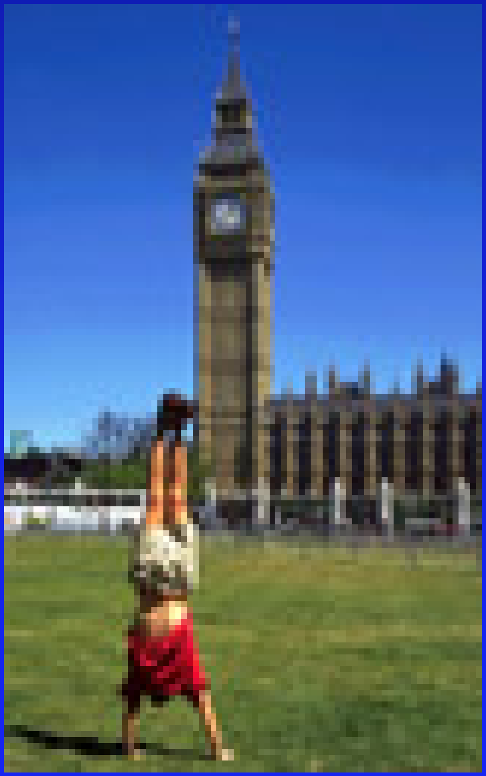
Physics 101: Lecture 02

Forces: Equilibrium Examples

- **Today's lecture will cover Textbook Sections 2.1-2.7**



Phys 101 URL:

http://online.physics.uiuc.edu/courses/phys101

Read the course description & FAQ!

Office hours start this Friday; see web page for locations & times.

Physics 101 is now on Illinois COMPASS!

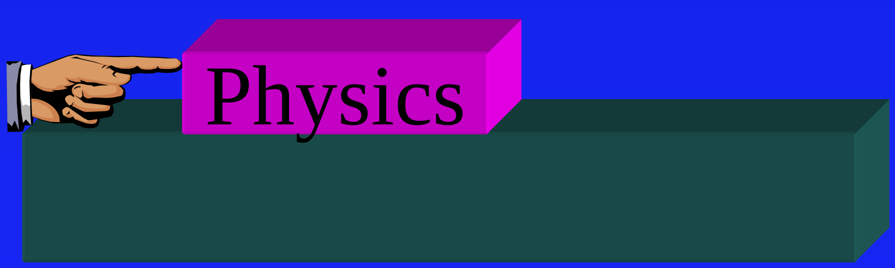
Bring Discussion Problems Book to your Discussion session!

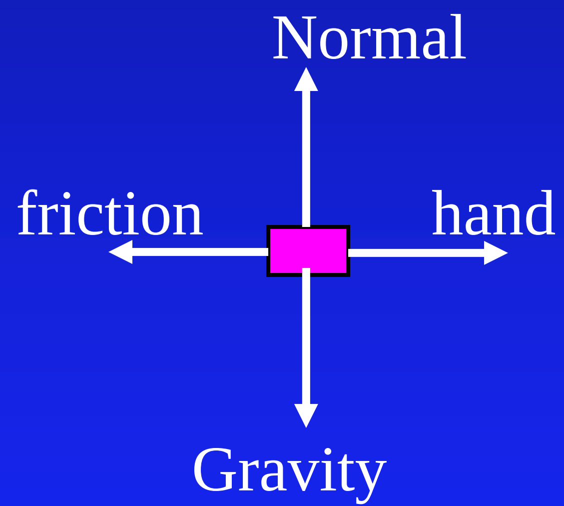
Overview

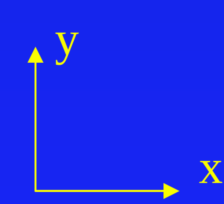
- Last Lecture
  - ➔ **Newton's Laws of Motion**
    - » Inertia
    - » $\Sigma F=ma$
    - » Pairs
  - ➔ **Free Body Diagrams**
    - » Draw coordinate axis, each direction is independent.
    - » Simple Picture
    - » Identify/draw all forces
  - ➔ Friction: kinetic $\mathbf{f = \mu_k N}$; static $\mathbf{f \leq \mu_s N}$
  - ➔ Gravity **W = m g** (near Earth's surface!)
- Today
  - ➔ Contact Force---Springs
  - ➔ Contact Force---Tension
  - ➔ 2-D Examples

