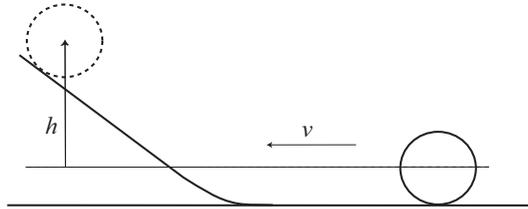


Name: _____ Section: _____ Score: _____/20

1. A disk of mass M and radius R rolls without slip on the flat horizontal surface as illustrated below. Its translational speed is v .

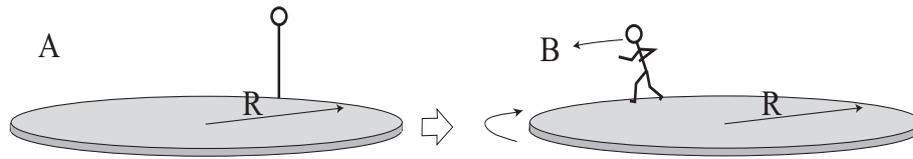


(a) Suppose the inclined surface is with friction, and the disk rolls up the surface without slip. What is the height h of the highest possible point that the disk can reach relative to the initial height (the height is that of the center of mass) (in terms of v and g , the acceleration of gravity)? [5]

(b) Suppose the inclined surface is frictionless, but the horizontal plane is as in (a). Can the disk with the same horizontal speed v climb up to the point higher than in the case (a)? You must justify your answer. [5]

(2 on the next page)

2. A horizontal circular stage of moment of inertia I and radius R can rotate freely around its center. An actor of mass M is on the stage. He is initially standing still on the edge of the stage which is stationary as shown in A in the figure below.

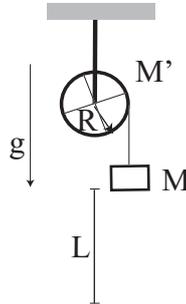


(a) The actor starts to jog on the stage along its edge (of radius R), and reaches the tangential speed V observed by a stationary observer outside the stage (on the ground). The situation is illustrated in B above. What is the total angular momentum of the actor + the stage [5]?

(b) What is the angular speed ω of the stage? [5]

Name: _____ Section: _____ Score: _____/20

1. A hoop of mass M' and radius R is used as a pulley which can rotate freely around its horizontal axle (ignore the mass of the spokes). A massless string is wound around the hoop and a block of mass M hangs on it. Initially, the system is stationary.

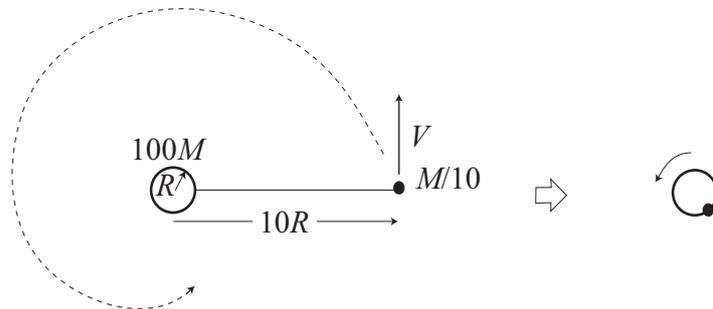


(a) Suppose $M = M'$. The block is released gently. When it descends by distance L , its speed is V . Write L in terms of V and g . [5]

(b) Suppose M' is much larger than M (say, $M' = 1000M$). Is the speed V' of the block when it descends by distance L as in (a) about the same as, much faster than, or much slower than V in (a)? You must justify your answer. [5]

(2 on the next page)

2. On a horizontal frictionless table is a disk of radius R and mass $100M$ that can rotate freely around its vertical axle which is fixed on the table. On its edge is tethered a small ball of mass $M/10$ with a massless string (of length $9R$). Initially, the disk is stationary, but the ball is given a speed V perpendicular to the tight tether as illustrated below (top view). Notice that the ball is initially $10R$ away from the center of the disk. You may ignore the size of the ball.

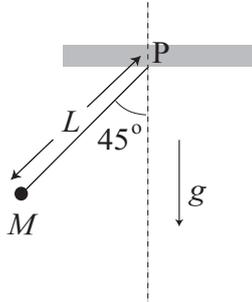


(a) Eventually, the tether winds around the disk and the ball sticks to the edge of the disk as illustrated above right. They must be rotating together around the disk axle. What is the final total angular momentum of the system?

(b) Does the total kinetic energy of the system increase? You must justify your answer. [Hint: $K = L^2/2I$] [5]

Name: _____ Section: _____ Score: _____/20

1. One end of a light bar of length L is attached to the ceiling at point P around which the bar can rotate freely. To the other end is fixed a small ball of mass M . Initially, the bar makes a 45° angle with the vertical as illustrated below. You may ignore the size of the ball.

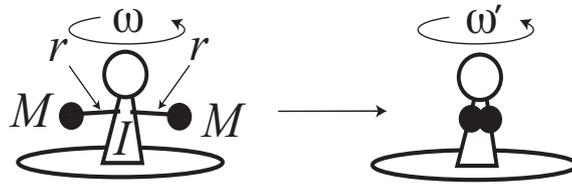


(a) Let us assume that we may ignore the mass of the light bar. The bar is gently released and is allowed to rotate freely around P. Write down the square V^2 of the speed V of the ball when it reaches the lowest point in terms of L and g , the acceleration of gravity. [5]

(b) Suppose a small mass of m is attached to the ball. Is the speed of the ball at the lowest position faster than in the case (a)? You must justify your answer. [Hint: don't think too much.] [5]

(2 on the next page)

2. On a light horizontal turntable (with zero moment of inertia) is a child whose moment of inertia around its body center is I . She is at the center of the turntable, and holds two small balls of mass M . Initially, she holds them with her arms extended as illustrated below left. The length of extended arm is r , but you may ignore its mass. Initially, she is rotating at an angular speed of ω .

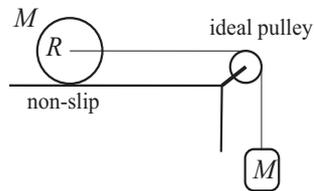


(a) She retracts her arms so that the balls may be assumed to be at the center of the turntable. What is the angular speed ω' of the child in the situation illustrated above right in terms of ω , I , M and r ?

(b) To retract the balls does she have to do some mechanical work? You must justify your answer. [5]

Name: _____ Section: _____ Score: _____/20

1. On a horizontal table is a cylindrical roller of mass M and radius R . The axle of the roller is pulled by a block of mass M with a massless string through an ideal pulley (no mass/no friction as usual). We assume that the roller rolls without slip on the table. Initially, the system is stationary.

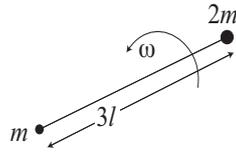


(a) The block is now allowed to descend without constraint. When the roller moves by distance D , its speed is V . Write V down in terms of D and g , the acceleration of gravity. [5]

(b) What is the angular momentum of the cylinder around its axle at this moment in terms of M , R and V . [5]

(2 on the next page)

2. On a frictionless horizontal table are two masses with mass m and $2m$, respectively, which are tied to each other by a massless wire of length 3ℓ initially. The system rotates with angular speed ω around the center of mass of the system. The top view is given below.



(a) Now, the wire is shortened to length ℓ . What is the angular speed Ω of the rotation of this system around its center of mass?

(b) Does the kinetic energy increase by this process? You must justify your answer. [5]