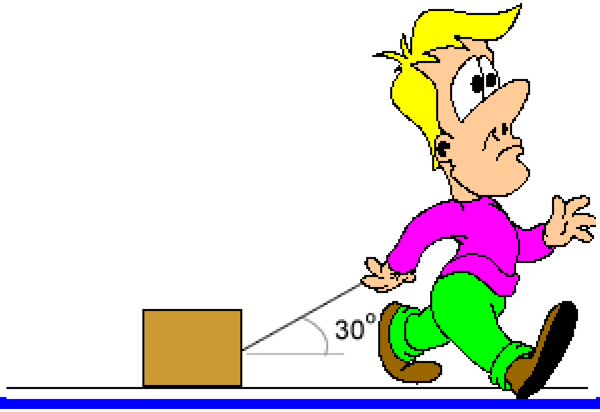
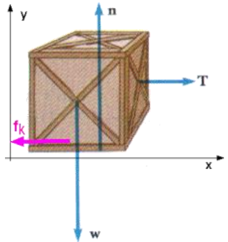
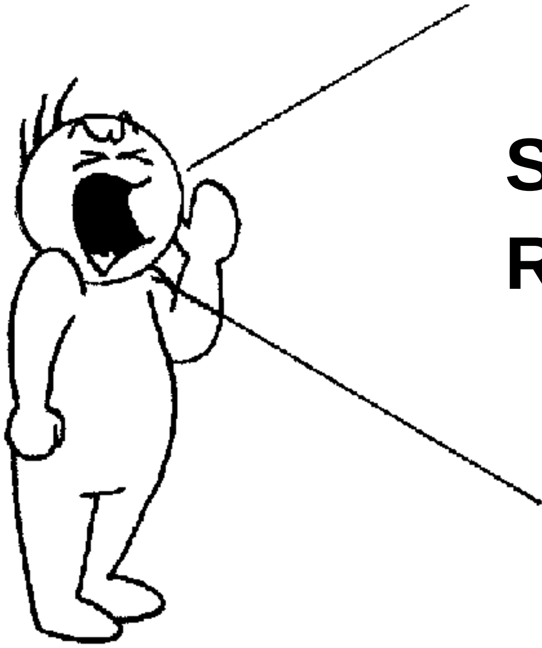
Physics 3204
Unit 1:
Section 2: Newton's Laws: Pulley's and Incline planes

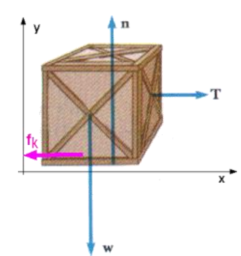






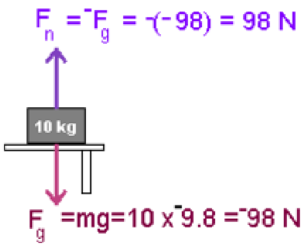
Section 2 Topic 1
Review of Physics 2204

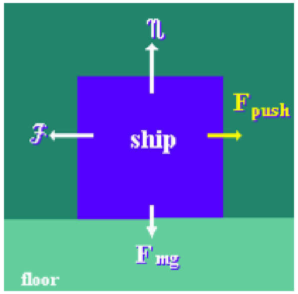
Text: 5.1 - 5.3

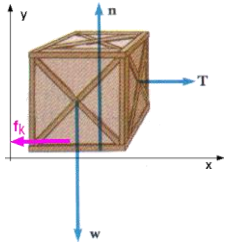


Drawing Free Body Diagrams (FBDs)

- **FBD** – a diagram showing all the forces acting on a single object.
- When drawing an FBD,
- (i) the object is drawn as a simple shape, and
- (ii) arrows are drawn outward from the object to represent the force vectors