Free Body Diagrams

- Choose Object (book)
- Label coordinate axis
- Identify All Forces
  - ➔ Hand (to right)
  - ➔ Gravity (down)
  - ➔ Normal (table, up)
  - ➔ Friction (table, left)







Book Pushed Across Table

- Calculate force of hand to keep the book sliding at a ***constant speed***, if the mass of the book is 1 Kg, $\mu_s = .84$ and $\mu_k = .75$.

Constant Speed => $\Sigma F=0$

x-direction: $\Sigma F=0$

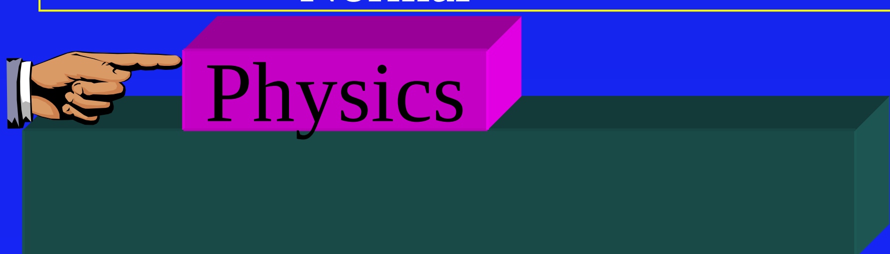
$$F_{hand} - F_{friction} = 0$$
$$F_{hand} = F_{friction}$$
$$F_{hand} = \mu_k F_{Normal}$$

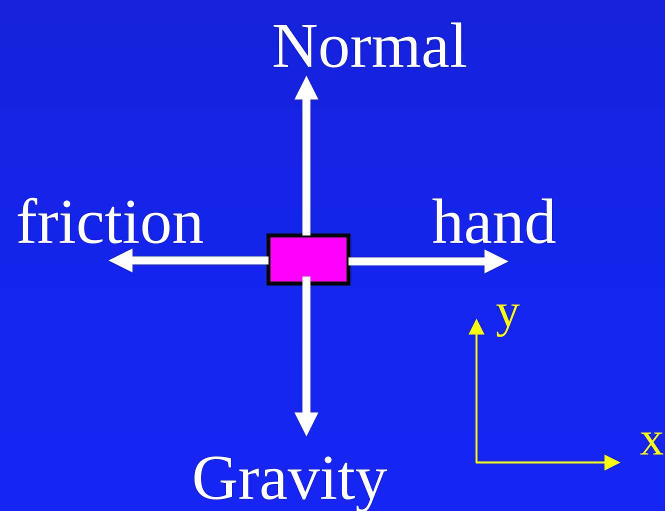
y-direction: $\Sigma F=0$

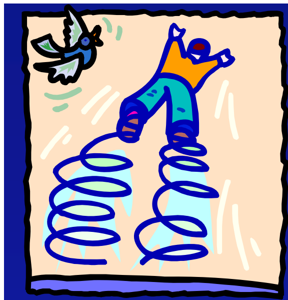
$$F_{Normal} - F_{Gravity} = 0$$
$$F_{Normal} = F_{Gravity}$$
$$F_{Normal} = 1 \text{x } 9.8 = 9.8 \text{ N}$$

Combine:

$$F_{hand} = \mu_k F_{Normal}$$
$$F_{hand} = 0.75 \text{ x } 9.8 \text{ N}$$
$$F_{hand} = 7.3 \text{ Newtons}$$



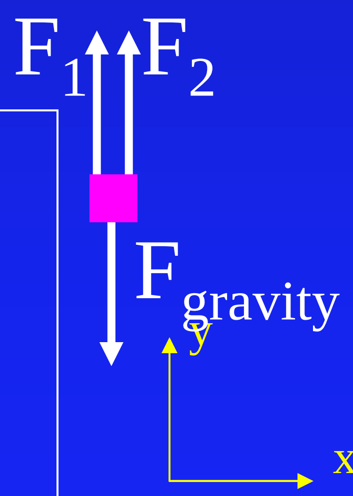




Contact Force: Springs

- Force exerted by a spring is directly proportional to its displacement x (stretched or compressed). $F_{spring} = -k\,x$
- Example: When a 5 kg mass is suspended from a spring, the spring stretches 8 cm. If it is hung by two identical springs, they will stretch

