PHYS 121: Homework #06

March 06, 2024

Physics 121: Spring 2024: Week 8 and 9 Reading assignment:

REQUIRED: ***Physics 121 Online Class Notes*** **Cycle 2, Chapters 9+ through 15+, posted on the Course Website, as follows:**

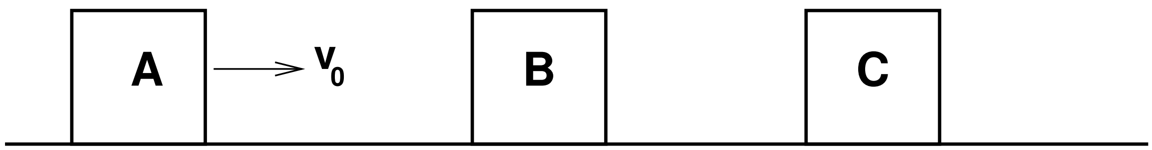
- **Read Chapter 09+**: This is quite an important chapter where we really get a handle on the idea of Work. I have some quibbles with the "push the car uphill" example, though. In particular, even though the work done by the Normal force here is zero, it's not accurate to say that "normal forces never do work". They can and do if the surface is moving.
- **Read Chapter 10+**: Here we start to contend with elastic collisions. The so called "master equations" (labeled "**E**" can be quite useful. Note that this is an alternate method relative to the "four-box" method that I showed in class (which is outlined in Cycle 2 Review Sheet, Part 3. Also make sure you can work a problem with an inelastic collision in 2-D.
- **Read Chapter 11+:** Here are all of the ways you can calculate the center-of-mass of a system. It's a technical issue. For me, more important is the conceptual issues that the Center-of-Mass represents the "point position" of a system when we apply Newton's Second Law to that position: $\vec{F}_{sys} = M_{sys}\vec{a}_{CM}$.
- **Read Chapter 12+**: Finally we come "full circle" to deal with non-uniform motion on a curved path. We want to be able to move back-and-forth between describing the motion in terms of translational parameters and rotational parameters. Note the RWB uses a somewhat different symbols than I use for the unit vectors (he uses $\hat{x}$, $\hat{y}$, and $\hat{z}$ instead of $\hat{\boldsymbol{\imath}}$, $\hat{\boldsymbol{\jmath}}$ and $\hat{\boldsymbol{k}}$. Make sure you know how to calculate the dot product of two vectors given in components: e.g.: $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$.
- **Read Chapter 13+**: 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 14+**: You should understand conceptually how the Moment of Inertia is calculated, although we won't ask you to actually calculate values I until the second half of the course. You should understand clearly how how to contend with a massive pulley. What Bob Brown calls the "tangential-linear acceleration relation" I call the "Rolling Constraint".
- **Read Chapter 15+**: Skim this chapter for now. Note that the pendulum system looks like a Simple Harmonic Oscillator. The concepts of the parallel axis theorem is nice to see but we won't really use it until the second half of the course.

OPTIONAL BUT RECOMMENDED: **Read** ***Physics for Scientist and Engineers*** **by Ohanian and Markert** as follows:

- **Read Chapter 6, Selected Sections as follows:**
  - **Review Review Section 6.1** Make sure you understand Example 2.
  - **Read Section 6.2** We will be dealing with springs and oscillations again.
  - **Review Section 6.3** Uniform Circular Motion should be getting quite familiar by now. Make sure that all of these examples makes sense to you now.
- **Read Chapter 7, Selected Sections as follows:**
  - **Review Section 7.1** This is the old definition of work when the force is constant.
  - **Read Carefully Section 7.2** Now we see that Work is really an *integral of the force over a distance along a path*. Make sure you understand Example 4.
  - **Review Section 7.3** The Work-Energy Relation (here called the "Work-Energy Theorem") is your friend.
  - **Read Section 7.4** Now we have potential energy expressions for three different conservative forces.
- **Read Chapter 8, Selected Sections as follows:**
  - **Read Section 8.1** Hopefully now the idea that the potential energy comes from the negative of the Work done by a conservative force is in your head.
  - **Read Section 8.2** This is "too complicated" but the basic idea is pretty useful.
- **Read Chapter 9, Selected Sections as follows:**
  - **Read Sections 9.1 and 9.3** Hopefully these make good sense to you by now.
  - **Read Section 9.5** Here is where the potential energy due to universal gravity comes from.

