PHYS 121: Homework #07

November 7, 2023

Physics 121: Spring 2024: Week 10 Reading assignment:

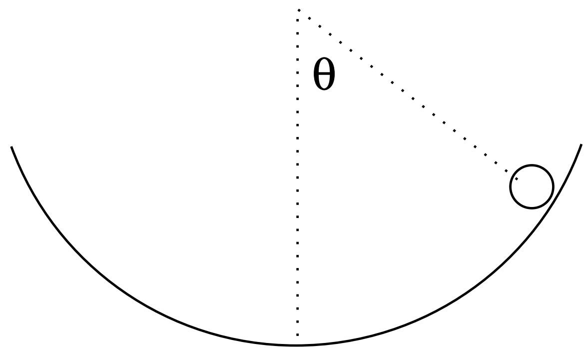
REQUIRED: ***Physics 121 Online Class Notes*** **Cycle 2, Chapter 13+ and Cycle 3, Chapters 1++ through 4++, 8++ and 9++, posted on the Canvas website, as follows:**

- **Re-Read Chapter 13+**: If you have not already read this chapter, take a good look now. This is really the most important chapter on torque for the entire semester. Make sure you understand the difference between the definition of torque (what Bob Brown called the "torque formula") and Newton's Second Law in rotational form. You should be able to tackle a "statics" problem like a board on a trestle or a bar held up with guy wires. The "Hinge Force" is now part of the Force Menu for the course.
- **Read Chapter 01++: Skim through this material. More important than being able to work calculations with arbitrary angles is being able to understand conceptually how relative velocity works as a vector concept.**
- **Read Chapter 02++: Skim this chapter. This is more for enriching your understanding of constant acceleration than anything else.**
- **Read Chapter 03++: This is worth a careful read. We will be getting back to more about Center-of-Mass and how it responds to external forces next week.**
- **Read Chapter 04++**: The most important thing here is the concept of escape velocity which follows from the application of Conservation of Energy to universal gravity.
- **Read Chapter 08++**: Massive pulleys, Extended Free Body Diagrams.
- **Read Chapter 09++**: Okay, now you can work with conservation of energy even when you have rotational motion. Skim the attached appendices. Now you know how to calculate the moment of inertia for a sphere if you really need to.

This Homework is due Monday, April 1 at 11 PM and must be submitted online as a PDF file via Canvas.

Homework continues next page....

Problem 1: A Final Exam Problem From 2011:



A round marble with a given mass m and given radius r is placed inside a smooth spherical bowl as shown. The radius of curvature for the inside of the bowl is given as R and the marble is released at rest at a position corresponding to a given angle θ_0 relative to the the vertical radius line as shown. Assume $r << R$. Assume that θ_0 is small enough so that the marble rolls without slipping.

a) Draw a Free Body Diagram (FBD) indicating the forces on the marble at the point it is released. Be sure to include a proper coordinate system that is aligned with the direction of acceleration.

b) Draw an Extended Free Body Diagram (XFBD) indicating the forces on the marble at the point it is released. Be sure to indicate a "pivot point" and also indicate the direction of positive torque.

c) Calculate the magnitude and direction of the torque about the center of the marble that is applied to the marble at the point instantly after it is released. Give you answer in terms of the given parameters. Explain your work.

