

Angular momentum and rolling motion

AP Physics C (Mechanics and E&M, calculus-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train the calculus-based view of rotation: $L = I\omega$, $\Sigma\tau = dL/dt$, conservation of angular momentum and the link between rotation and translation in rolling. They cover collisions with rods and turntables, energy accounting and inclined planes.

Level 1 problems check definitions and one-step calculations, level 2 problems combine two ideas, and level 3 problems need calculus, several steps or a full argument, as in the free-response section of AP Physics C unit 6.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 6

Problem 1 Rolling bicycle wheel (easy)

A bicycle wheel of radius 0.34 m rolls without slipping at 5.1 m/s on a flat road.

1. Calculate the angular speed of the wheel.
2. Calculate how many revolutions it makes each second.
3. State the speed of the top of the wheel relative to the road.

Problem 2 Cricket ball and the umpire (easy)

A cricket ball of mass 0.16 kg moves at 30 m/s in a straight line. The perpendicular distance from the line of motion to the umpire is 1.5 m.

1. Calculate the ball's angular momentum about the umpire.
2. Calculate it for a point 0.50 m from the line.
3. Explain why the answers differ.

Problem 3 Spinning disc (easy)

A uniform disc of mass 3.0 kg and radius 0.20 m spins about its central axis at 12 rad/s.

1. Calculate its moment of inertia.
2. Calculate its angular momentum.
3. Calculate its rotational kinetic energy.

Problem 4 Skater pulling in her arms (easy)

A skater turns at 2.0 rad/s. She pulls in her arms and her moment of inertia falls to 40 % of its original value.

1. Calculate her new angular speed.
2. Calculate the ratio of final to initial kinetic energy.

Problem 5 Order of the race (easy)

A hoop, a solid disc, a thin spherical shell and a solid sphere, all with different masses and radii, are released together from rest at the top of a long rough slope.

1. Rank them from first to last to reach the bottom.
2. Explain why the masses and radii do not matter.

Problem 6 Energy split (easy)

Calculate the percentage of the total kinetic energy that is rotational for

1. a hoop ($\beta = 1$)
2. a solid sphere ($\beta = 0.4$).

Problem 7 Sphere down a ramp (medium)



Problem 7: the sphere is released from rest at the top.

A solid sphere of mass 0.50 kg and radius 0.040 m is released from rest at the top of a ramp that drops 0.35 m (figure).

1. Calculate its speed at the bottom.
2. Calculate its angular speed there.
3. Calculate its total kinetic energy at the bottom.

Problem 8 Hoop on a 25° slope (medium)

A hoop rolls from rest down a 3.0 m long slope inclined at 25°.

1. Calculate its acceleration.
2. Calculate the time to reach the bottom.
3. Calculate its final speed.

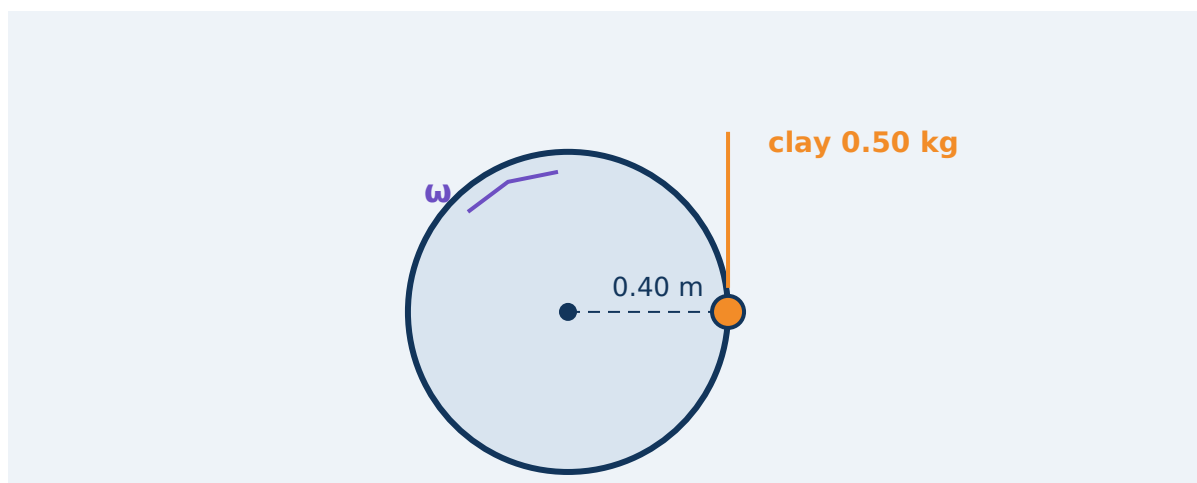
Problem 9 Friction on a cylinder (medium)