This Homework is due TUESDAY, March 19 at 11 PM and must be submitted online as a PDF file via Canvas.

Problem 6: Two 1-D Collisions



Three blocks, are placed on a frictionless surface as shown above. Block A has a given mass of m, Block B has a given mass of $2m$ and Block C has a given mass of $5m$. Block A has initial velocity given as v_0 while the other two blocks are *initially* at rest. Then the following happens:

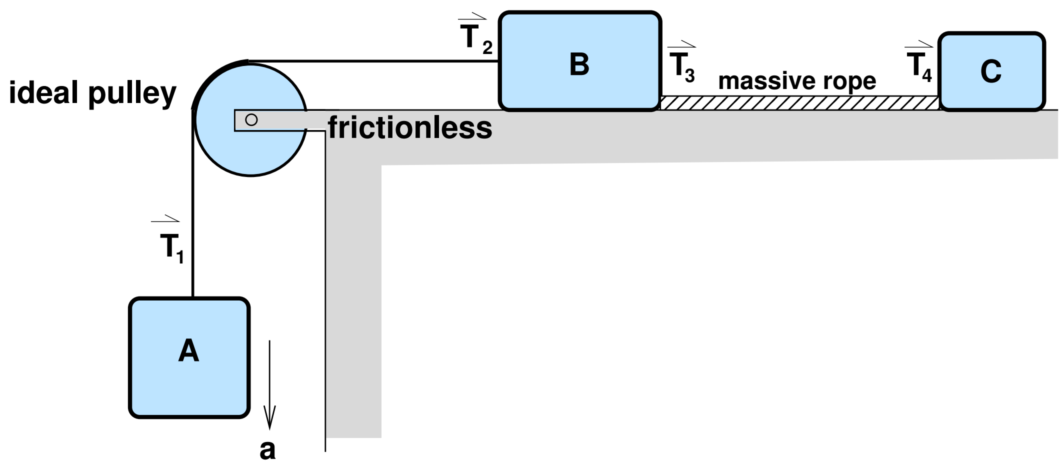
- First Collision: Block A collides with Block B and this collision is ***totally inelastic***.
- Second Collision: Block B collides with Block C and this collision is ***totally elastic***.

Part (a): Determine the final velocity of every block immediately after the First Collision.

Part (b): Determine the final velocity of every block immediately after the Second Collision.

Part (c): Suppose we define V_{CM} as the velocity of the Center-of-Mass of the *entire system* of three blocks, A, B, and C. What is V_{CM} just *before* the First collision. What is V_{CM} just *after* this First Collision? What is V_{CM} just *after* this Second Collision?

Problem 2: Newton's Second Law and a Massive Rope



Three blocks A, B, and C with a given mass m_A, m_B, and m_C respectively, are positioned as shown above. Blocks B and C are accelerated to the left along the frictionless surface . The pulley is ideal as is the string between Blocks A and B. A massive rope of mass m_r connects Blocks B and C. Assume that the rope sits flush on the frictionless surface so that there is no component of the tension in the vertical direction.

