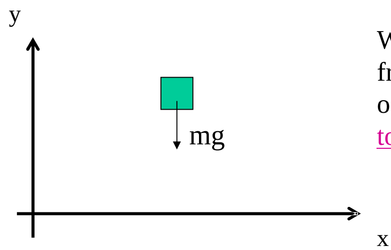
More on the Force Due to Gravity

Consider an object in free fall:



We said earlier than an object in free fall has an acceleration downward of 9.80m/s². We will now connect this to the force of gravity:

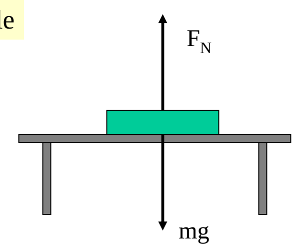
Apply Newton's 2nd Law to the object in free fall:

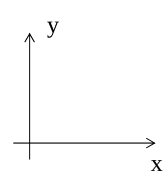
$$\sum F = ma$$
$$-mg = ma$$
$$a = -g = -9.80\text{m/s}^2$$

If the force of gravity is the only force acting on an object, then that object has an acceleration equal to "g", pointed downward.

More on the Normal Force

Example: Book on table





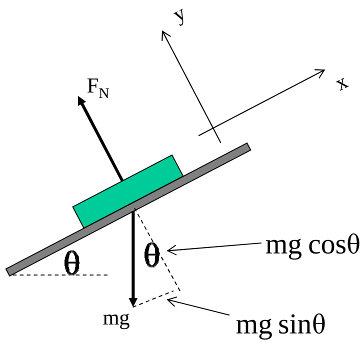
Apply Newton's 2nd Law along the y-direction:

$$\sum F_y = ma_y$$
$$F_N - mg = 0$$
$$F_N = mg$$

The acceleration in the y-direction is zero - since the block does not move in the y-direction

More on the Normal Force

Example: Book on smooth incline



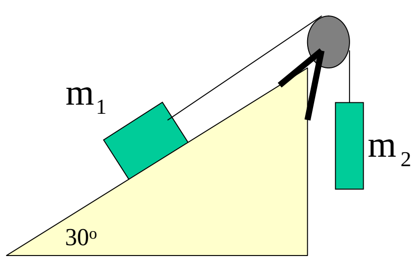
Apply Newton's 2nd Law along the y-direction:

$$\sum F_y = ma_y$$
$$F_N - mg\cos\theta = 0$$
$$F_N = mg\cos\theta$$

The acceleration in the y-direction is zero - since the block does not move in the y-direction

Example: Block 1 (m_1=8.00kg) is moving on a frictionless 30.0° incline. This block is connected to block 2 (m_2=22.0kg) by a cord that passes over a massless and frictionless pulley. Find the acceleration of each block and the tension in the cord.

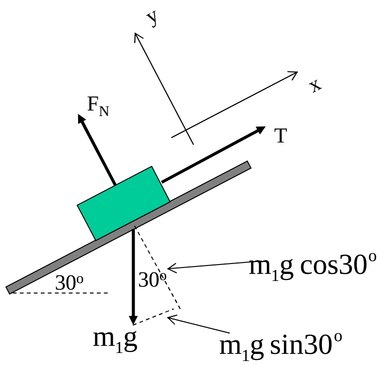
I) Draw a picture of the problem:



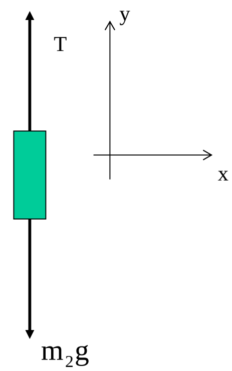
Example: Blocks and pulley continued...