A) 4 cm B) 8 cm C) 16 cm



$$F_1 + F_2 - F_{gravity} = 0$$

$$F_1 + F_2 = F_{gravity}$$

$$k_1 x_1 + k_2 x_2 = m\,g$$

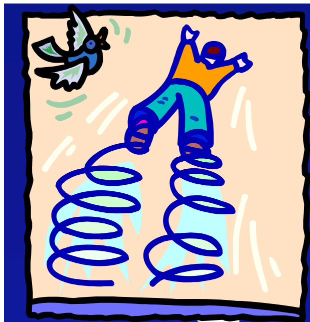
$$2\,k\,x = mg$$

$$x = m\,g / (2k)$$

$$= (\tfrac{1}{2}\,m)\,g / k$$

We know $mg/k = 8$ cm.

So: $\tfrac{1}{2}\,mg/k = 4$ cm.



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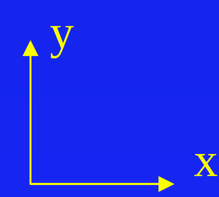


Contact Force: Tension

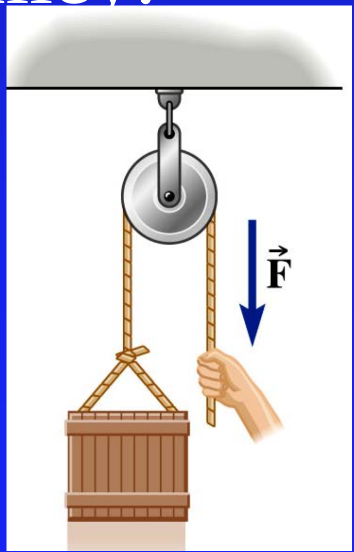
- Tension in an Ideal String:
  - ➔ Magnitude of tension is equal everywhere.
  - ➔ Direction is parallel to string (only pulls)

- Example : Determine force applied to string to suspend 45 kg mass hanging over pulley:
  Answer:
  - ➔ FBD
  - ➔ $\Sigma F = ma$

From Prelecture

$F = mg$

$= 440$ Newtons



Pulley ACT

- Two boxes are connected by a string over a frictionless pulley. **In equilibrium**, box 2 is lower than box 1. Compare the weight of the two boxes.