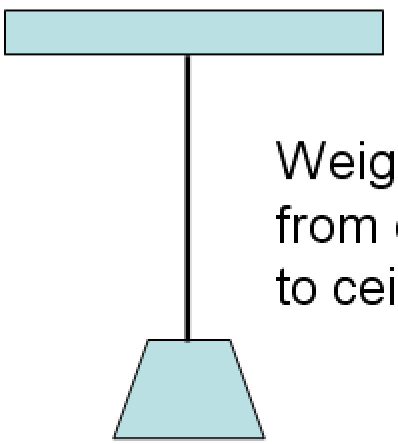




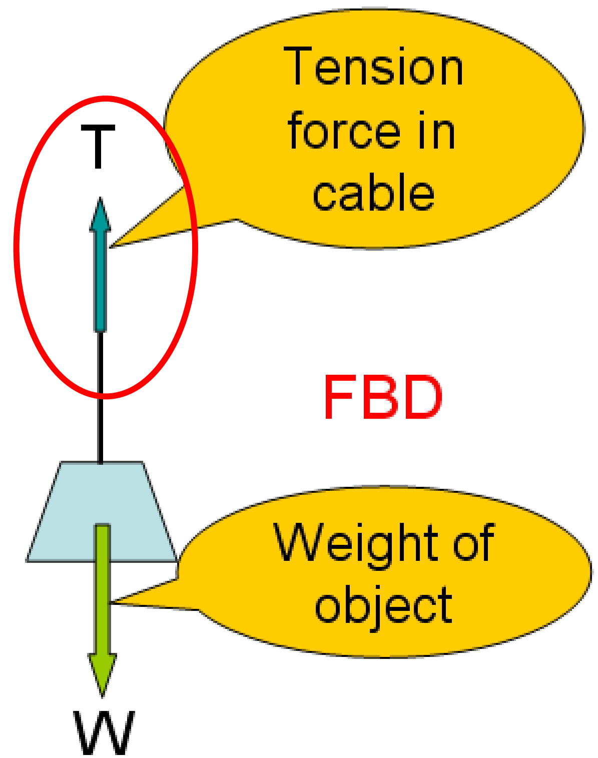


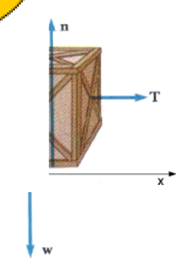
Free Body Diagram Practice 1

- Cable, rope, chain – Replace with a tension force only.



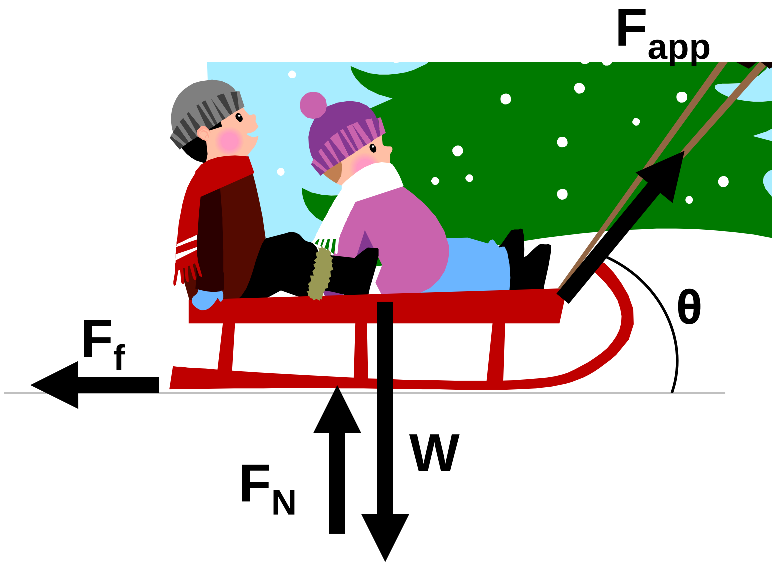
Weight supported from cable attached to ceiling

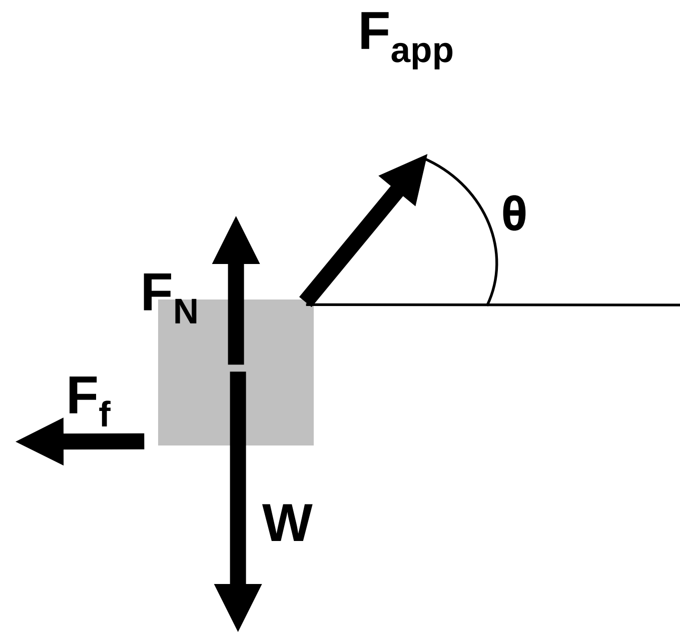


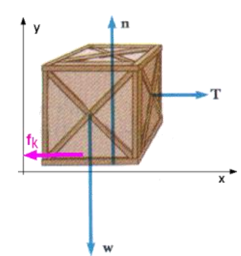


Free Body Diagram Practice 2

Create a FBD for the sled pictured below.

