PH 220 Homework Assignment Chapter on Rotational Kinematics – 37 Problems Total

1. The Moon subtends an angle of about $0.50°$ in the sky. The Moon is located a distance of $3.84 \text{ x } 10^8 \text{ m}$ away. Estimate the Moon's radius.

<u>Solution for Problem 1</u>

2. A laser beam is directed at the Moon $3.84 \text{ x } 10^8 \text{ m}$ away from the Earth. The beam diverges at an angle of $1.74 \text{ x } 10^{-4} \text{ rad}$. What is the diameter of the spot the laser will make on the Moon?

<u>Solution for Problem 2</u>

3. The width of the Lunar Lander that the Apollo missions left behind on the Moon is about 9.40 m. The distance to the Moon is $3.84 \text{ x } 10^8 \text{ m}$. What angle does the Lander subtend?

<u>Solution for Problem 3</u>

4. A common car tire has a diameter of 0.838 m. How many revolutions will the tire make if the car travels 9.56 km

<u>Solution for Problem 4</u>

5. A rotating merry-go-round is rotating with a constant speed and makes one complete rotation in a period of 5.60 s.

(a) What is the tangential speed of a child located 2.20 m from the center?

(b) What is the total acceleration of the child in component form?

<u>Solution for Problem 5</u>

6. The Earth has a radius $(R_E = 6.38 \text{ x } 10^6 \text{ m})$ and a period of rotation $(T = 24 \text{ hr} = 8.64 \text{ x } 10^4 \text{ s})$. Considering this rotation, what is the tangential speed of a point on:

(a) On the Equator(Latitude of $0.00°$).

(b) On the Arctic Circle (Latitude of $66.5°$)

(c) At Marquette Michigan (Latitude of $46.5°$)

<u>Solution for Problem 6</u>

7. How many revolutions per minute must a centrifuge rotate if a test tube of materials whose center is located $4.56 \text{ x } 10^{-2}$ m away from the center of rotation is to experience a centripetal acceleration of 200,000 g's?

Solution for Problem 7

8. A game show wheel has a diameter of 1.50 m. It is given an acceleration that has it uniformly increase from a rate of $105.$ rpm to $320.$ rpm in a time of 6.00 s. Determine:

(a) Its angular acceleration.

(b) Its radial acceleration component of linear acceleration of a point on the rim of the wheel at the $\text{t} = 3.00$ s time.

(c) Its tangential acceleration component of linear acceleration of a point on the rim of the wheel at the $\text{t} = 3.00$ s time.

Solution for Problem 8

9. Test pilots are sometimes stress tested in human centrifuges which consists of flight seats at the end of a centrifuge arm. The centrifuge arm begins at rest and completes a total of 20.0 complete rotations in a time of 75.0 s.

(a) Assuming the angular acceleration is constant, what is the angular acceleration for the pilot?

(b) What was the final angular speed the pilot obtained in this scenario?

Solution for Problem 9

10. A dentist drill turns through an angle described by the relationship:

$$\theta = (0.65t^4 + 11.0t^2 - 3.40t)\ \text{rad}$$

Time is assumed to be in units of seconds.

(a) Find the expression for the instantaneous angular velocity.

(b) Find the expression for the instantaneous angular acceleration.

(c) Evaluate the angular displacement at time $t = 2.00\ \text{s}$.

(d) Evaluate angular displacement at time $t = 4.00\ \text{s}$.

(e) Find the average angular velocity between times $t = 2.00\ \text{s}$ and $t = 4.00\ \text{s}$.

(f) Evaluate the angular velocity at time $t = 2.00\ \text{s}$.

(g) Evaluate angular velocity at time $t = 4.00\ \text{s}$.

(h) Find the average angular acceleration between times $t = 2.00\ \text{s}$ and $t = 4.00\ \text{s}$.

(i) Evaluate the angular acceleration at time $t = 2.00\ \text{s}$.

(j) Evaluate angular acceleration at time $t = 4.00\ \text{s}$.

<u>Solution for Problem 10</u>

11. A propeller on a submarine has an angular acceleration given as:

$$\alpha(t) = (2.76t^3 - 1.45t^2 + 0.876t)\ {}^{\text{rad}}/_{\text{s}^2}$$

t is assumed to be in units of seconds. The propeller starts at rest and we will use the initial angular position as "zero" so we have

$$\text{at } t = 0, \omega_0 = 0.00\ {}^{\text{rad}}/_{\text{s}} \text{ and } \theta_0 = 0.00 \text{ rad}$$

(a) Determine an expression for the angular velocity as a function of time.