A) Box 1 is heavier

B) Box 2 is heavier

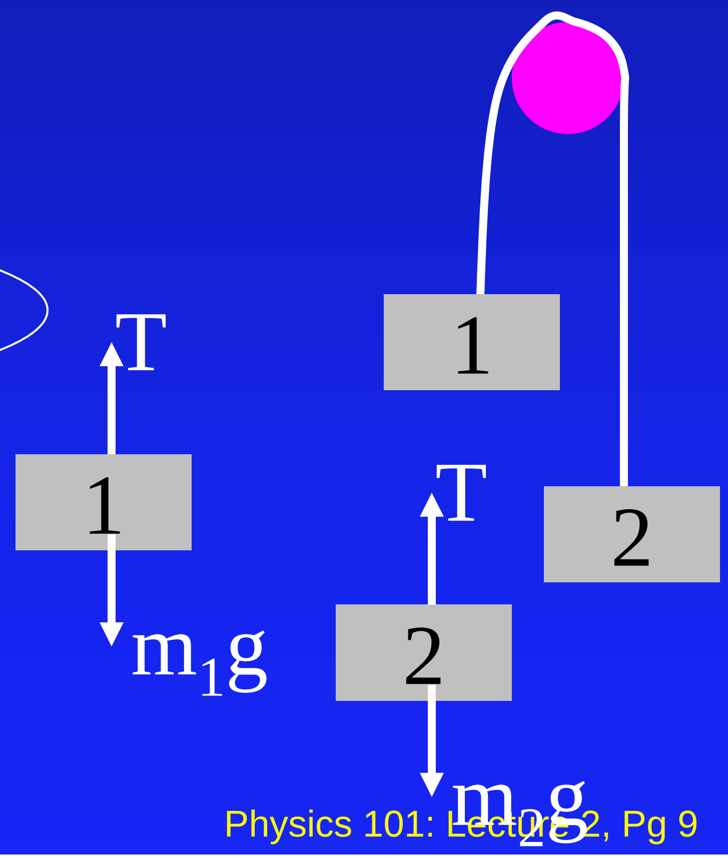
C) They have the same weight

$\Sigma F = m\,a$

1) $T - m_1\,g = 0$

2) $T - m_2\,g = 0$

$\Rightarrow m_1 = m_2$

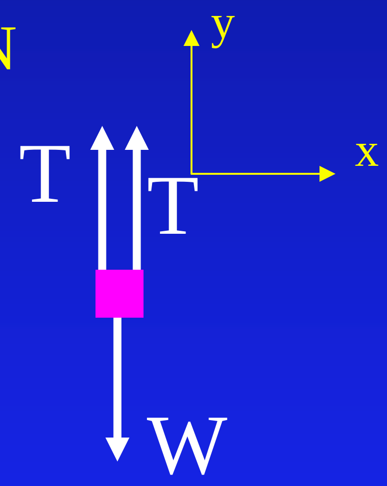


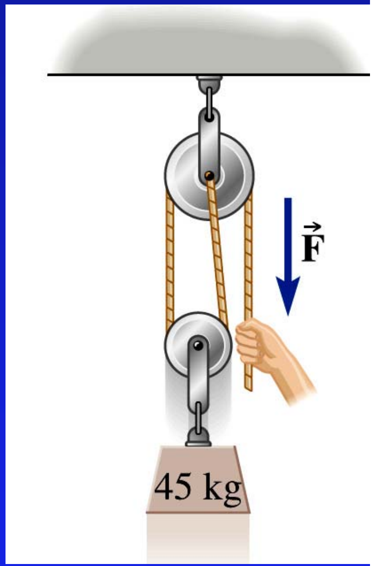
Tension Example:

- Determine the force exerted by the hand to suspend the 45 kg mass as shown in the picture.

A) 220 N B) 440 N C) 660 N

D) 880 N E) 1100 N





$\Sigma F = m\,a$

$T + T - W = 0$

$2\,T = W$

$T = m\,g / 2$

$= (45\text{ kg} \times (9.8\text{ m/s}^2) / 2$

$= 220\text{ N}$

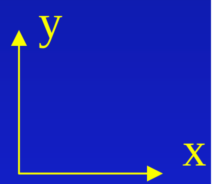
- Remember the magnitude of the tension is the same everywhere along the rope!

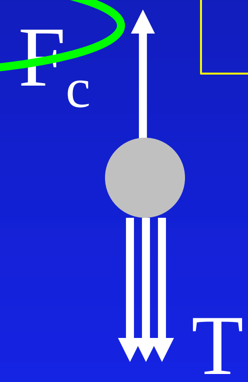
Tension ACT II

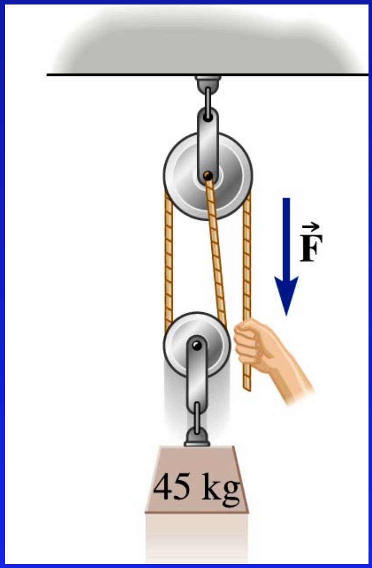
- Determine the force exerted by the ceiling to suspend pulley holding the 45 kg mass as shown in the picture.