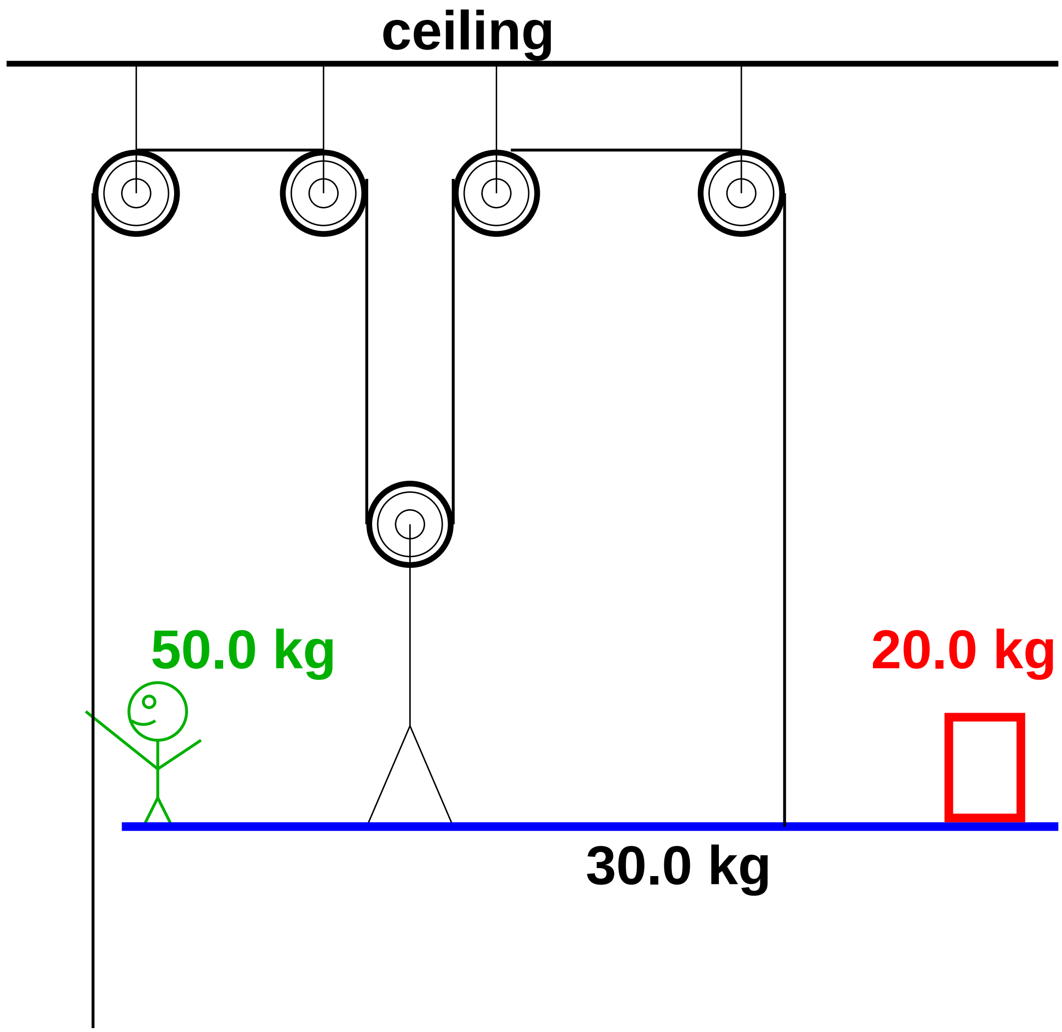
Part (a): Rank the four tension forces from largest to smallest. Explain how you determined this. Hint: this is a *conceptual* question. No algebra or calculations required. Important hint: any solution that includes either of the words "system" or "motion" is probably not correct. You want to invoke a Law of Physics here.

Part (b): Determine the magnitude of the acceleration a of Block A. Explain your work. Give your answer in terms of the given parameters. Hint: you will simplify your calculation if you consider these three items: Blocks B, Block C and the massive rope, altogether, as one "system".

Part (c): Assume that the massive rope has length L. Determine the tension *in the massive rope* as a function of horizontal position x along the rope measured relative to the *right* edge of Block B. Give your answer in terms of the given parameters. Explain your work.

Problem 3. Pulleys and Systems:

Leonard Nimoy stands on a platform and pulls on an ideal rope, which is attached to a system of ideal pulleys as shown:



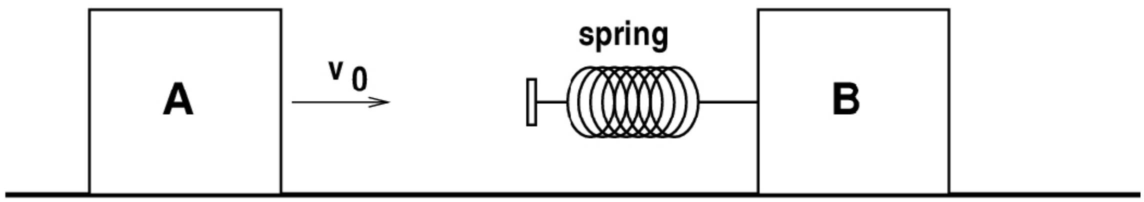
The mass of Leonard is given as $m_\ell \equiv 50.0$ kg. The mass of the platform is given as $m_p \equiv 30.0$ kg. The mass of a box that sits on the platform is given as $m_b \equiv 20.0$ kg. Assume that Leonard pulls the rope so that the platform moves upward with given constant acceleration $A_0 \equiv 0.200$ meters per second squared.