(b) Determine an expression for the angular displacement as a function of time.

(c) Evaluate the angular velocity at $t = 3.45$ s.

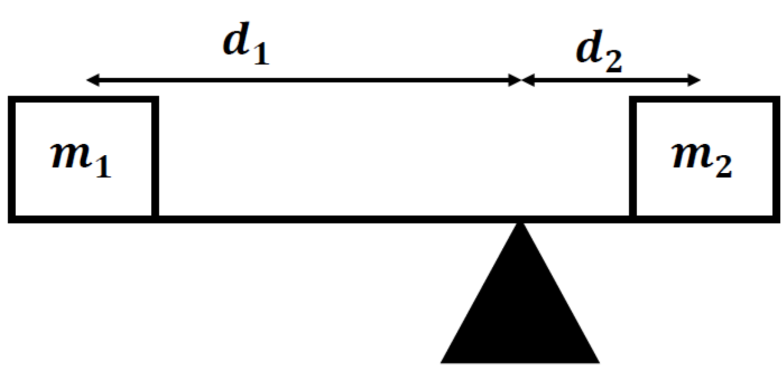
(d) Evaluate the angular displacement at $t = 3.45$ s.

<u>**Solution for Problem 11**</u>

12. A plumber is tightening a nut using a wrench which has a handle length of 30.0 cm. Assume the force applied by the plumber makes a right angle with the wrench handle. The resulting torque is 15.9 m N. How much force was applied to the wrench handle?

<u>**Solution for Problem 12**</u>

13. As shown below a massless unbreakable board has two masses on it. $m_1 = 11.3\ kg$ and $m_2 = 17.7\ kg$. While $d_1 = 3.76\ m$ and $d_2 = 1.39\ m$. If the system is allowed to move, what is the magnitude and direction of the net torque about the fulcrum point which is where the distances d_1 and d_2 meet?

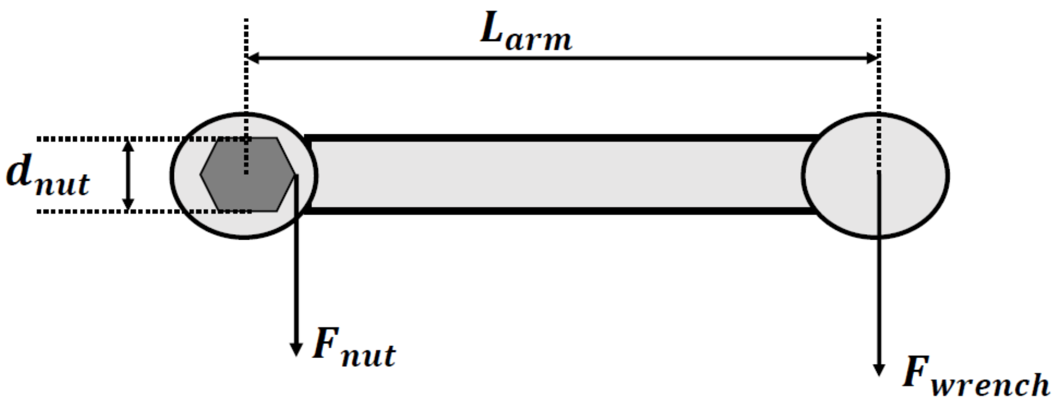


<u>**Solution for Problem 13**</u>

14. Consider a six-sided nut (hex nut) being tightened by a wrench as shown below. The length of the wrench arm is $L_{arm} = 3.20 \times 10^{-1}$ m. The distance between parallel sides of the hex nut is $d_{nut} = 1.20 \times 10^{-2}$ m. The total force applies to the wrench as indicated is $F_{wrench} = 2.86 \times 10^{2}$ N