A solid cylinder of mass 4.0 kg rolls without slipping down a 30° incline.

1. Calculate the static friction force on it.

- Calculate the minimum coefficient of static friction needed.

Problem 10 Clay on a turntable (medium)



Problem 10: the clay is dropped onto the turntable.

A turntable of moment of inertia 0.80 kg m^2 spins at 6.0 rad/s . A lump of clay of mass 0.50 kg is dropped onto it, 0.40 m from the axis, and sticks (figure).

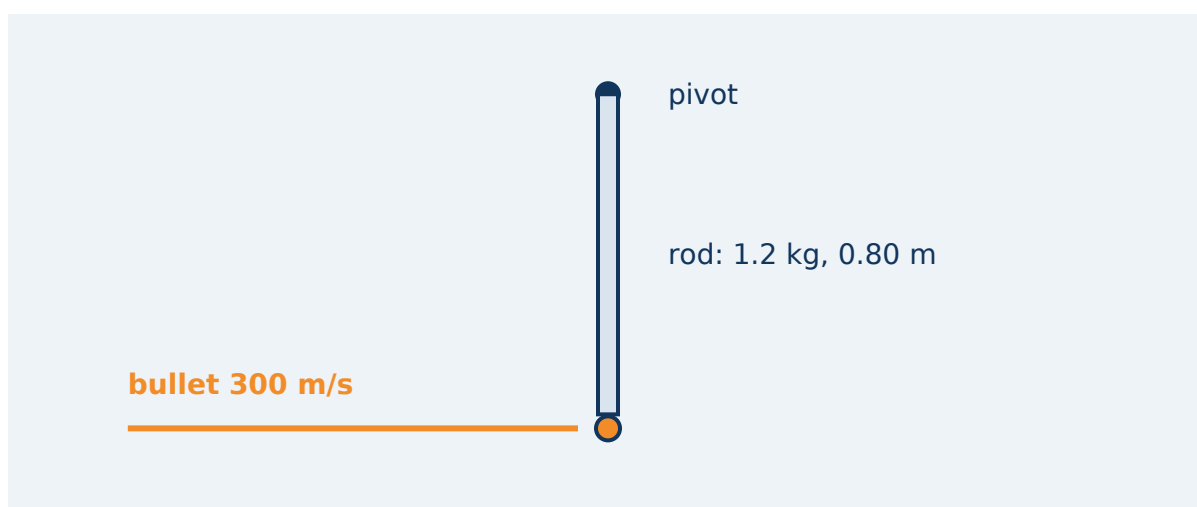
- Calculate the new angular speed.
- Calculate the kinetic energy lost.

Problem 11 Child on a roundabout (medium)

A playground roundabout has $I = 250 \text{ kg m}^2$ and turns at 0.80 rad/s . A 40 kg child standing at the rim ($r = 2.0 \text{ m}$) walks to a point 0.50 m from the axis.

- Calculate the total angular momentum.
- Calculate the final angular speed.

Problem 12 Bullet and rod (medium)