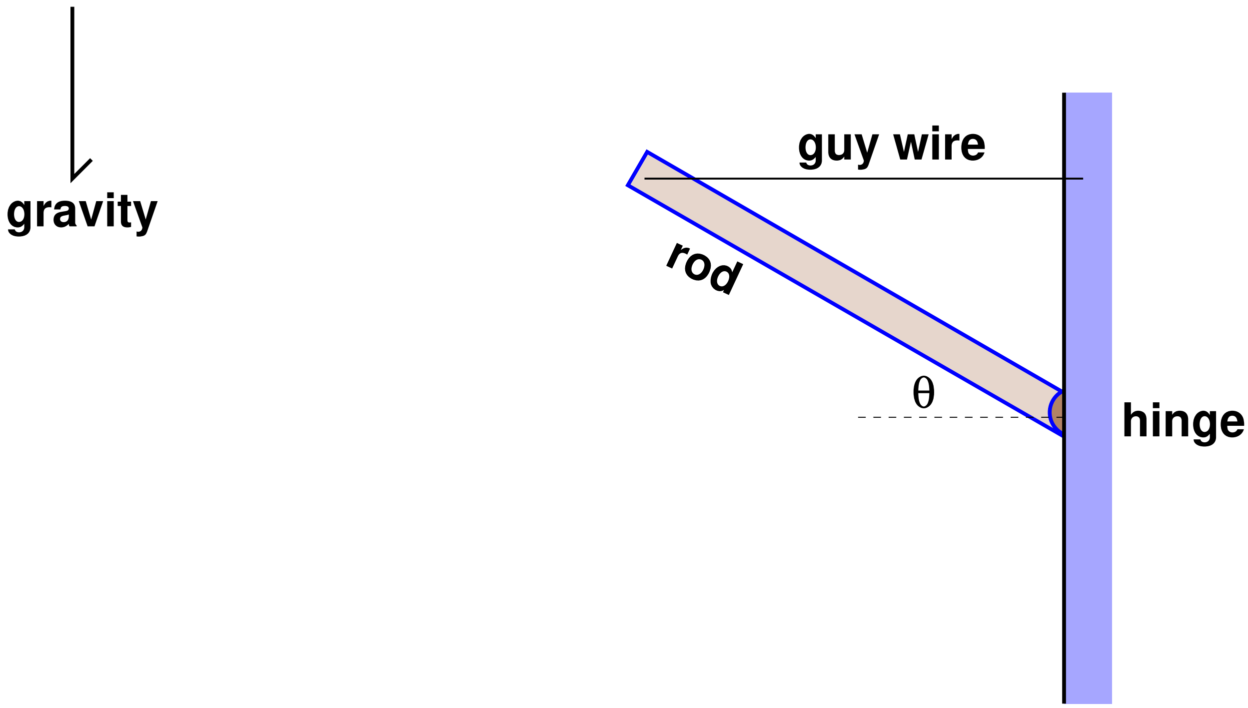
d) Calculate the magnitude of the translational acceleration of the marble at the point instantly after it is released? Give you answer in terms of the given parameters. Explain your work.

e) Use Conservation of Energy to determine the linear speed of the marble when it is at the bottom of the bowl. Don't forget that you must include both linear and rotational kinetic energy. Give you answer in terms of the given parameters. Explain your work.

f) What is the magnitude of the Normal Force on the marble when it is at the bottom of the bowl? Give you answer in terms of the given parameters. Explain your work. Hint: $N = mg$ is the wrong answer.

Problem 2: From a Previous Exam:

A thin rod of given mass m is attached to an hinge so that it can swing vertically. The length of the rod is given as ℓ and the rotational inertial of the rod about one end is $I = \frac{1}{3}m\ell^2$. The rod is held in place at a given angle θ with respect to the horizontal by an guy wire which we represent as an ideal string which connects the far end of the bar to the wall as shown.