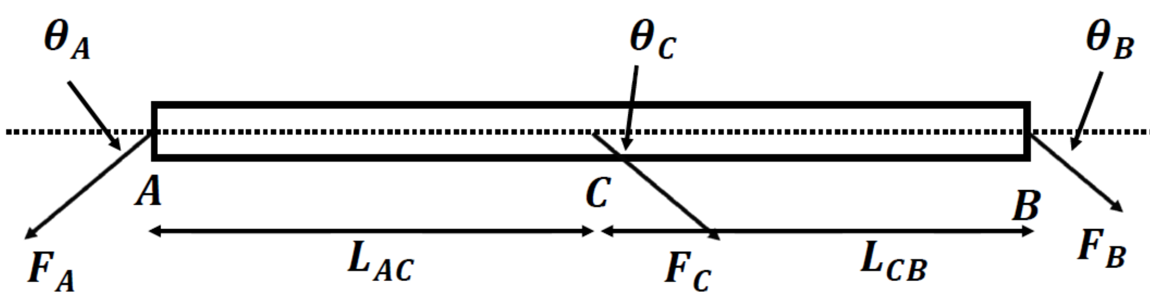
(a) What is the net torque acting on the hex nut?

(b) What is the force acting on each of the six points of the hex nut?



Solution for Problem 14

15.



As shown above a massless board has three forces acting on it. The lengths are: $L_{AC} = 2.34$ m, and $L_{CB} = 2.34$ m. The forces are $F_A = 12.7$ N, $F_B = 21.3$ N, and $F_C = 18.6$ N. The angles are $\theta_A = 34.5°$, $\theta_B = 28.9°$, and $\theta_C = 41.1°$ Determine the magnitude and direction of the net torque about

(a) Point C.

(b) Point B.

Solution for Problem 15

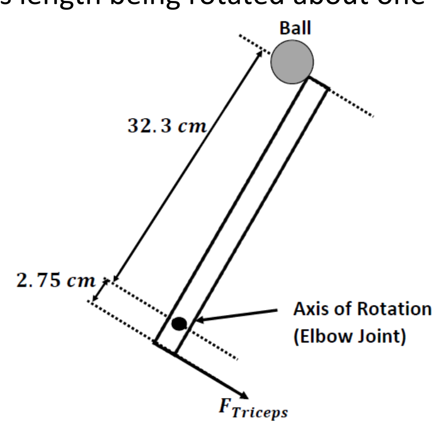
16. A katana sword has a mass of 1.48 kg and a length of 0.870 m. A sword master brings the sword from rest to a speed of $21.4 \ ^{\text{rad}}/_{\text{s}}$ in a time of 0.180 s. Consider the sword to be a rod of length L and rotated about one end. Estimate the torque the sword master must apply to the sword to bring it up to speed.

<u>Solution for Problem 16</u>

17. A grinding wheel in a machine shop has a mass of 1.67 kg and has a radius of $8.78 \text{ x } 10^{-2} \text{ m}$. Assume the wheel is a disk with mass uniformly distributed throughout it. When the power is cut off to the grinder, only friction is occurring and the wheel slows down from a rotational speed of $1200 \ ^{\text{rev}}/_{\text{min}}$ to a full stop in 18.3 s. If the wheel is able to accelerate from rest to a running speed of $1650 \ ^{\text{rev}}/_{\text{min}}$ in a time of 6.12 s, What is the torque needed to run the grinder?

<u>Solution for Problem 17</u>

18. Consider a person is going to throw a ball with using only their forearm as it rotates about the elbow joint due to the force of the triceps muscle. The ball is accelerated from rest to a speed of $9.23 \ ^{\text{m}}/_{\text{s}}$ in a time of 0.380 s at which point the ball leaves the hand. The ball has a mass of 1.15 kg. The forearm has a mass of 3.65 kg. The other dimensions are shown in the diagram below. To simplify the problems slightly, treat the forearm as a rod with mass uniformly distributed along its length being rotated about one end.



(a) Determine the angular acceleration of the arm.

(b) Determine the magnitude of the triceps force needed to impart the speed to the ball.

<u>Solution for Problem 18</u>

19. A solid sphere has its mass uniformly distributed and is rotated about an axis through its center by an applied torque of $20.7\ \mathrm{m\ N}$. This torque results in the sphere going from being at rest to rotating with an angular speed of $56.9\ ^{\mathrm{rad}}/_{\mathrm{s}}$ in time of $12.0\ \mathrm{s}$. If the mass of the sphere is $30.4\ \mathrm{kg}$, what is the radius of the sphere?