a) What are the magnitudes and directions of all forces on the box? Give your answer both in terms of given symbolic parameters and in terms of numeric values. Explain your work.

b) What is the tension in the rope? Give your answers in terms of given symbolic parameters and in terms of numeric values. Explain your work.

c) What are the magnitudes and directions of all forces on Leonard? Give your answers in terms of given symbolic parameters and in terms of numeric values. Explain your work.

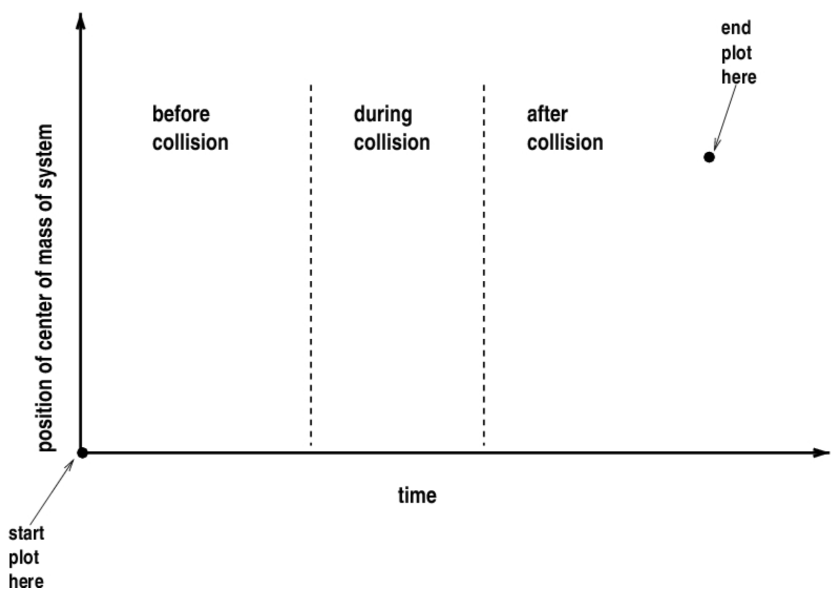
Problem 4: A Springy Collision that Is Way Simpler Than It Looks



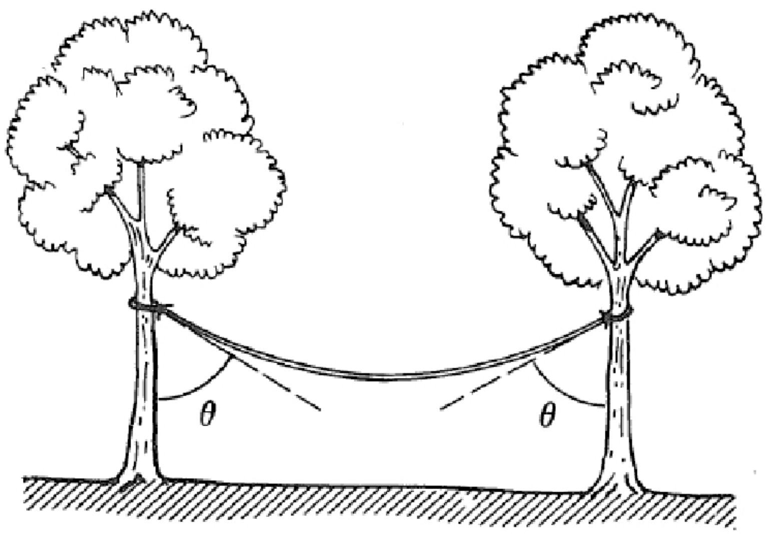
Two blocks A and B each with mass m= 2.0 kg sit on a frictionless surface. Block A has a velocity v_0 = 5.0 m/s towards block B which is at rest. There is a massless spring with spring constant k =1.00 N/m attached to Block B as shown. Block A collides with the spring that is attached Block B. The spring is compressed, and then after a while it is uncompressed and the two blocks separate from each other. Note that because the spring force is Conservative, the collision is ***totally elastic***.

a) What is the final velocity of block A? What is the final velocity of block B? Be sure to show your work.

b) Consider the system which is made of block A, block B, and the spring. On the following figure make a *qualitative plot* of the position of the center of mass x_{cm} for this entire system as a function of time. Start and end your plot at the points indicated. What is the slope of your plot during the intervals of time corresponding to each of these three periods: (1) before, (2) during, and (3) after the collision? Be sure to explain your work. Use physics!



