Pulleys & Tension

Unit: Dynamics (Forces) & Gravitation

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A

AP Physics 1 Learning Objectives: 1.C.1.1, 2.B.1.1, 3.A.2.1, 3.B.1.1, 3.B.1.2, 3.B.1.3, 3.B.2.1, 4.A.2.3, 4.A.3.1, 4.A.3.2

Skills:

- set up & solve problems involving ropes under tension

Language Objectives:

- Understand and correctly use the terms “pulley” and “tension.”
- Set up and solve word problems involving pulleys and/or tension.

Labs, Activities & Demonstrations:

- Air track & pulley.
- Atwood machine.

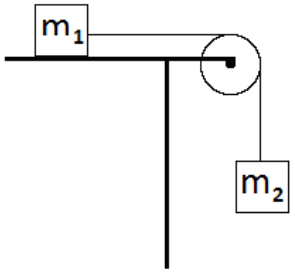
Notes:

tension: the pulling force on a rope, cable, etc.

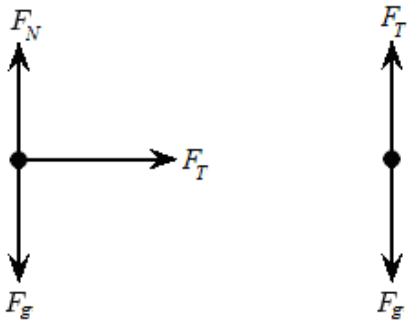
pulley: a wheel used to change the direction of tension on a rope

Use this space for summary and/or additional notes.

A typical problem involving pulleys and tension might be to find the acceleration of blocks m_1 and m_2 in the following situation. (Assume that the pulley has negligible mass and the surface and the pulley are frictionless.)



Free-body diagrams for the two masses would look like the following:



m_1 m_2

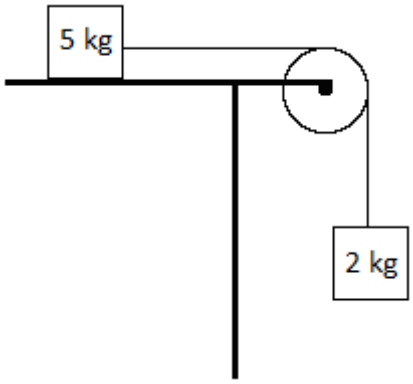
We know the following:

- F_T is the net force on m_1. Therefore, for m_1, $F_{net} = m_1 a$.
- For m_2, gravity and tension are pulling in opposite directions. The net force is therefore $F_{net} = F_g - F_T = m_2 a$
- Because the blocks are connected, both F_T and a must be the same for both blocks.

Use this space for summary and/or additional notes.

Sample Problem:

Q: Suppose we had the following situation:



Calculate the acceleration of the pair of blocks.

A: For the block on the table:

$F_T = ma = (5)(a)$

For the block hanging from the pulley:

$F_{net} = F_g - F_T = ma = (2)(a)$

$(2)(10) - F_T = 2a$

$20 - F_T = 2a$

Now we substitute $F_T = 5a$ into the second equation:

$20 - 5a = 2a$

$20 = 7a$

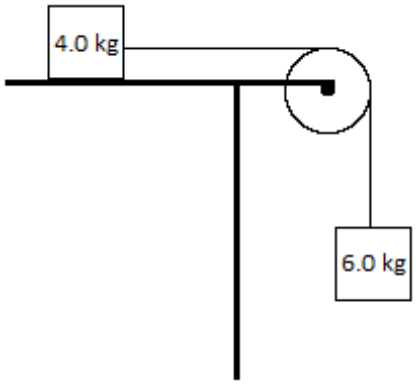
$a = \frac{20}{7} = 2.9 \frac{\text{m}}{\text{s}^2}$

Use this space for summary and/or additional notes.

Homework Problem

1. A block with a mass of 4.0 kg sitting on a frictionless horizontal table is connected to a hanging block of mass 6.0 kg by a string that passes over a pulley, as shown in the figure below.

   Assuming that friction, the mass of the string, and the mass of the pulley are negligible, at what rate do the blocks accelerate?

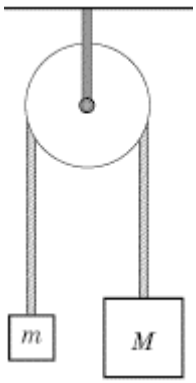


Answer: $6.0\,\frac{m}{s^2}$

Use this space for summary and/or additional notes.

2. Two masses, *m* and *M*, are connected by an ideal (massless) rope over an ideal pulley (massless and frictionless).

   What is the acceleration of the larger mass, in terms of *m*, *M*, and *g*?



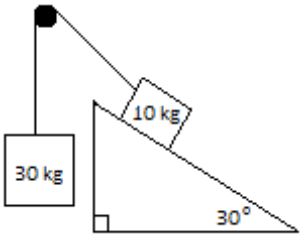
Answer: $a = \dfrac{g(M-m)}{M+m}$

Use this space for summary and/or additional notes.

AP problems often combine ramps and pulleys in the same problem:

Homework Problems: Ramps & Pulleys

1. A mass of 30. kg is suspended from a massless rope on one side of a massless, frictionless pulley. A mass of 10. kg is connected to the rope on the other side of the pulley and is sitting on a frictionless ramp with an angle of inclination of 30°. The system is shown in the following diagram:

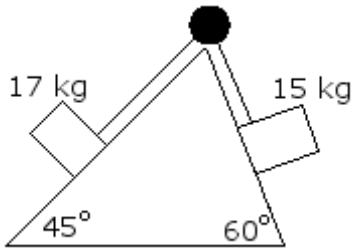


Determine the tension in the rope and the acceleration of the system.

Answers: $a = 6.25 \frac{m}{s^2}$; $\vec{F}_T = 112.5\,N$

Use this space for summary and/or additional notes.

2. Two boxes with masses 17 kg and 15 kg are connected by a light string that passes over a frictionless pulley of negligible mass as shown in the figure below. The surfaces of the planes are frictionless.



When the blocks are released, which direction will the blocks move?

At what rate will the masses accelerate?

Answer: $0.303\,\frac{m}{s^2}$

Use this space for summary and/or additional notes.