Solution for Problem 19

20. Mom pushes tangentially on a no motorized merry-go-round at a local park with her two kids riding it. The merry-go-round has a radius of $1.78\ \mathrm{m}$ and has a total mass of $320.\ \mathrm{kg}$. The mass is uniformly distributed through out the disk of the merry-go-round. Mom starts with the merry-go-round at rest and gets it up to making $6.50\ \mathrm{rpm}$ in a time of $7.67\ \mathrm{s}$. She applies a force of $36.3\ \mathrm{N}$ tangentially to the edge of the merry-go-round. Both children sit on the edge of the merry-go-round disk. If one child has a mass of $40.0\ \mathrm{kg}$, what is the mass of the second child? Ignore any resistive forces such as friction and air resistance.

Solution for Problem 20

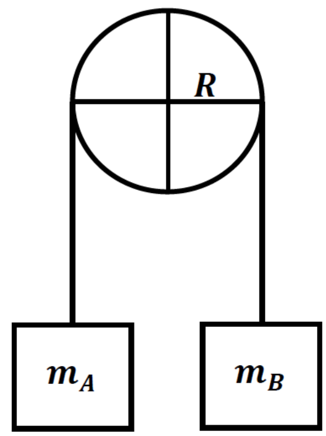
21. A potter's wheel has a disk of uniformly distributed mass of $137.\ \mathrm{kg}$ and a radius of $0.175\ \mathrm{m}$. The wheel is rotating at $250.\ \mathrm{rpm}$ when the power fails. The wheel experiences a frictional torque of $0.765\ \mathrm{m\ N}$.

(a) Determine the angular displacement the wheel goes through as it is brought to rest by the frictional torque.

(b) How long does it take the wheel to come to rest?

Solution for Problem 21

22. Pictured on the right is an experimental set-up known as “Atwood’s Machine”. It contains two masses $(\mathrm{m_A} \text{ and } \mathrm{m_B})$, which are attached to a massless, stretchless and unbreakable cord that passes over a pulley. The pulley has a radius (R) and a moment of inertia (I) about the central axis. Initially the system is held at rest. Then the system is allowed to move. Assume $\mathrm{m_A} < \mathrm{m_B}$.



(a) Determine the acceleration of the masses when the system is allowed to move.

(b) Determine the tension in the cord attached to mass A when the system is allowed to move.

(c) Determine the tension in the cord attached to mass B when the system is allowed to move.

(d) Determine the acceleration of the masses when the system is allowed to move, If you assume $I \to 0$.

(e) Determine the tension in the cord attached to mass A when the system is allowed to move, If you assume $I \to 0$.

(f) Determine the tension in the cord attached to mass B when the system is allowed to move, If you assume $I \to 0$.

Solution for Problem 22

23. A track and field competition includes the event "Hammer Throw". The "Hammer" has a mass $(\mathrm{m} = 7.26\ \mathrm{kg})$. The "Hammer" is accelerated uniformly from rest by swinging it in a horizontal circle with a radius of $1.22\ \mathrm{m}$. Assume the competitor makes three complete revolutions bringing the hammer up to a linear a speed of $28.2\ \mathrm{m}/_\mathrm{s}$ when the "Hammer" is released upon completing the third rotation around the circle. For all questions below ignore any effects of gravity and/or air resistance.

(a) What is the final angular speed when the "Hammer" is released?

(b) What is the angular acceleration of the "Hammer" when released?

(c) What is the tangential acceleration of the "Hammer' when released?

(d) What is the centripetal acceleration just before the "Hammer" is released?

(e) What is the net force being exerted on the "Hammer" by the competitor just before it is released?

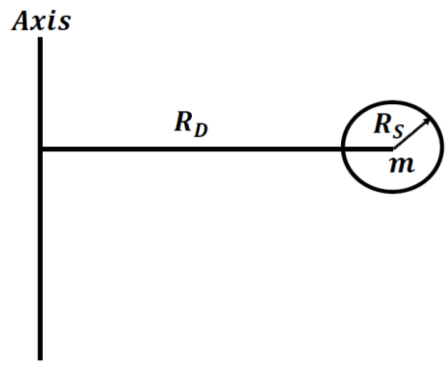
(f) What is the angle of the net force with respect to the radius of circular motion?

<u>**Solution for Problem 23**</u>

24. Consider a door, mass is $36.0\ \mathrm{kg}$, a width of $0.914\ \mathrm{m}$ and a height of $2.032\ \mathrm{m}$. Assume the door has hinge all along the left side of the door. Determine the moment of inertia for the door. Assume mass is uniformly distributed throughout the door. Calculate its moment of inertia.