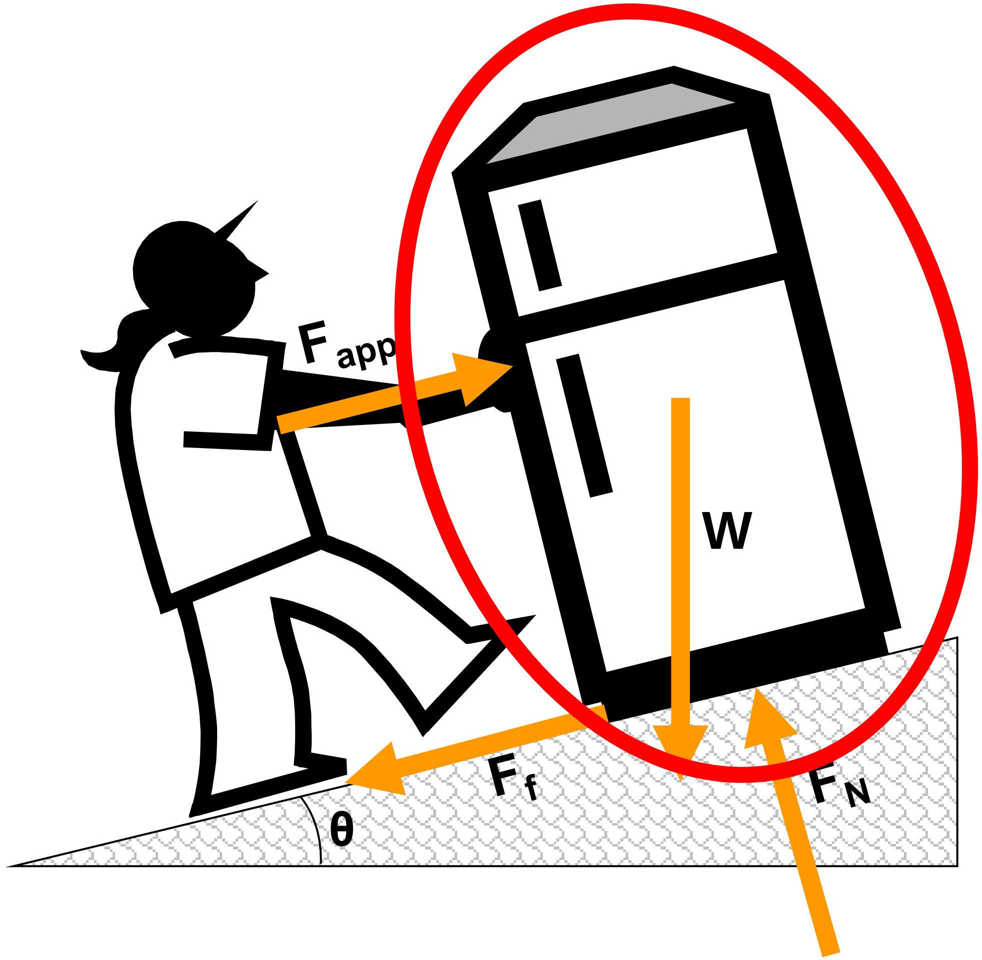


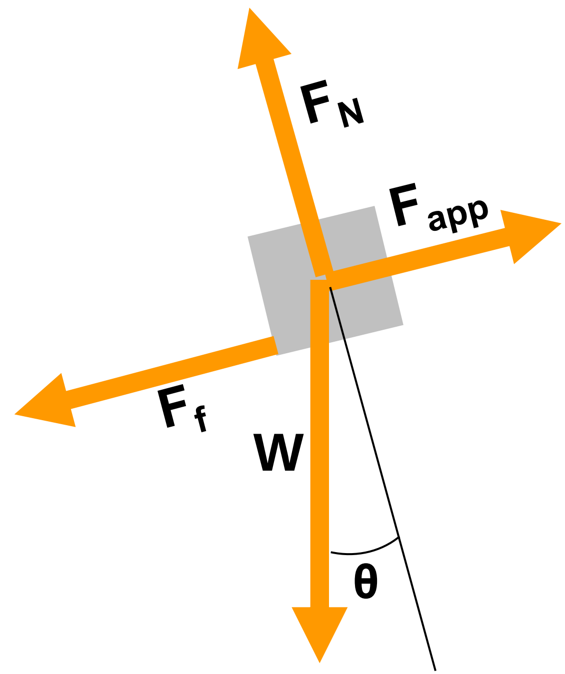


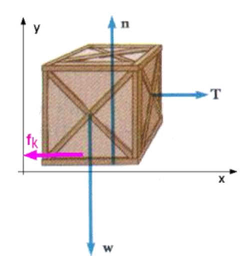


Free Body Diagram Practice 3

Create a FBD for the refrigerator pictured below.