A) 220 N   B) 440 N   C) 660 N

D) 880 N   E) 1100 N







$\Sigma F = m\,a$

$F_c - T - T - T = 0$

$F_c = 3\,T$

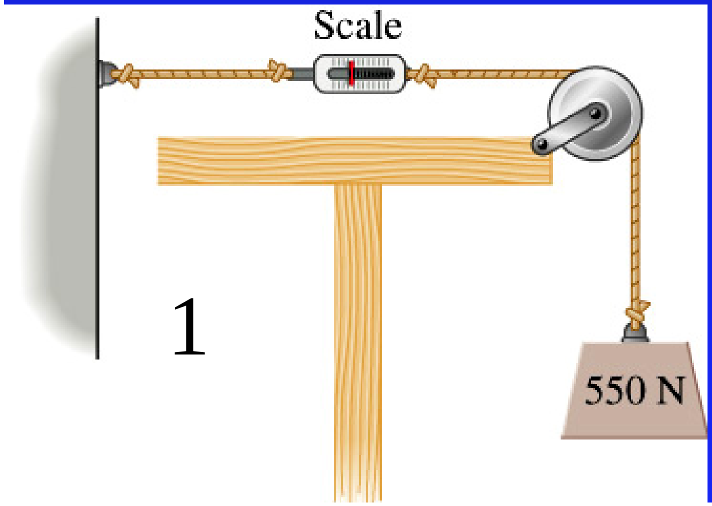
$F_c = 3 \times 220\ N = 660\ N$

- Remember the magnitude of the tension is the same everywhere along the rope!

Springs Preflight

- What does scale 1 read? (91% got correct!)
- A) 225 N B) 550 N C) 1100 N

The magnitude of tension in a ideal string is equal everywhere.



Excused absences

You must have appropriate documentation (in writing) in order to have a valid excuse from a class. If you are too sick to get out of bed you should call Dial-a-Nurse. Please complete the ABSENCE FORM and take it along with the appropriate documentation relating to your absence to Room 231/233 Loomis as soon as you return to class. The deadline for submitting an excuse is within TWO weeks of the absence. (Excuses from the emergency dean must be turned in within ONE week of the date on the letter.) .

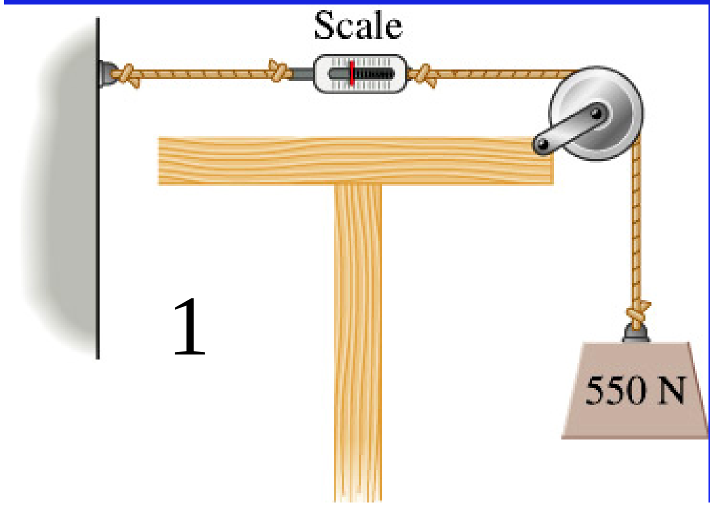
Excuses need to be taken to Loomis room 231/233 in person. (An EX means that the absence will not count against your grade, but an AB becomes a zero.) Please be sure to indicate your section(s) and TA name(s) of the classes you missed on the ABSENCE FORM.