<u>**Solution for Problem 24**</u>

25. A solid sphere has a radius R_S and a mass m. The sphere is connected to a massless rod of length R_D. The sphere is then free to rotate without friction around the labelled axis shown below.



(a) First consider that the sphere has all of its mass acting only at its center of mass. Calculate the moment of inertia of the sphere rotating around the axis.

(b) Second calculate the moment of inertia of the sphere rotating around the axis by using the parallel axis theorem.

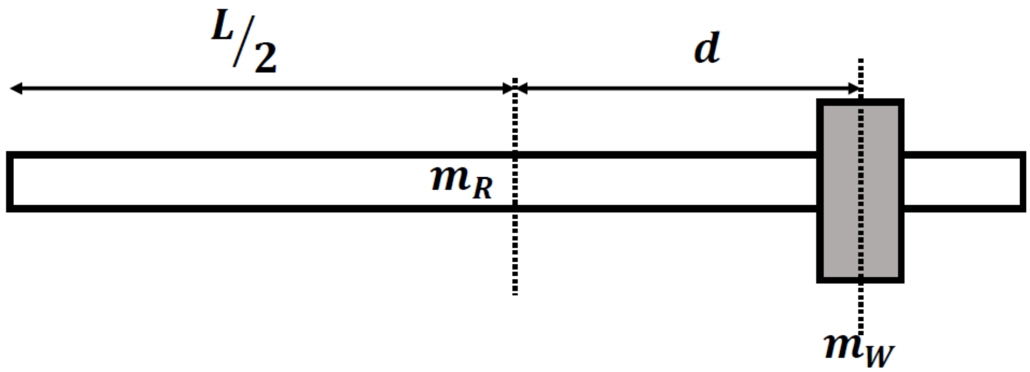
(c) Calculate the difference in moment of inertia values between these two methods of calculating the moment of inertia of the sphere rotating around the axis.

(d) Determine a numerical value for this %diff if $R_S = 0.100\text{ m}$ and $R_D = 0.500\text{ m}$

(e) Determine a numerical value for this %diff if $R_S = 0.100\text{ m}$ and $R_D = 1.00\text{ m}$

<u>**Solution for Problem 25**</u>

26. A thin rod of length $(L = 1.80\text{ m})$ and a mass $(m_R = 2.68\text{ kg})$ has an addition weight $(m_W = 4.20\text{ kg})$ which is placed on the rod a distance $(d = 0.600\text{ m})$ from the center of the rod. This is shown below.



(a) Find the location of the center of mass along the rod due to the rod and the added weight.

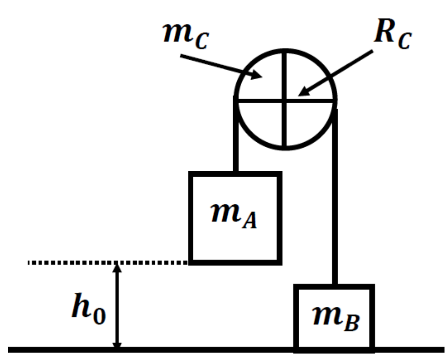
(b) If you placed an axle at this new center of mass, what would the moment of inertia for this combination of rod and weight be as it rotates about this axle?

<u>Solution for Problem 26</u>

27. A simple Merry-Go-Round is a disk which has a mass $(m_D = 1720.\text{ kg})$ and has a radius of $(R_D = 6.80\text{ m})$. Consider this to be a solid disk. How much work is needed to bring the Merry-Go-Round from rest up to a speed of 2.00 Revolutions in a time of 12.0 s?

<u>Solution for Problem 27</u>

28. As shown below there are two masses $m_A = 28.0\text{ kg}$ and $m_B = 23.5\text{ kg}$ which are connected by a massless, stretchless and unbreakable cable. The cable passes over a solid cylinder of mass $m_C = 4.30\text{ kg}$ and a radius of $R_C = 0.650\text{ m}$. Assume the mass in the cylinder is uniformly distributed and the center bearing of the cylinder is frictionless. Before the system is allowed to move, mass A is located a height $h_0 = 2.34\text{ m}$. When mass A is just about to touch the ground, what is its speed?