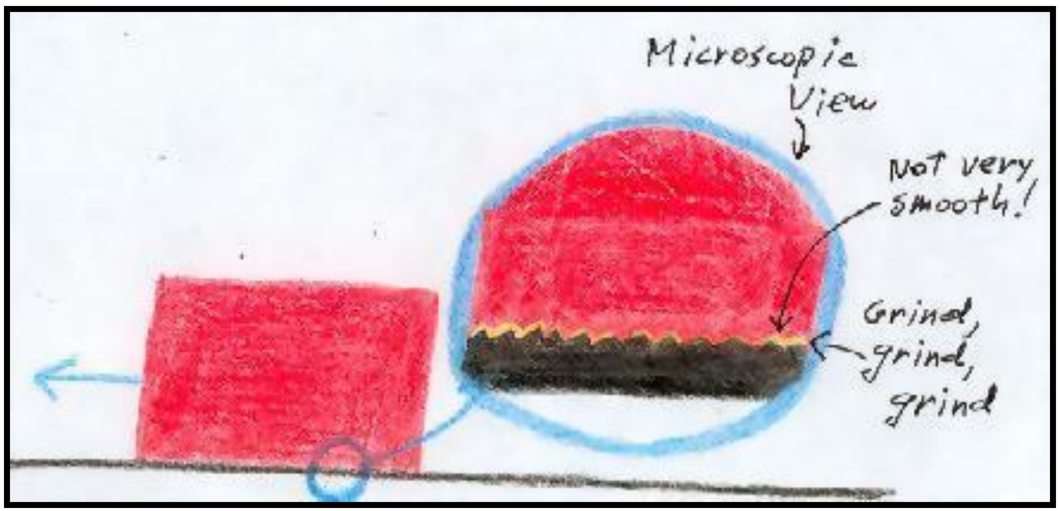




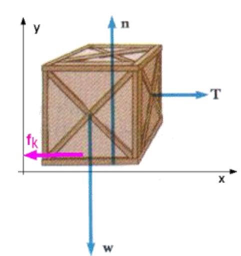
FRICTION

Friction (***F_{fr}***)is *the force that results when one object moves against another. Friction ALWAYS opposes motion.*

Although two objects might look smooth, microscopically, they're very rough and jagged.

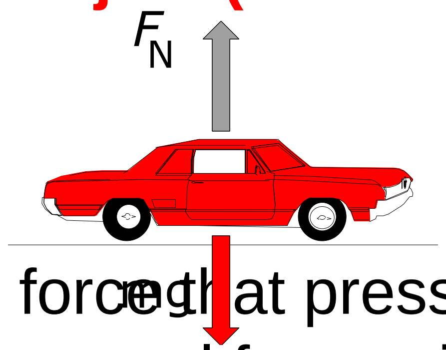


As they slide against each other, their contact is anything BUT smooth. They both kind of grind and drag against each other. This is where friction comes from.



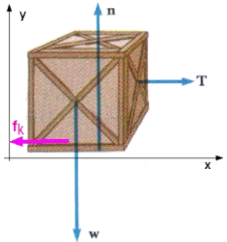
There are two factors that may affect friction:

1) Weight of the object (Normal force, F_N)



Normal force: the force that presses two surfaces together. In most cases, the normal force will be the weight of an object that is resting on the surface.

2) Smoothness of the surface (type of material, μ)



Formula for Friction:

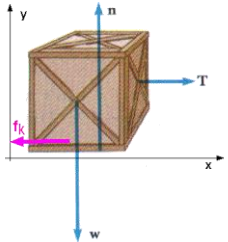
friction force = coefficient of friction x normal force

or

$$F_f = \mu F_N$$

The Greek letter μ is called the coefficient of friction and has no units because it is a ratio of two forces F_f / F_n

Force of Friction is affected by two factors:



1) Coefficient of Friction

Where:

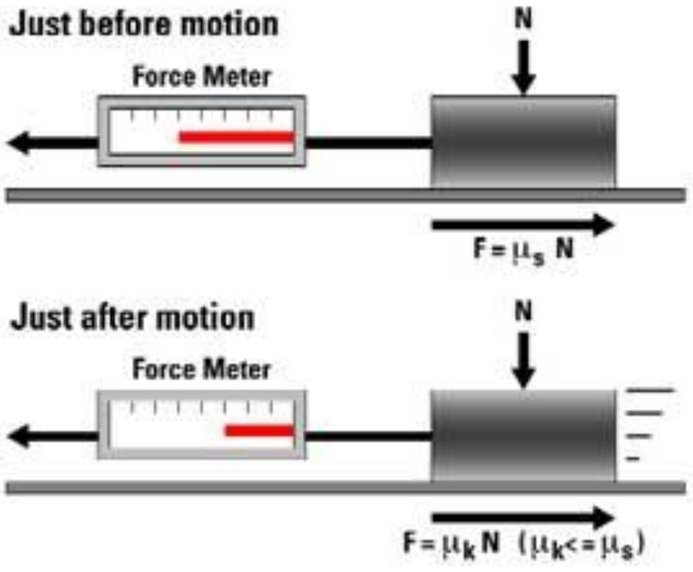
μ (mu)= coefficient of friction. It indicates how rough or smooth the surface is.   The higher the value of the coefficient of friction, the rougher the surface

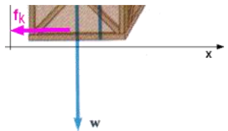
There are two types of frictional forces:

μ_k = coefficient for kinetic friction

μ_s = coefficient for static friction

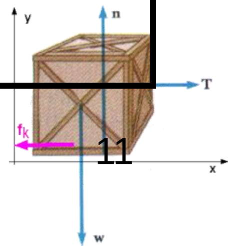
Static friction > Kinetic friction
Therefore, it takes more force to start moving an object





