

Concept Questions with Answers

8.01
W11D1

Rigid Body: Rotational and Translational Motion; Rolling without Slipping

8.01
W11D1

W11D1 and W11D2 Reading Assignment:
MIT 8.01 Course Notes

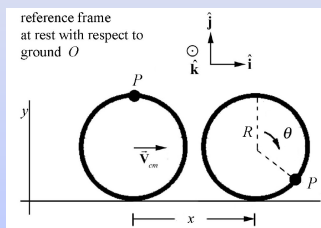
[Chapter 20 Rigid Body: Translation and Rotational Motion Kinematics for Fixed Axis Rotation](#)
Sections 20.1-20.5

[Chapter 21 Rigid Body Dynamics: Rotation and Translation about a Fixed Axis](#)
Sections 21.1-21.5

Concept Question: Rolling Without Slipping

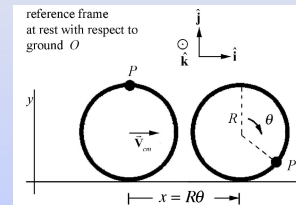
If a wheel of radius R rolls without slipping through an angle θ , what is the relationship between the distance the wheel rolls, x , and the product $R\theta$?

1. $x > R\theta$.
2. $x = R\theta$.
3. $x < R\theta$.



Concept Q. Ans. : Rolling Without Slipping

Answer 2. Rolling without slipping condition, $x = R\theta$.



Concept Question: Cylinder Race

Two cylinders of the same size and mass roll down an incline, starting from rest. Cylinder A has most of its mass concentrated at the rim, while cylinder B has most of its mass concentrated at the center. Which reaches the bottom first?

- 1) A
- 2) B
- 3) Both at the same time.

Concept Q. Ans.: Cylinder Race

Answer 2: Because the moment of inertia of cylinder B is smaller, more of the mechanical energy will go into the translational kinetic energy hence B will have a greater center of mass speed and hence reach the bottom first.

Concept Question: Cylinder Race Different Masses

Two cylinders of the same size but different masses roll down an incline, starting from rest. Cylinder A has a greater mass. Which reaches the bottom first?

- 1) A
- 2) B
- 3) Both at the same time.

Concept Q. Ans.: Cylinder Race Different Masses

Answer 3. The initial mechanical energy is all potential energy and hence proportional to mass. When the cylinders reach the bottom of the incline, both the mechanical energy consists of translational and rotational kinetic energy and both are proportional to mass. So as long as mechanical energy is constant, the final velocity is independent of mass. So both arrive at the bottom at the same time.

Concept Questions with Answers

8.01
W11D2

Rotational and Translational Motion Dynamics

8.01
W11D2

W11D1 and W11D2 Reading Assignment:
MIT 8.01 Course Notes

[Chapter 20 Rigid Body: Translation and Rotational Motion
Kinematics for Fixed Axis Rotation](#)

Sections 20.1-20.5

[Chapter 21 Rigid Body Dynamics: Rotation and Translation
about a Fixed Axis,](#)
Sections 21.1-21.5

Concept Question: Pulling a Yo-Yo 1

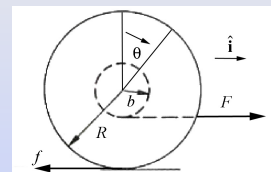


Two disks are separated by a spindle of smaller diameter. A string is wound around the spindle and pulled gently. In which direction does it roll?

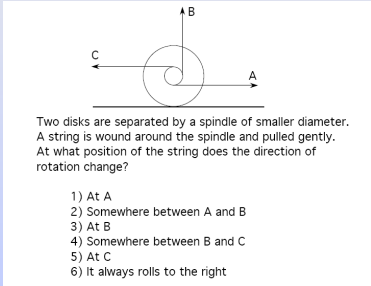
- 1) To the right, in the direction of F , winding up the string
- 2) To the left, opposite to F , unwinding the string
- 3) It does not roll, it slides to the right
- 4) It does not roll, it slides to the left

Concept Q. Ans.: Pulling a Yo-Yo 1

Answer 1. For forces below a fixed maximum value, the torque about the contact point between the ground and yo-yo is only due to the force F and produces an angular acceleration directed into the plane of the figure. Hence the cylinder rolls to the right, in the direction of F , winding up the string. The torque about the center of mass due to the force of friction is larger in magnitude than the torque due to the pulling force.