Problem 5: Massive Rope Hung Between Two Trees



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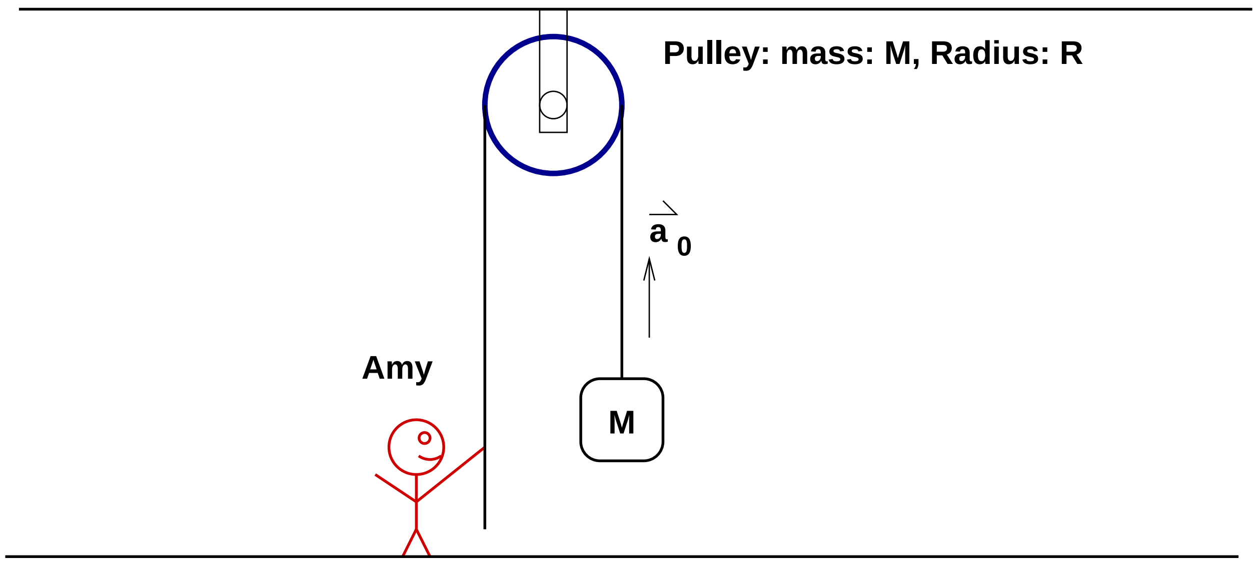
A massive uniform rope of total mass m and length L is attached to two trees as shown in the figure above. The connection point for the rope is the same height on each tree, each rope makes an given angle θ with each tree as shown.

Part (a): Find the tension at either end of the rope.

Part (b): Find the tension at the center of the rope.

Hint: Perhaps this looks like a problem where detailed calculus is required. It's not. If you are doing the problem correctly, each part require just a few lines of simple mathematical work.

Problem 6: A massive pulley problem



Amy stands on the floor and pulls hard on a rope that is attached to a massive pulley and a block as shown above. The mass of the block is given as M. The mass of the pulley has the same given mass M. Amy's mass is given as $3M$. Amy pulls so that the block accelerates upward with a given constant acceleration $\vec{a}_0$. Assume that the pulley wheel can be represented as a solid disk with rotational inertia given by $I = \frac{1}{2}mR^2$.

What are all of the forces on Amy? Determine the type, magnitude, and direction of each force. Explain your work. If you are using Newton's Laws here, be sure to include clearly labeled Free-Body-Diagrams and/or Extended-Free-Body-Diagrams as needed. Your work for this problem needs to be complete, neat, coherent, and completely explained to earn full credit.