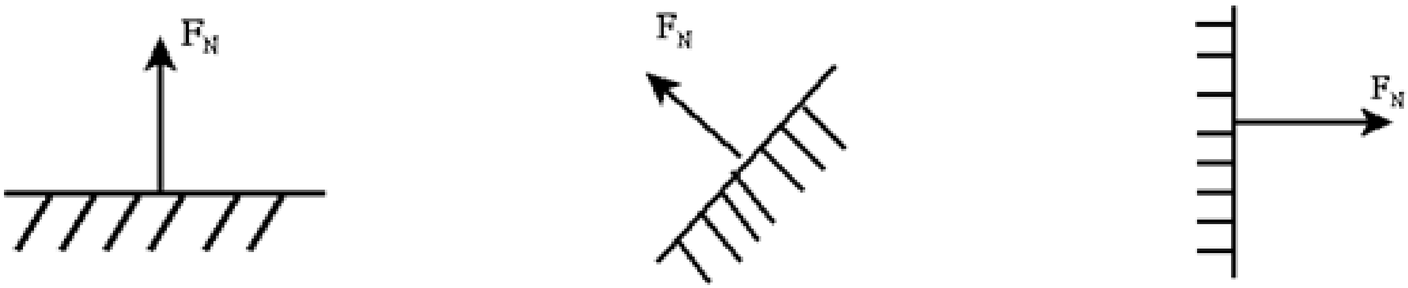
Coefficient of Friction

Material on Material	μ_s = static friction	μ_k = kinetic friction
steel / steel	0.6	0.4
add grease to steel	0.1	0.05
metal / ice	0.022	0.02
brake lining / iron	0.4	0.3
tire / dry pavement	0.9	0.8
tire / wet pavement	0.8	0.7

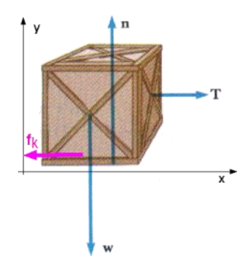


2. Normal force (F_N):

The Normal force (F_N): the reaction force of surface pushing back when the body receiving the action force is a surface.



Note that the Normal force is always perpendicular to the surface



NEWTON’S LAWS OF MOTION

- **Newton’s 1st Law (Law of inertia)**

Objects at rest will remain at rest, and objects in motion will remain in motion at a constant speed in a straight line, unless an unbalanced force acts on them.

- Examples:

1. Shifting cargo in a truck during hard braking and/or turning

- Inertia” is the tendency of all objects to resist accelerating. Objects with a greater mass have a greater resistance to accelerating. Thus, **mass** and **inertia** are essentially the same thing!

Definition:

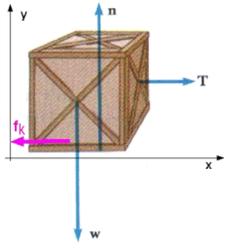
- An **Inertial Reference Frame** is one that is at rest or moving at a constant velocity, and thus Newton’s 1st law is valid.

Newton's Second Law

"The acceleration of an object is directly proportional tothe force acting on the object and inversely proportional to the mass of the object."

$$a = \frac{F_{net}}{m}$$

From the formula we can see that **m/s² = N/kg**



Three Forms
of
Newton's Second Law

:

Use . . .	if you want to find . . .	and you know . . .
$a = \frac{F}{m}$	*The acceleration (a)*	*The net force (F) and the mass (m)*
$F = ma$	*The net force (F)*	*The acceleration (a) and the mass (m)*
$m = \frac{F}{a}$	*The mass (m)*	*The acceleration (a) and the net force (F)*

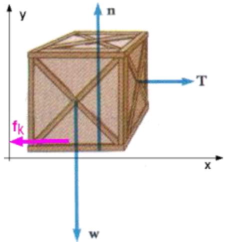
Net Force (F_{net})

- $F_{net} = F_1 + F_2 + F_3 + ...$ where the right hand sign is often written as **Σ F**, which means "the sum of" the forces.

- Important Point from Newton's second Law:

$\Sigma F = F_1 + F_2 + F_3 + ... = ma$ (object accelerating)

$\Sigma F = F_1 + F_2 + F_3 + ... = 0$ (constant speed or at rest)



Newton's 3rd Law

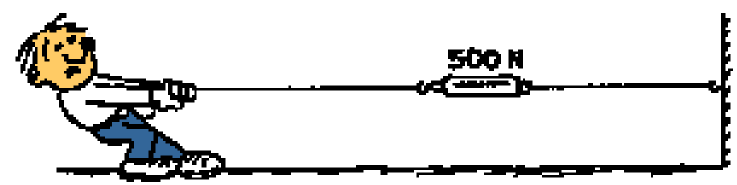
When object A exerts a force on object B, then object B exerts the same amount of force back on object A.
For every action force there is an equal and opposite reaction force.