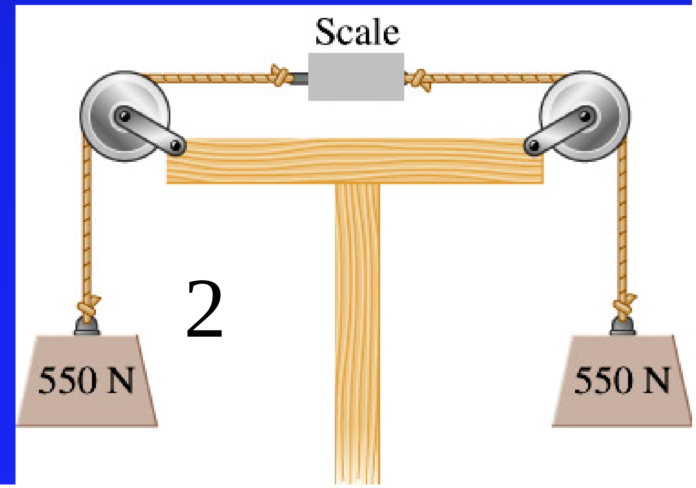
Springs ACT

•Scale 1 reads 550 Newtons. What is the reading on scale 2?

A) 225 N B) 550 N C) 1100 N

In both cases the NET FORCE on the spring is zero, and the force to the right is 550N. Therefore the force to the left is also 550 N.





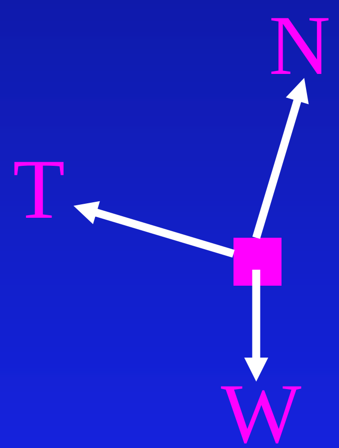
Forces in 2 Dimensions: Ramp

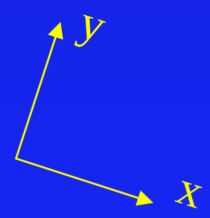
- Calculate tension in the rope necessary to keep the 5 kg block from sliding down a **frictionless** incline of 20 degrees.

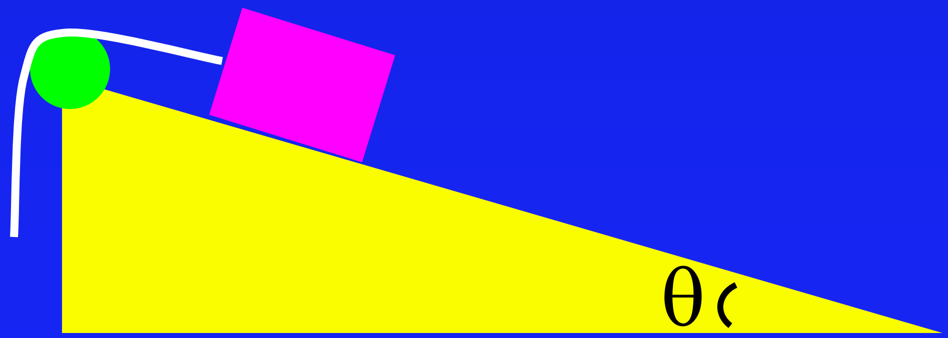
1) Draw FBD

2) Label Axis

Note, weight is not in x or y direction! Need to decompose it!