II) Draw the forces on each block

Block 1:



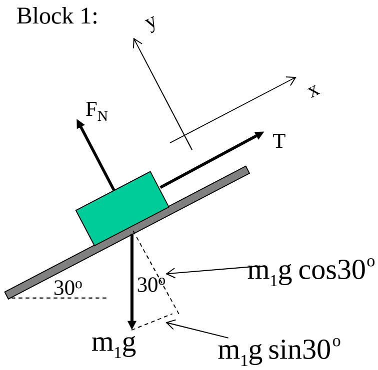
Block 2:



Example (continued)

III) Apply Newton's 2nd Law to the blocks:

Block 1:



Block 1, x direction:

$$\sum F_{x1} = m_1 a_{x1}$$
$$T - m_1 g\sin\theta = m_1 a_{x1}$$

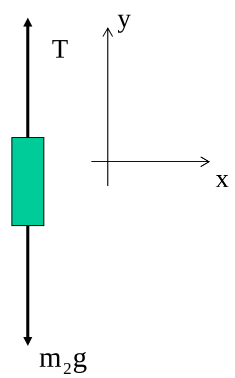
Block 1, y direction:

$$\sum F_{y1} = m_1 a_{y1}$$
$$F_N - m_1 g\cos\theta = 0$$
$$F_N = m_1 g\cos\theta$$

Example (continued)

III) Apply Newton's 2nd Law to the blocks:

Block 2:



Block 2, y direction:

$$\sum F_y = m_2 a_{y2}$$
$$T - m_2 g = m_2 a_{y2}$$

Example (continued)

IV) Since the blocks are connected by an unstretchable cord: $a_{x1} = -a_{y2}$

Solve equation for Block 2 for T:

$$T - m_2 g = m_2 a_{y2} = -m_2 a_{x1}$$
$$T = \underbrace{m_2 g - m_2 a_{x1}}$$

Substitute this into the equation for block 1.

Equation for Block 1:

$$T - m_1 g \sin\theta = m_1 a_{x1}$$
$$(m_2 g - m_2 a_{x1}) - m_1 g \sin\theta = m_1 a_{x1}$$

Example (continued)

V) Some Algebra:

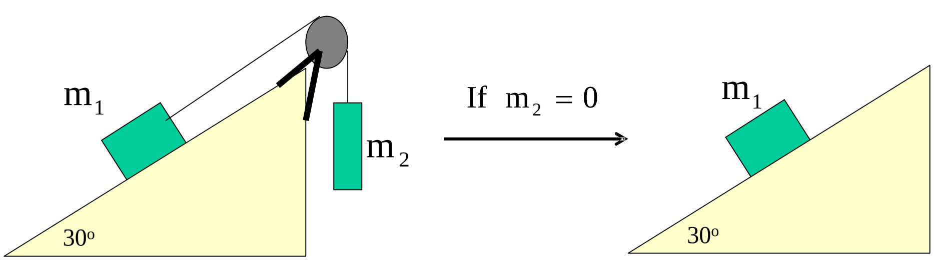
$$(m_2 g - m_2 a_{x1}) - m_1 g \sin\theta = m_1 a_{x1}$$
$$m_2 g - m_1 g \sin\theta = (m_1 + m_2) a_{x1}$$
$$a_{x1} = \frac{m_2 g - m_1 g \sin\theta}{m_1 + m_2}$$
$$a_{x1} = \frac{(22.0)(9.80) - (8.00)(9.80)(0.5)}{8.00 + 22.0} = 5.88\text{m/s}^2$$

Substitute the acceleration in one of the equations from the previous page, and solve for T:

$$T = m_2 g - m_2 a_{x1}$$
$$T = 86.3\text{N}$$

Example (continued)

What happens if the mass of Block #2 is set to zero? Since the string is also (assumed) massless, the problem becomes just a single block on an incline plane:



Example (continued)

We don't have to go back through writing Newton's 2nd Law to get the acceleration of block 1. We can just use the equation from the previous page for a_{x1} and set m_2=0:

$$a_{x1} = \frac{m_2 g - m_1 g \sin\theta}{m_1 + m_2}$$

$$a_{x1} = \frac{-m_1 g \sin\theta}{m_1} \quad \text{if} \quad m_2 = 0$$

$$a_{x1} = -g \sin\theta$$

NOTE: The acceleration a_{x1} does ***not depend*** on the mass m_1!

$$\text{For} \quad \theta = 30^o, \quad a_{x1} = -0(9.80)(0.5) = -4.9\text{m/s}^2$$