<u>Solution for Problem 28</u>

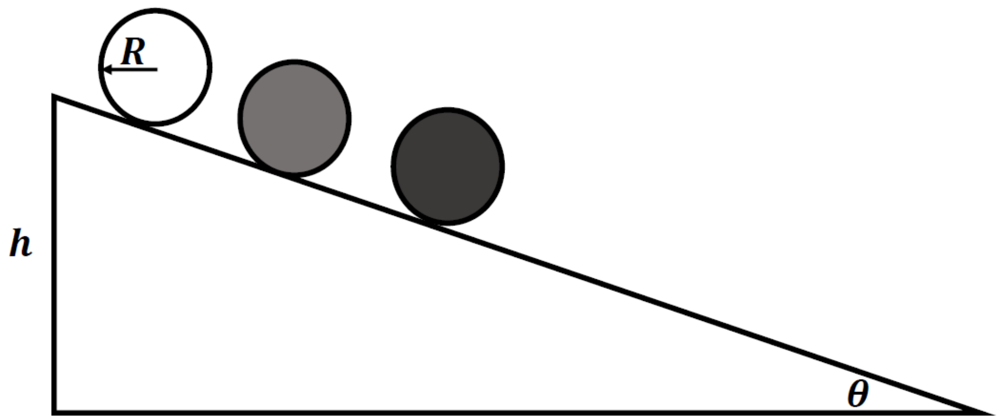
29. The Earth has a mass ($m_E = 5.98 \times 10^{24}$ kg) and a radius ($R_E = 6.38 \times 10^6$ m). Consider the Earth to be a uniform solid sphere. The Earth is a distance ($d_{ES} = 1.50 \times 10^{11}$ m) from the Sun. Estimate the Earth's kinetic energy from:

(a) The daily rotation of the Earth about its internal rotation axis.

(b) The yearly rotation of the Earth about the Sun.

Solution for Problem 29

30. Three objects are released a height ($h = 5.30$ m) and they are allowed to roll without slipping down a plane which is inclined an angle ($\theta = 32.0°$) with respect to the horizontal. Each of the three objects has a mass ($m = 5.56$ kg) and a radius ($R = 0.175$ m). All start at the top of the incline at rest and roll down the incline with enough space that the three objects start side by side at the beginning. One object is a solid sphere, one is a solid disk and the last is a ring. Ignore any effects of air resistance.



(a) Calculate the translational speed of each object.

(b) Which object wins "the race to the bottom"?

(c) Calculate the rotational speed of each object.

(d) Determine the ratios of translational kinetic energy to rotational kinetic energy for each object.

Solution for Problem 30

31. A solid cylinder has a radius R and a mass m. Around it a stretchless, massless and unbreakable cord is wrapped around the cylinder. A tension force is applied to the cord and pulls up causing the cord to unwrap around the cylinder. The tension is such that the cylinder remains at the same height while the cord is being pulled.

(a) What is that tension force?

(b) Determine the expression for angular speed as a function of time.

(c) Determine the expression for the work done by the tension force as a function of time.

Solution for Problem 31

32. A Jeep Wrangler has a mass $(\mathrm{m_{Jeep}} = 2450.\,\mathrm{kg})$. It of course has four wheels which have radii $(\mathrm{R_{Tire}} = 0.422\ \mathrm{m})$ and each tire/wheel has a mass $(\mathrm{m_{Tire}} = 30.9\ \mathrm{kg})$. Assume the tire/wheel combination acts like a solid cylinder. The Wrangler is traveling with a constant speed of $53.6\ ^{\mathrm{m}}/_{\mathrm{s}}$.

(a) What is the total kinetic energy of the Jeep Wrangler?

(b) What fraction of the total kinetic energy is the rotational kinetic energy of the tires/wheels?

Solution for Problem 32

33. A compact disc has a radius of $0.060\ \mathrm{m}$. The binary information is encoded along a spiral which begins with an inner radius $(\mathrm{R_{In}} = 0.025\ \mathrm{m})$ and the spirals work out to an outer radius $(\mathrm{R_{Out}} = 0.058\ \mathrm{m})$. The laser interacts with encoding to reveal the information stored on the CD. To read it properly the rotational speed of the CD is changed as the laser moves outward to produce a constant linear speed of the data equal to $1.25\ ^{\mathrm{m}}/_{\mathrm{s}}$.

(a) What is the angular speed of the CD when the laser is at the inner radius?