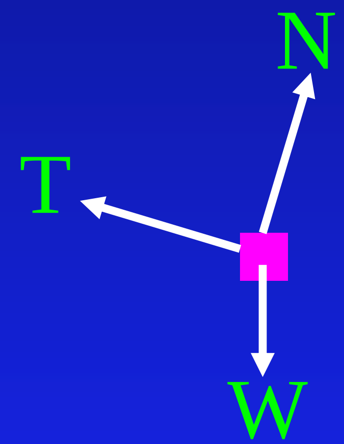


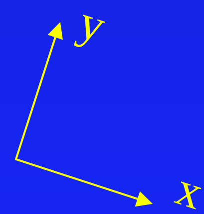


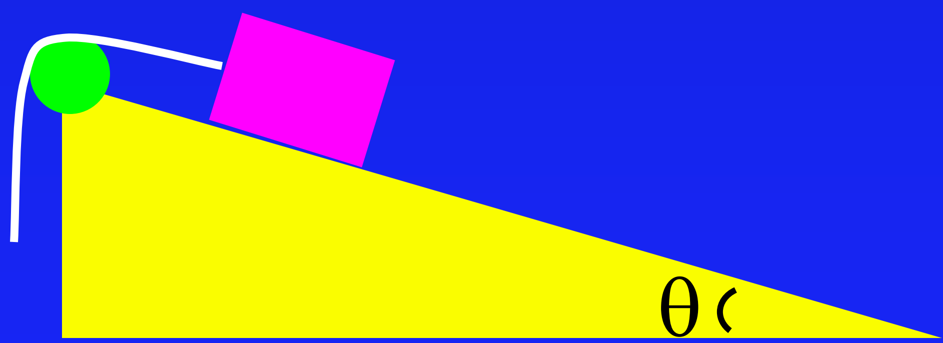


Forces in 2 Dimensions: Ramp

- Calculate force necessary to keep the 5 kg block from sliding down a frictionless incline of 20 degrees.







Forces in 2 Dimensions: Ramp

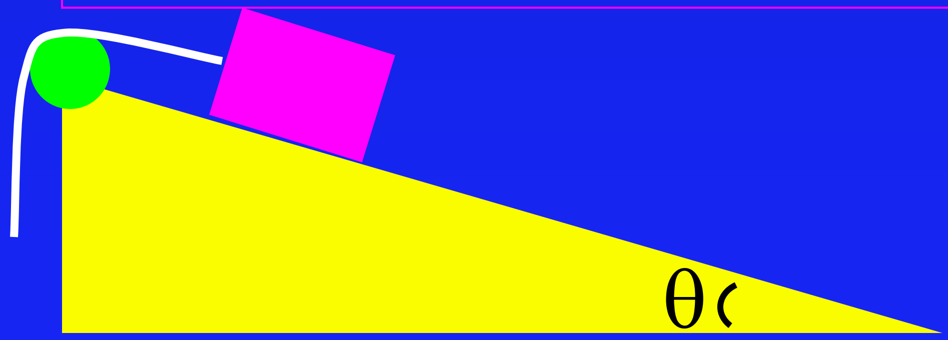
- Calculate force necessary to keep the 5 kg block from sliding down a frictionless incline of 20 degrees.

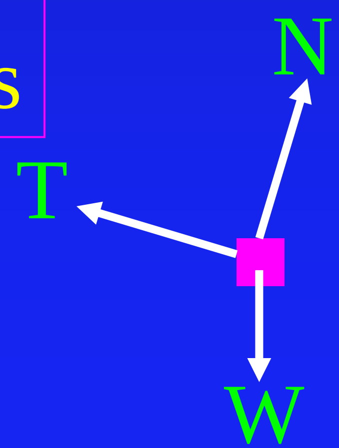
x- direction

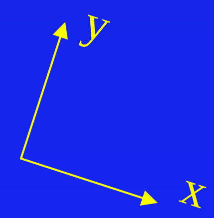
$W \sin\theta - T = 0$

$T = W \sin\theta$

$\quad = m\, g \sin\theta = 16.8$ Newtons







Normal Force ACT

What is the normal force of ramp on block?

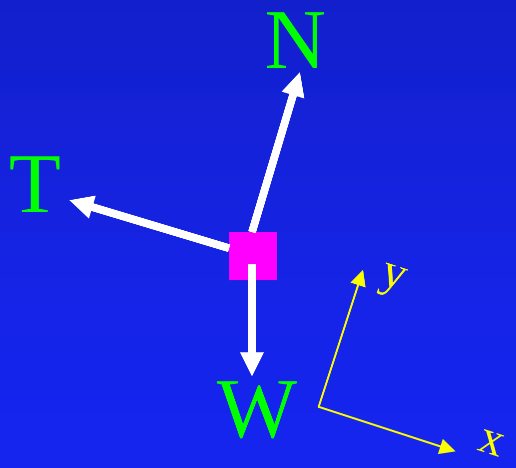
A) $F_N > mg$ B) $F_N = mg$ C) $F_N < mg$