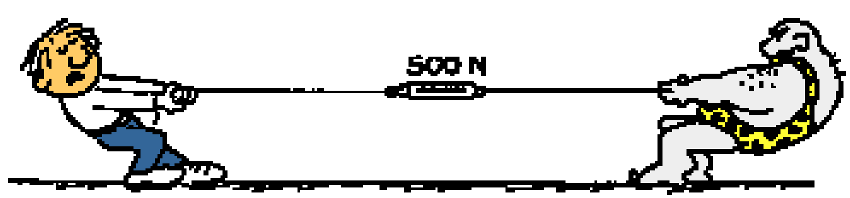
From Newton's 3rd law, forces always come in pairs.

Examples:

1. You hurt you knuckles when you punch a hard object

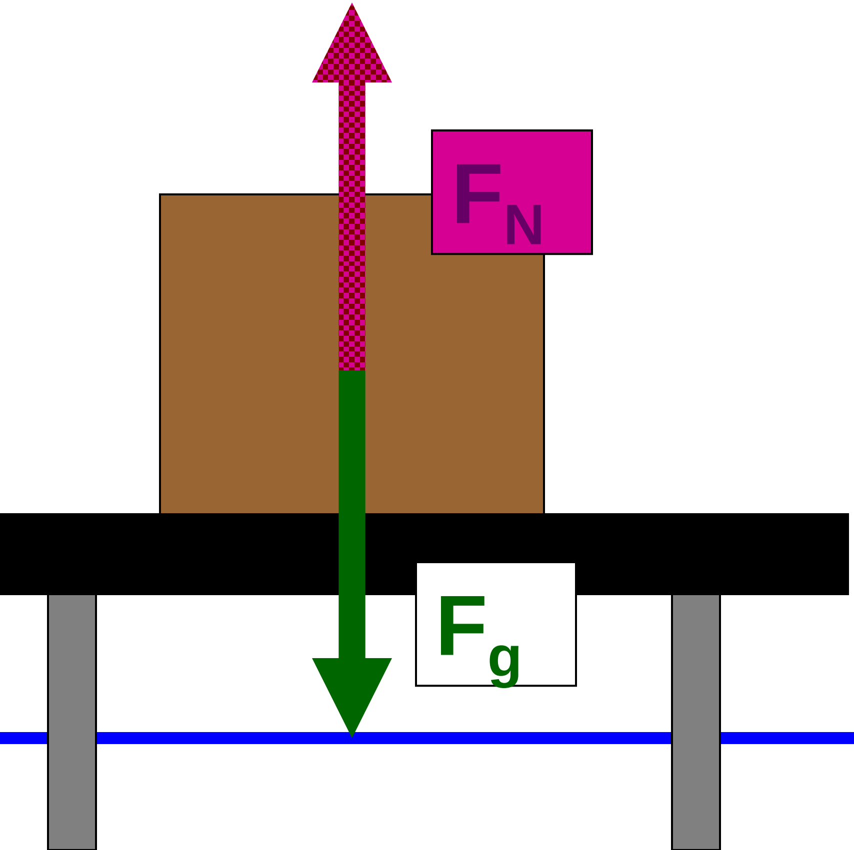
2. To swim forwards you push water backwards.

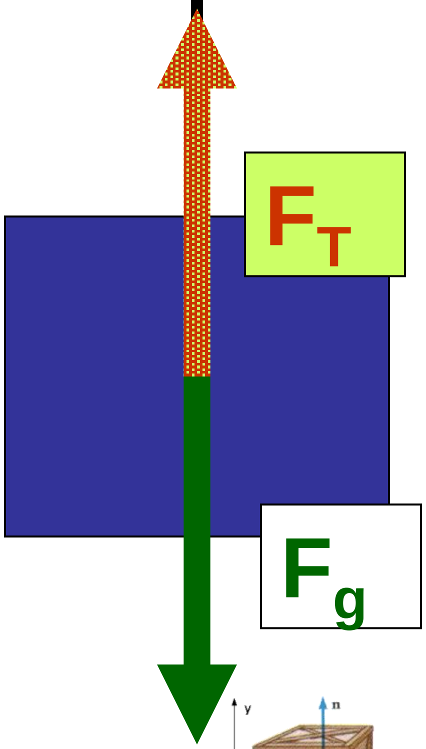


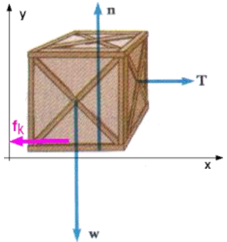


Newton’s Third Law

“For every action, there is an equal and opposite reaction”



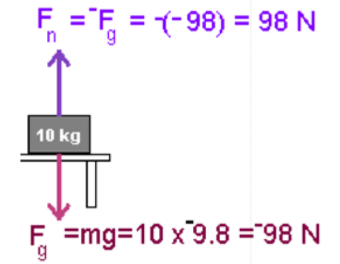




FORCES IN ONE DIMENSION

- **Example 1**:

- The picture shows a 10.0 kg block sitting on a table.