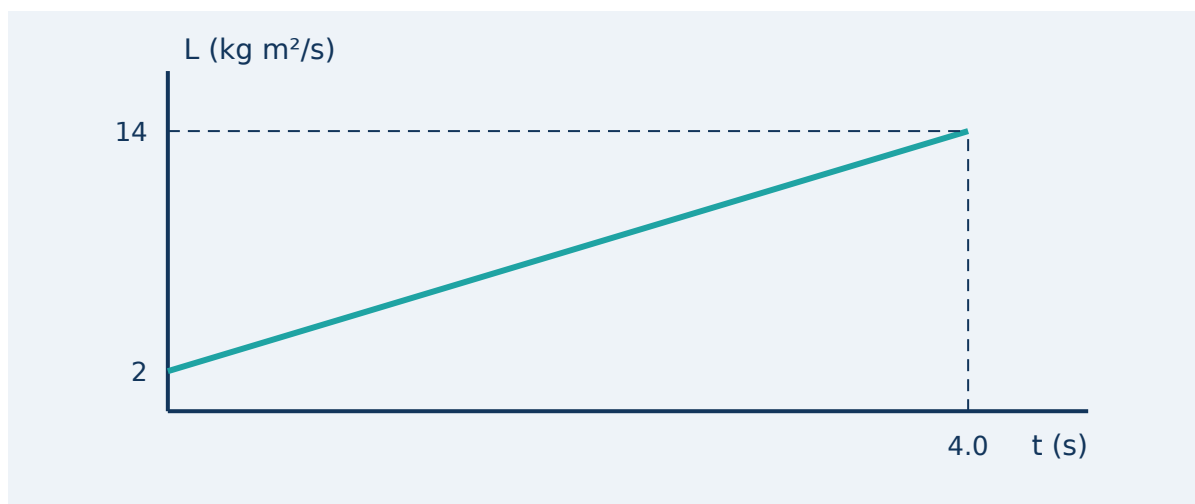
Problem 12: the bullet embeds in the rod.

A bullet of mass 0.020 kg travelling at 300 m/s strikes the lower end of a uniform rod (1.2

kg, 0.80 m) that hangs from a frictionless pivot at its top, and embeds (figure).

1. Calculate the angular momentum of the bullet about the pivot.
2. Calculate the moment of inertia of the rod plus bullet.
3. Calculate the angular speed just after impact.

Problem 13 Reading an L-t graph (medium)



Problem 13: angular momentum of a flywheel.

The graph shows the angular momentum of a flywheel against time.

1. Calculate the net torque on it.
2. The moment of inertia is 1.5 kg m^2 . Calculate the angular acceleration.
3. State what the area under a torque-time graph would represent.

Problem 14 Spot the error (medium)

A student writes: 'A ball rolls without slipping at constant speed on flat ground. Friction does negative work, so the ball must slow down.'

1. Identify the errors.
2. Give the correct statement.

Problem 15 Angular momentum about the contact point (medium)

A uniform disc of mass 2.0 kg and radius 0.30 m rolls at 4.0 m/s along level ground.

1. Calculate its angular momentum about its centre.
2. Calculate its angular momentum about a point on the ground below the centre.

Problem 16 Hoop against disc (hard)

A hoop and a solid disc of equal mass and radius are released together from rest at the top of a 5.0 m long incline that is 2.0 m high.

1. Calculate the speed of each at the bottom.
2. Calculate how far along the slope the hoop is when the disc arrives at the bottom.

Problem 17 Sphere on a loop-the-loop (hard)

A small solid sphere rolls without slipping from rest down a track and around a vertical loop of radius $R = 0.50$ m. The sphere's own radius is much smaller than R .

1. Write the condition for the sphere to just stay in contact at the top.
2. Calculate the minimum release height above the bottom of the loop.

Problem 18 Falling yo-yo (hard)

A solid cylinder of mass 0.20 kg has a light string wound around it. The free end is tied to a fixed support and the cylinder is released so that it unrolls as it falls.

1. Calculate its acceleration.
2. Calculate the tension in the string.
3. Calculate its speed after it has fallen 1.5 m.

Problem 19 Child jumping on a roundabout (hard)

A stationary roundabout has $I = 300$ kg m^2 and radius 2.5 m. A 35 kg child runs at 4.0 m/s along a tangent and jumps on at the rim.

1. Calculate the angular speed after the jump.
2. Calculate the kinetic energy lost.

Problem 20 Torque from calculus (hard)

A flywheel with $I = 2.0$ kg m^2 starts from rest. A motor applies a torque $\tau = 6.0t$ N m, with t in seconds.

1. Use $\Sigma \tau = dL/dt$ to find $L(t)$.
2. Calculate ω and α at $t = 4.0$ s.
3. Calculate the work done by the motor in the first 4.0 s.