontal table and is pivoted at one end. A 0.20 kg lump of putty moving at 3.0 m/s perpendicular to the rod strikes the free end and sticks.

1. Calculate the angular momentum of the putty about the pivot.
2. Calculate the rotational inertia of the rod plus putty.
3. Calculate the angular speed after impact and the kinetic energy lost.

Problem 16 Acceleration on a slope (hard)

A solid disk of mass 2.0 kg rolls without slipping down a 30° slope.

1. Write Newton's second law along the slope, including the friction force f at the contact point.
2. Write the rotational equation and use $a = R\alpha$.
3. Calculate the acceleration and the friction force.

Problem 17 Rolling hoop up a hill (hard)

A hoop of mass 1.5 kg and radius 0.20 m rolls on level ground at 4.0 m/s, then rolls up a hill without slipping.

1. Calculate its total kinetic energy at the bottom.
2. Calculate the maximum height reached.
3. Calculate the height reached by a block sliding without friction at the same initial speed, and compare.

Problem 18 Jumping onto a roundabout (hard)

Kofi in Accra, mass 30 kg, runs at 4.0 m/s tangentially to a roundabout of rotational inertia 200 kg m^2 and radius 2.0 m, which is turning at 1.2 rad/s in the same direction. He jumps on at the rim and stays there.

1. Calculate the total angular momentum before the jump.
2. Calculate the angular speed after the jump.
3. Calculate the kinetic energy lost.

Problem 19 Spot the error (hard)

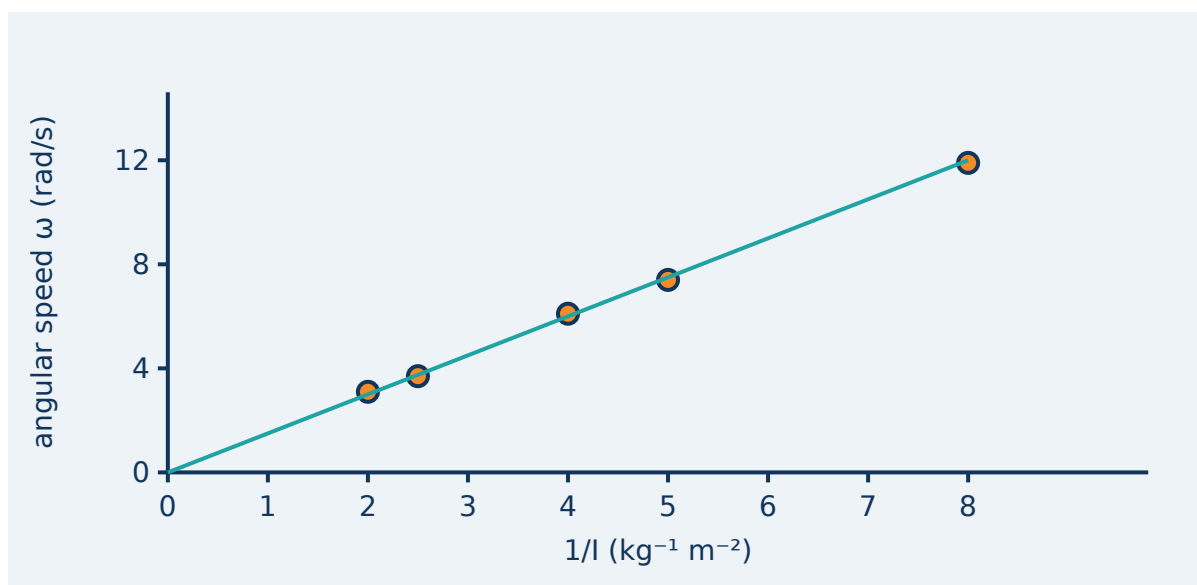
Diego in Texas says: "When a spinning skater pulls in her arms, her angular momentum is conserved, so her kinetic energy is also unchanged." Her I goes from 3.0 kg m^2 to 1.0 kg m^2 and her ω from 2.0 rad/s .

1. Calculate her final angular speed.
2. Calculate her kinetic energy before and after.
3. Explain the error in Diego's statement.

Problem 20 Testing conservation of angular momentum (hard)

A student on a rotating stool changes her rotational inertia and measures her angular speed each time. The graph shows ω against $1/I$.

1. Use the first and last points to calculate the gradient.
2. State what the gradient represents and give its value with units.
3. The true initial angular momentum was $1.50 \text{ kg m}^2/\text{s}$. Calculate the percentage difference.



Angular speed of a spinner after changing its rotational inertia; the line is a best fit through the origin.