Concept Question: Pulling a Yo-Yo 2

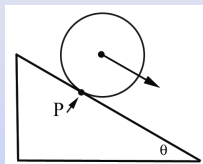


Concept Q. Ans.: Pulling a Yo-Yo 2

Answer 2. When the string is pulled up, the only horizontal force is static friction and it points to the left so the yo-yo accelerates to the left. Therefore somewhere between A and B the direction of rotation changes.

Concept Question: Cylinder Rolling Down Inclined Plane

A cylinder is rolling without slipping down an inclined plane. The friction at the contact point P is

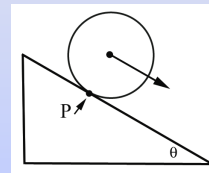


1. Static and points up the inclined plane.
2. Static and points down the inclined plane.
3. Kinetic and points up the inclined plane.
4. Kinetic and points down the inclined plane.
5. Zero because it is rolling without slipping.

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Concept Q. Ans.: Cylinder Rolling Down Inclined Plane

Answer 1. The friction at the contact point P is static and points up the inclined plane. This friction produces a torque about the center of mass that points into the plane of the figure. This torque produces an angular acceleration into the plane, increasing the angular speed as the cylinder rolls down.



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Concept Question: Constants of the Motion



A bowling ball is initially thrown down an alley with an initial speed v_0 , and it slides without rolling but due to friction it begins to roll until it rolls without slipping. Which quantity is constant before it rolls without slipping?

1. Energy.
2. Angular momentum about the center of mass.
3. Angular momentum about a fixed point on the ground.

Concept Q. Ans.: Constants of the Motion



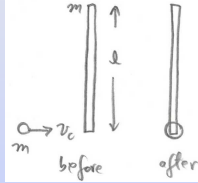
Answer 3. Energy is not conserved because there are energy losses due to kinetic friction. Angular momentum about the center of mass is not constant because the friction exerts a torque about the center of mass. Angular momentum about a fixed point on the ground is constant because the sum of the torques about that point is zero. The friction force will always be parallel to the line of contact between the bowling ball and the surface. So, if we pick any fixed point along the line of contact between the bowling ball and the surface then the vector from the point to the contact point where friction acts is either parallel or anti-parallel and hence the torque is zero. The torque about a fixed point on the ground due to the gravitational force and the normal forces are in opposite directions, have the same moment arms, and because $mg = N$ have the same magnitudes hence add to zero.

Concept Question: Angular Collisions

A long narrow uniform stick lies motionless on ice (assume the ice provides a frictionless surface). The center of mass of the stick is the same as the geometric center (at the midpoint of the stick). A puck (with putty on one side) slides without spinning on the ice toward the stick, hits one end of the stick, and attaches to it.

Which quantities are constant?

1. Angular momentum of puck about center of mass of stick.
2. Momentum of stick and ball.
3. Angular momentum of stick and ball about any point.
4. Mechanical energy of stick and ball.
5. None of the above 1-4.
6. Three of the above 1-4.
7. Two of the above 1-4.



Concept Q. Ans.: Angular Collisions

Answer: 7

(2) and (3) are correct. There are no external forces acting on this system so the momentum of the center of mass is constant (1). There are no external torques acting on the system so the angular momentum of the system about any point is constant (3). However there is a collision force acting on the puck, so the torque about the center of the mass of the stick on the puck is non-zero, hence the angular momentum of puck about center of mass of stick is not constant. The mechanical energy is not constant because the collision between the puck and stick is inelastic.

