LECTURE 14: The massless frictionless pulley

Select LEARNING OBJECTIVES:

i. Introduce the massless frictionless pulley, specifically how it redirects the tension but does not affect the value of tension on either end of the pulley.
ii. Demonstrate the ability to translate a FBD into Newton's second law equations.
iii. Strengthen the ability to decompose vectors into components along the chosen coordinate system.
iv. Demonstrate the ability to quantitatively solve algebraic expressions, including quadratic equations.

TEXTBOOK CHAPTERS:

- Giancoli (Physics Principles with Applications 7th) :: 4-7
- Knight (College Physics : A strategic approach 3rd) :: 5.8
- BoxSand :: Forces (Coupled Systems)

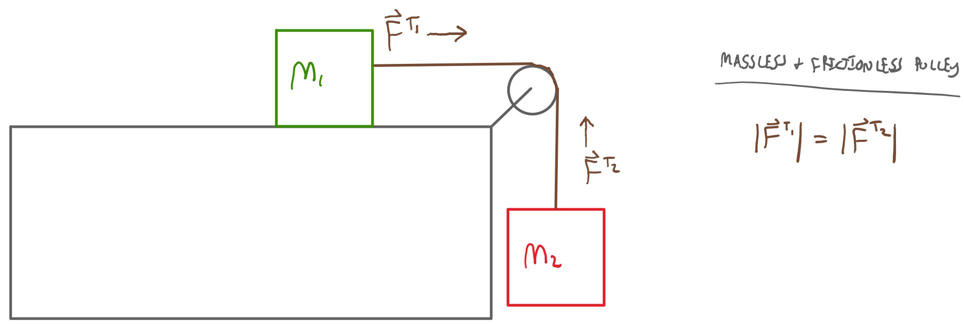
WARM UP: (T/F) A box of mass m hangs from a massless rope in an elevator that is moving upwards but slowing down.

(1) The magnitude of the force of tension in the rope is greater than the magnitude of the force of gravity from Earth acting on the box.
(2) The magnitude of the force of tension in the rope is less than the magnitude of the force of gravity from Earth acting on the box.
(3) The magnitude of the force of tension in the rope is equal to the magnitude of the force of gravity from Earth acting on the box.
(4) Need more information.

Pulleys are fantastic tools with many different uses. This lecture will introduce a simplified version of a pulley and some basic applications. We will build in this simplified pulley model as we get further into the series. The simplification we will make is via two approximations:

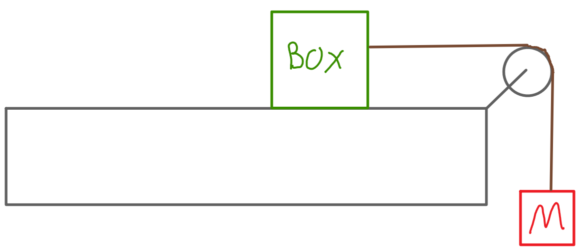
1. The pulley itself is of negligible mass (we will just call it massless for short).
2. There is negligible friction in the pulley's bearings (we will call it frictionless for short).

By assuming both of these approximations together, the result is a pulley which effectively just changes the direction of the force of tension in the string that is hung around the pulley, but does not change the magnitude of the force of tension on either side of the pulley. An example of this result is shown below.



This lecture will have just a few practice problems. The massless frictionless pulley will make more appearances in all the following sections using Newton's laws of motion to analyze the motion of objects.

