Pulley Problems Cheat Sheet

IDEAL STRINGS, FIXED PULLEYS

- Each string has one tension, the same all along it and on both sides of a pulley. Separate strings can have different tensions.
- While a string stays taut over a fixed pulley, the blocks it connects share speed and the size of the acceleration.
- A slack string pulls with zero force, and the blocks it joined move independently.
- Tension pulls along the string, away from each block.
- The support of an Atwood pulley pulls up with $2F_T$. A pulley with mass needs rotational dynamics, in Unit 5.

SET UP ANY PULLEY PROBLEM

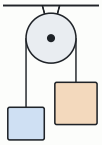
1. Choose one positive direction along the string for every block.
2. Draw a free-body diagram for each block.
3. With friction, test static friction before using kinetic.
4. System equation along the string for a. Tension cancels.
5. One block's equation for F_T.
6. If $a < 0$, the acceleration points the other way. Without friction, blocks at rest move that way, and moving blocks slow down first. With friction, redo step 3.

THE SYSTEM EQUATION, ALONG THE STRING

$$a = \frac{\text{forces pulling the + way} - \text{forces pulling the other way}}{\text{total mass of all the blocks}}$$

The numerator is the net driving force along the string, a sum of force components along the string's path. Single block: $\Sigma F = ma$ with that block's mass and the tension included.

ATWOOD MACHINE

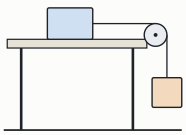


$$a = \frac{(m_2 - m_1)g}{m_1 + m_2}$$

$$F_T = \frac{2m_1m_2g}{m_1 + m_2}$$

- Equal masses: $a = 0$ and $F_T = mg$.
- F_T lies between m_1g and m_2g, and $a < g$.

BLOCK ON A LEVEL TABLE

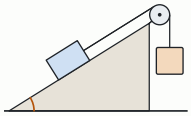


No friction: $a = \frac{m_2g}{m_1 + m_2}$

$F_T = \frac{m_1m_2g}{m_1 + m_2}$

- From rest, stays at rest if $m_2 \le \mu_s m_1$, with static friction and F_T both equal to m_2g.
- Sliding toward the pulley: $a = \frac{(m_2 - \mu_k m_1)g}{m_1 + m_2}$
- Then $F_T = m_1(a + \mu_k g)$.

BLOCK ON AN INCLINE



- Direction from rest: compare m_2g with $m_1g \sin\theta$. $F_N = m_1g\cos\theta$.
- From rest, stays at rest if $m_1(\sin\theta - \mu_s\cos\theta) \le m_2 \le m_1(\sin\theta + \mu_s\cos\theta)$.
- Block 1 slides up: $a = \frac{[m_2 - m_1(\sin\theta + \mu_k\cos\theta)]g}{m_1 + m_2}$
- Block 1 slides down: $a = \frac{[m_1(\sin\theta - \mu_k\cos\theta) - m_2]g}{m_1 + m_2}$
- Hanging block: $F_T = m_2(g - a)$ when it accelerates downward, $m_2(g + a)$ when it accelerates upward.

FIVE CHECKS BEFORE YOU HAND IT IN

1. For a block that hangs freely, is the tension less than its weight when it accelerates downward, and more than its weight when it accelerates upward?
2. When only weights drive the blocks, is a less than g? A hanging weight also has to accelerate its own mass.
3. Is static friction the value needed, and no more than $\mu_s F_N$?
4. On an incline, did you use $F_N = m_1g\cos\theta$ for friction?
5. In an Atwood machine, do equal masses give $a = 0$? On an incline, does $\theta = 0$ give the table result?

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