Pulleys & Tension

Unit: Dynamics (Forces) & Gravitation

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A


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
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:

We know the following:

- \( F_T \) is the net force on \( m_1 \). Therefore, for \( m_1 \), \( F_{net} = m_1a \).

- For \( m_2 \), gravity and tension are pulling in opposite directions. The net force is therefore \( F_{net} = F_g - F_T = m_2a \).

- Because the blocks are connected, both \( F_T \) and \( a \) must be the same for both blocks.
**Sample Problem:**

Q: Suppose we had the following situation:

![Diagram of pulleys and tension](image)

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:

\[ 20 - 5a = 2a \]

\[ 20 = 7a \]

\[ a = \frac{20}{7} = 2.9 \text{ m/s}^2 \]
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: \(6.0 \, \text{m/s}^2\)
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: 
\[
a = \frac{g(M - m)}{M + m}
\]
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:

   ![Diagram of a mass suspended from a pulley and a mass on a ramp](diagram)

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

   \[ a = 6.25 \text{ m/s}^2; \quad F_T = 112.5 \text{ N} \]

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: $0.303 \, \text{m/s}^2$