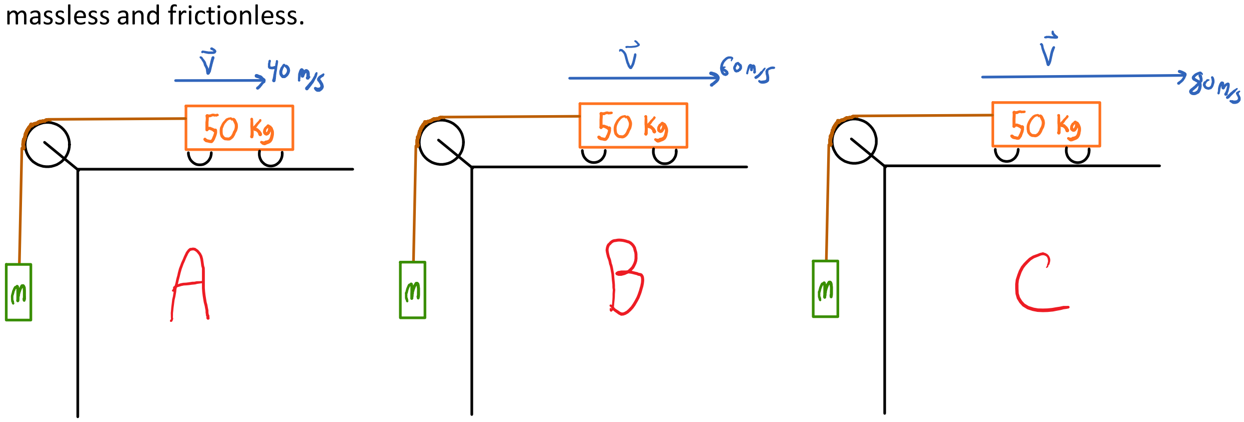
PRACTICE: A large box sits on top of a horizontal frictionless table connected via a massless string and massless/frictionless pulley to a box of mass M that hangs off the edge of the table as seen in the figure below.



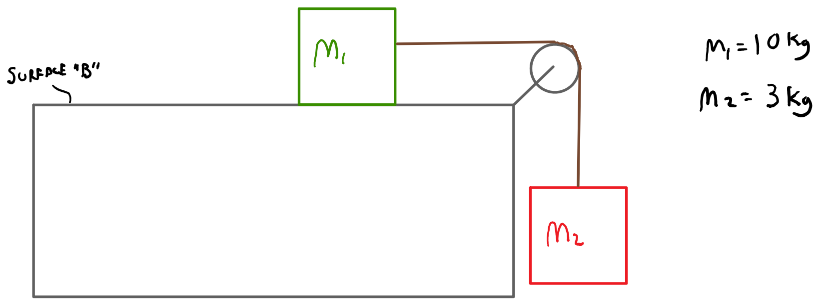
The tension in the string is __________ ?

1) equal to Mg
2) less than Mg
3) greater than Mg

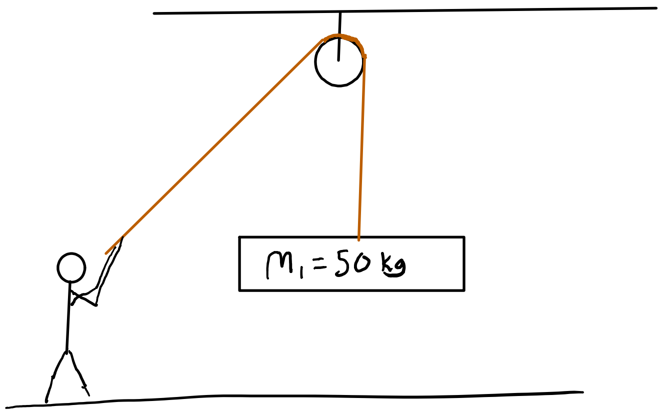
PRACTICE: Rank the following situations, greatest to least, based on the tension in the string. Assume the hanging mass in each case is the same, friction is negligible, the rope is massless, and the pulley is massless and frictionless.



PRACTICE: A 10 kg box sits on top of a frictionless surface. A string hung around a massless/frictionless pulley connects the 10 kg box to another box of mass 3 kg as shown in the figure below. Determine the acceleration of both boxes.



PRACTICE: A person lifts a hanging 50 kg platform connected to a massless/frictionless pulley that is fixed to the ceiling of a building as shown in the image below. If the tension in the rope can withstand a maximum of 740 N, what is the fastest acceleration the person can lift the platform?



Conceptual questions for discussion

1) What might be some benefits of using a single pulley that is massless and frictionless?
2) Pulleys are made out of "stuff", so it seems silly to say that a pulley is massless. When and why can we assume a massless pulley?