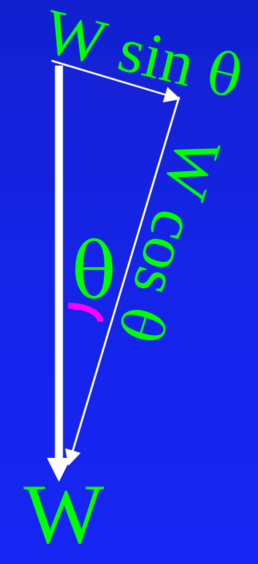
In "y" direction

$\Sigma F = ma$

$N - W \cos\theta = 0$

$N = W \cos\theta$





$N = m\,g \cos\theta$

Force at Angle Example

- A person is pushing a 15 kg block across a floor with $\mu_k = 0.4$ at a constant speed. If she is pushing down at an angle of 25 degrees, what is the magnitude of her force on the block?

x- direction: $\Sigma F_x = ma_x$

$$F_{push}\cos(\theta) - F_{friction} = 0$$
$$F_{push}\cos(\theta) - \mu F_{Normal} = 0$$
$$F_{Normal} = F_{push}\cos(\theta) / \mu$$

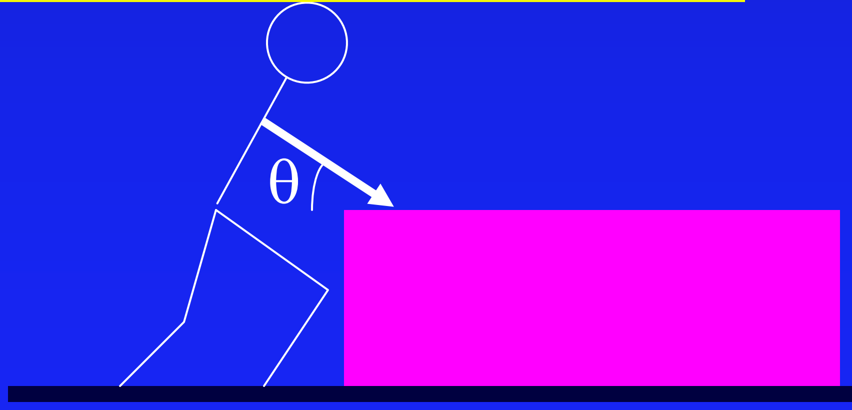
y- direction: $\Sigma F_y = ma_y$

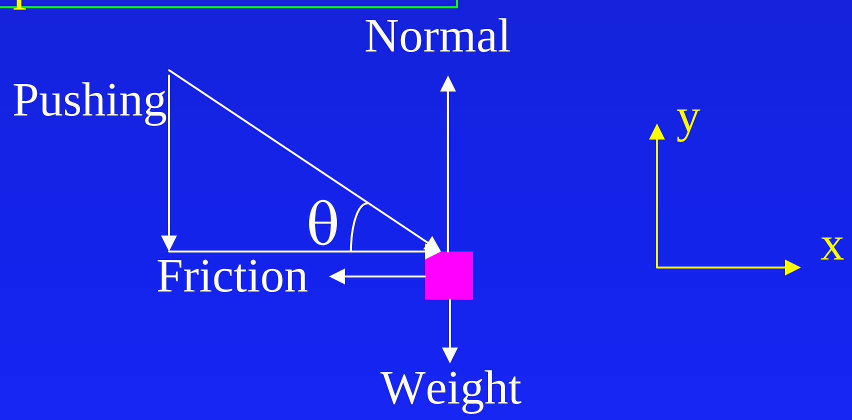
$$F_{Normal} - F_{weight} - F_{Push}\sin(\theta) = 0$$
$$F_{Normal} - mg - F_{Push}\sin(\theta) = 0$$

Combine:

$$(F_{push}\cos(\theta) / \mu) - mg - F_{Push}\sin(\theta) = 0$$
$$F_{push}(\cos(\theta) / \mu - \sin(\theta)) = mg$$
$$F_{push} = mg / (\cos(\theta)/\mu - \sin(\theta))$$

$$F_{push} = 80\text{ N}$$





Summary

- Contact Force: Spring
  - ➔ Can push or pull, force proportional to displacement
  - ➔ $F = k\,x$
- Contact Force: Tension
  - ➔ Always Pulls, tension equal everywhere
  - ➔ Force parallel to string
- Two Dimensional Examples
  - ➔ Choose coordinate system
  - ➔ Analyze each direction is independent