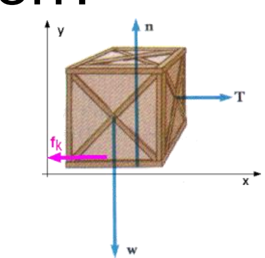


a) What force is the block exerting on the table?

b) What force is the table pushing back on the block?

c) If a force of 49 N is required to overcome friction and start the block sliding, calculate the coefficient of static friction.

d) Once the block is moving, the friction force is smaller so that a 39 N force is all that is required to maintain a constant speed. What is the coefficient of kinetic friction?



Example 2:

110 kg crate is moving on a surface with a coefficient of kinetic friction of 0.6. What applied force (F) is necessary to maintain a constant speed?

Givens:

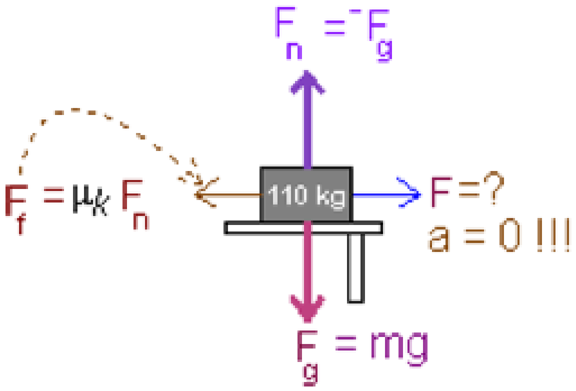
$m = 110$ kg

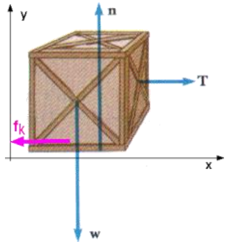
$g = -9.8$ N/kg

$\mu_k = 0.6$

$a = 0$ m/s2

F = applied force = ?



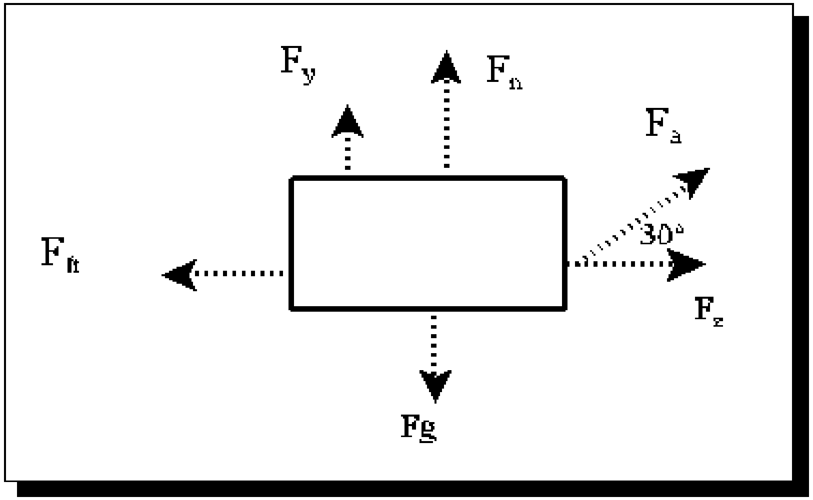


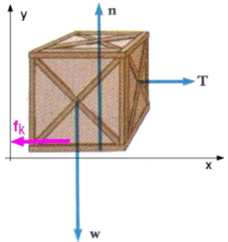
Forces In Two Dimensions

- **Example 3**

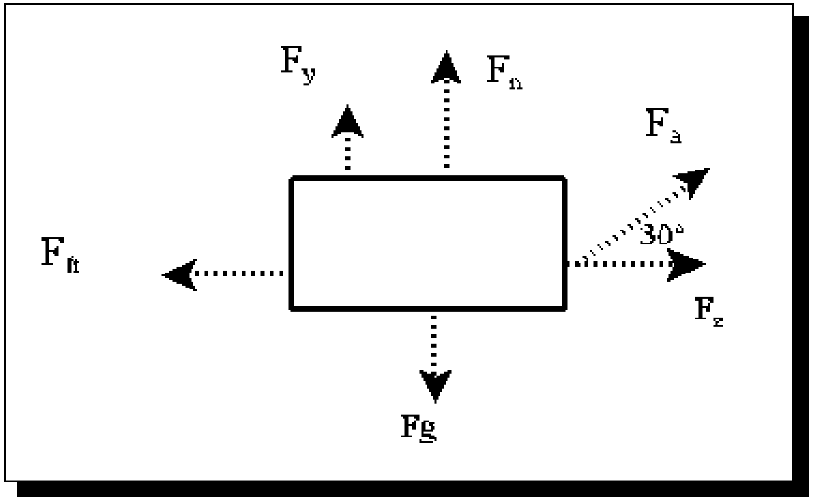
50 Kg block is being pulled (upward) with a force of 150 N [E] at 30º to the horizontal. If the then determine the acceleration.

