SPH4U: Tension and Pulleys

Recorder: ______
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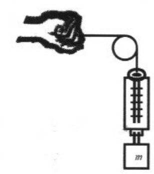
A: Physics Pulleys

You will need two pulleys, some string, 500 g masses and a spring scale. Set up your equipment as shown in the diagram.



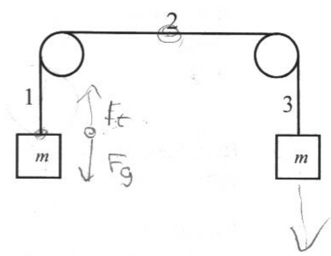
1. **Observe.** Change the angle of the string that passes over the pulley. Describe what you observe.
   No matter the angle of the string that passes over the pulley, the forces do not change.

2. **Reason.** Devise a rule describing how a pulley affects the magnitude and direction of the force of tension in a string.

Physics Pulleys: Pulleys can affect the direction, but not the magnitude of the force of tension in a string.

B: Testing String Theory

1. **Predict.** Don't set this up yet! Consider the two pulley situation shown in the next diagram which uses two 500 g masses. Suppose we measure the tension in the string at the three positions indicated. Predict the values of those three tension measurements. Provide a rationale for each.



Prediction	Rationale
(1) 4.9N	F_{t1} must equal F_g since they must balance. ∴, we found F_g
(2) 0N	The force of tension are acting in opposite directions, so they cancel out.
(3) 4.9N	F_{t3} must equal F_g since they must balace, so we found F_g

$F_{net} = ma_x$

$F_g = mg$

2. **Reason.** What is the readability of your spring scale? Estimate the uncertainty in the results you will get.
   The readability of our spring scale is 0.1 N. The uncertainty is ±0.05N

3. **Test and Evaluate.** Set up the materials as shown (just hold the pulleys in the air). Record your results along with uncertainties. Do you results agree with your predictions? Offer an explanation for the results you found.

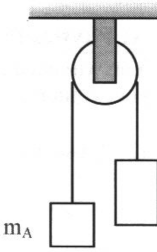
Result	Explanation
(1) 4.90N ± 0.05N	F_t must equal F_g since the mass is not accelerating so they must balance out
(2) 4.90N ± 0.05N	F_t must be the same on all points on the string
(3) 4.90N ± 0.05N	F_t must equal F_g since the mass is not accelerating so they must balance out

4. **Reason.** Create a definition of how tension works that explain what it means when we say, "there is 4.9 N of tension in a string".

Tension
The force of tension must be the same on all points of a string.

C: The Atwood Machine

An Atwood machine consists of two masses tied together and suspended over a pulley.For this part of the investigation, you will use the equipment set up at the front of the class.



1. **Predict.** The two masses are identical. You give agentle push to one mass.Predict the motion of the mass**after** it leaves contact with your hand. Justify your prediction.

   The motion of the masses will be constant velocity. because there are no additional forces exerted and also the mass will move in the direction you push in.

2. **Test.** Try it out.Describe your observations.Do they agree with your prediction?

   Our observations agree with our prediction. The mass we pushed on moved with a constant velocity in the direction we pushed in.

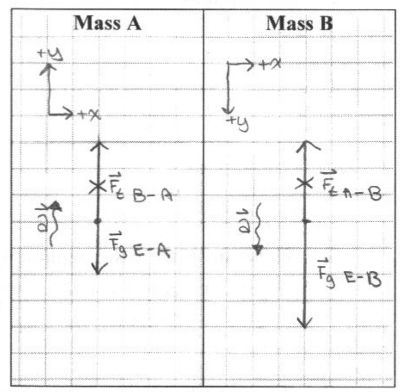
3. **Predict.** The mass of A is now less than B. Predict the motion of mass A after you release it. How will the motion of the two objects compare? Justify your prediction.

   Mass A will accelerate upwards after we release it. Mass B will move downwards with the same acceleration as A. Since the force of gravity acting on the objects are different, but the force of tension in the string must be the same, there will be an unbalance.

4. **Test.** Try it out. Describe your observations. Do they confirm your predictions?

   The mass travelled with constant acceleration. Therefore, they confirm our predictions.

5. **Represent.** Draw a FD for mass A and for mass B.($m_A<m_B$).Choose your sign conventions so they agree with the acceleration of **each** object!



6. **Reason.** For the FDs, do you need to use a different symbol for the magnitude of the acceleration of mass A and mass B? What about the forces of tension and gravity acting on each mass? Explain.

   We don't need a different symbol for the acceleration of mass A and mass B since the acceleration is the same. The force of tension will have the same magnitude b/c they are the same on all points of the string. The force of gravity will be different b/c of the different masses.

7. **Predict.** How will the magnitude of the force of tension compare with F_{gA} and F_{gB}? Explain.

   The magnitude of F_t will be greater than F_{gA} b/c the mass accelerates upwards. The magnitude of F_t will be smaller than F_{gB} b/c the mass accelerates downwards.

8. **Represent.** Write a complete expression for Newton's 2nd Law for each mass. Be very careful with your notation!

   Mass A

   $F_{net\,y} = m_A a_y$

   $F_{t\,B-A} - F_{g\,E-A} = m_A a_y$

   Mass B

   $F_{net\,y} = m_B a_y$

   $F_{g\,E-B} - F_{t\,A-B} = m_B a_y$

   $F_{g\,E-B} = 0.550\text{kg}(9.8\text{N/kg})$
   $= 5.39\text{N}$

   $F_{g\,E-A} = 0.500\text{kg}(9.8\text{N/kg})$
   $= 4.90\text{N}$

9. **Solve and Test.** Algebraically eliminate F_T from the above two equations and solve for the acceleration of the masses. Use the masses from the Atwood machine set up in the classroom and solve for the acceleration. Then test this result using the motion detector.

   $F_t = m_A a_y + F_{g\,E-A}$

   $F_t = F_{g\,E-B} - m_B a_y$

   $m_A a_y + F_{g\,E-A} = F_{g\,E-B} - m_B a_y$

   $m_A a_y + m_B a_y = F_{g\,E-B} - F_{g\,E-A}$

   $a_y(m_A + m_B) = F_{g\,E-B} - F_{g\,E-A}$

   $a_y = \dfrac{F_{g\,E-B} - F_{g\,E-A}}{m_A + m_B}$

   $a_y = \dfrac{5.39\text{N} - 4.90\text{N}}{0.500\text{kg} + 0.550\text{kg}}$

   $= 0.47\text{m/s}^2$

   ∴ the acceleration is 0.47m/s^2

8. **Evaluate.** Now go back and solve for the force of tension.How does this result compare with your prediction? Explain.

   $F_t = m_A a_y + F_{g\,E-A}$

   $= 0.500\text{kg}(0.47\text{m/s}^2) + 4.9\text{N}$

   $= 5.13\text{N}$

   ∴ the force of tension is 5.13N. This agrees with our prediction since it is greater than $F_{g\,E-A}$ (4.9N), but smaller than $F_{g\,E-B}$ (5.39N)