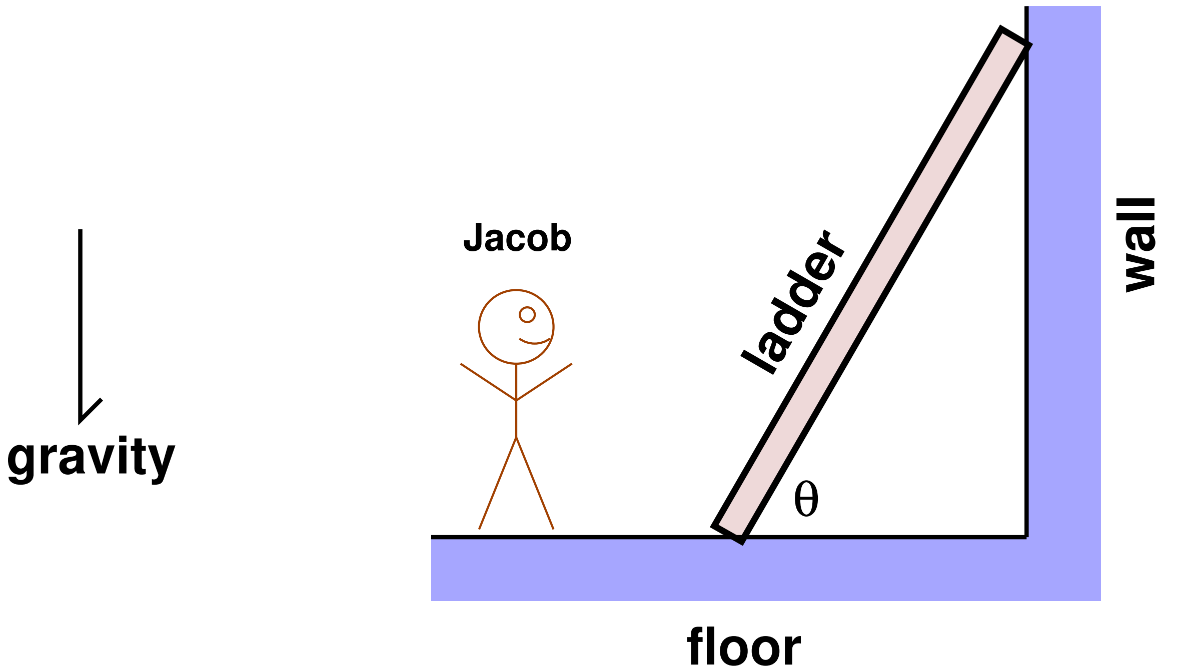
Part (a) – Draw a careful and properly labeled Free-Body Diagram (FBD) that shows *all* of the forces on the thin rod. Also, draw a careful and properly labeled Extended Free-Body Diagram (XFBD) for the thin rod. In your diagrams, the unknown *hinge force* should be represented by two components, H_H and H_V, corresponding to the *horizontal* and *vertical* components respectively.

Part (b) – Calculate the magnitudes of both H_V and H_H. Express your answers in terms of the given parameters. Explain. Hint: for this part use a coordinate system that is lined up with the Hinge Force components (*not* tilted). Another hint: $\sin(90^\circ - \theta) = \sin(\frac{\pi}{2} - \theta) = \cos\theta$.

Part (c) – Suppose the guy wire is cut so that the rod is suddenly free to begin to rotate on the hinge. What is the magnitude of the acceleration of the center-of-mass point of the rod just at the instant after the wire is cut? Express your answer in term of the given parameters. Explain your work. Hint: for this part use a coordinate system that is *tilted* so that it is aligned with the instantaneous direction of acceleration.

Part (d) – After the wire is cut, the rod swings down and collides flush with the wall. What is ω_{hit}, the angular speed of the rod at the instant just before it hits the wall? Express your answer in term of the given parameters. Explain your work.

Problem 3: Jacob's Ladder – from an old exam



A ladder of given length L and mass M leans ***at rest*** against the wall at a given angle θ as shown. Assume that the surface of the *wall* is **frictionless**, but assume that the *floor* applies both a **Normal** force *and* an **Friction** force to the ladder.

Part (a): Draw a **Free Body Diagram** and also an **Extended Free Body Diagram** for the ladder. Be sure to label each of your forces appropriately.

Part (b) Calculate the **magnitude** of *each and every force* on the ladder. Present your answers in terms of given parameters. Explain your work.

Part (c) – (10 points): Suppose the coefficients of **kinetic friction** and **static friction** are *given* as μ_k and μ_s respectively. What is the ***constraint*** that applies to the value of $\boldsymbol{\theta}$ that ensures that the ladder stays *at rest* and does **not** slip and fall down? Explain your work.