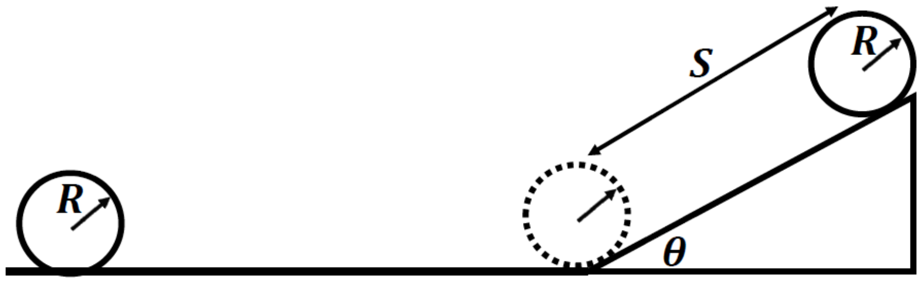
(b) What is the angular speed of the CD when the laser is at the outer radius?

Solution for Problem 33

34. Charles has a glow stick $(\mathrm{m} = 0.331\ \mathrm{kg})$ that is attached to a massless, stretchless and unbreakable cord. He swings the glow stick around a nearly horizontal circle $(\mathrm{R} = 1.75\ \mathrm{m})$ trying to attract attention. Charles begins with the glow stick at rest and in a time of $4.35\ \mathrm{s}$, he is causing the glow stick to make 95 revolutions per minute. What is the magnitude of the torque used?

Solution for Problem 34

35. A hollow sphere $(\mathrm{m} = 3.76\ \mathrm{kg}$ and $\mathrm{R} = 0.450\ \mathrm{m})$ is rolling along a horizontal surface with a speed of $\mathrm{v} = 6.21\ {}^{\mathrm{m}}/_{\mathrm{s}}$. The sphere encounters a plane inclined by an angle $(\theta = 13.0°)$ with respect to the horizontal. See below.

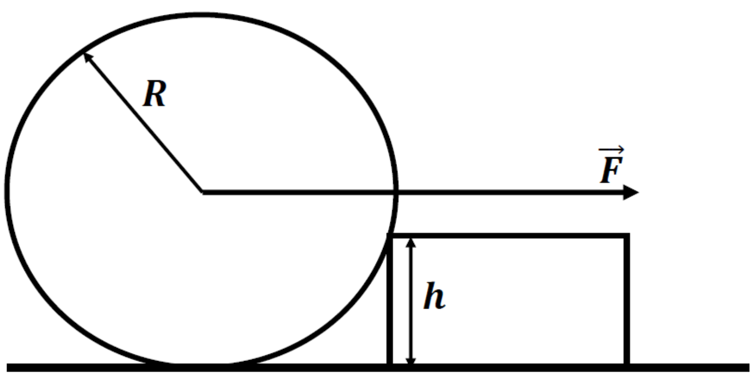


(a) How far up the incline (S) does the sphere roll before it momentarily stops?

(b) How long is the sphere rolling up and down the inclined plane?

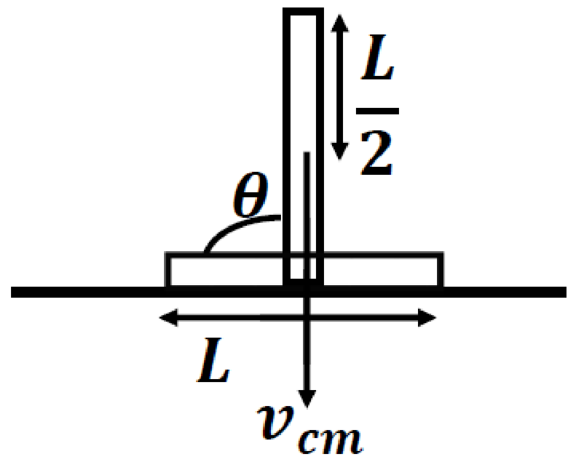
Solution for Problem 35

36. A wheel of mass (m) and radius (R) is standing vertically on the floor next to and touching a step of height $(\mathrm{h} < \mathrm{R})$. A force $(\vec{\mathrm{F}})$ acts on the center of the wheel as indicated below. What is the minimum magnitude of the force that is necessary to start to raise the wheel up the step?



Solution for Problem 36

37. A thin rod of length (L) and mass (m), which is uniformly distributed, is started vertically at rest on a frictionless surface. It is released from rest and allowed to slip and fall. Find the expression for the speed of the center of mass just before it hits the frictionless surface.



Solution for Problem 37

Please send any comments or questions about this page to ddonovan@nmu.edu

This page last updated on April 7, 2024