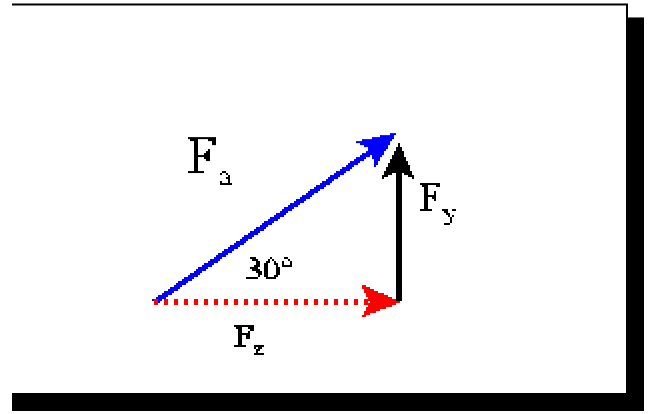
First, FBD





Find the horizontal (F_x) and vertical (F_y) components of the applied force (F_a):





$$\sin\theta = \frac{F_Y}{F_A}$$

$$F_Y = F_A \sin\theta$$

$$F_y = 150 \sin 30^o$$

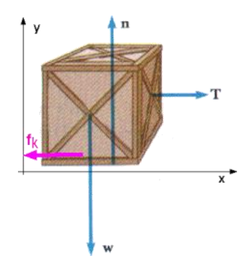
$$F_y = 75N$$

$$\cos\theta = \frac{F_x}{F_A}$$

$$F_X = F_A \cos\theta$$

$$F_X = 150 \cos 30^o$$

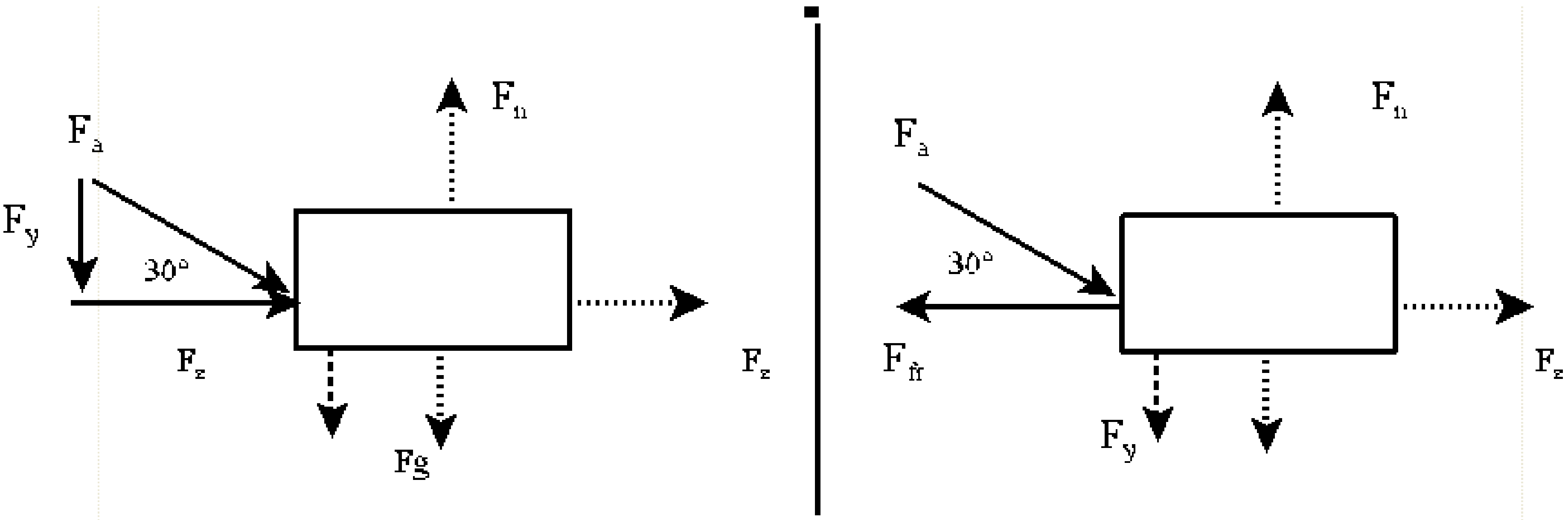
$$F_X = 130N$$

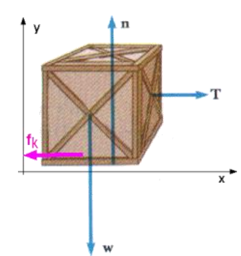


Example 2:

In this scenario the same block in Example 1 is being pushed (downward) at an angle of 30º to the horizontal

Draw the FBD





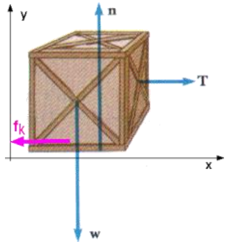
Example 4:

A 3-man bobsled team push their bobsled with a total force of 715 N along the handle bars that make an angle of 60º with a level track. The mass of the bobsled is 125 kg, and the coefficient of kinetic friction between the sled and the ice is 0.05. The team pushes for 5.5 s before jumping on.

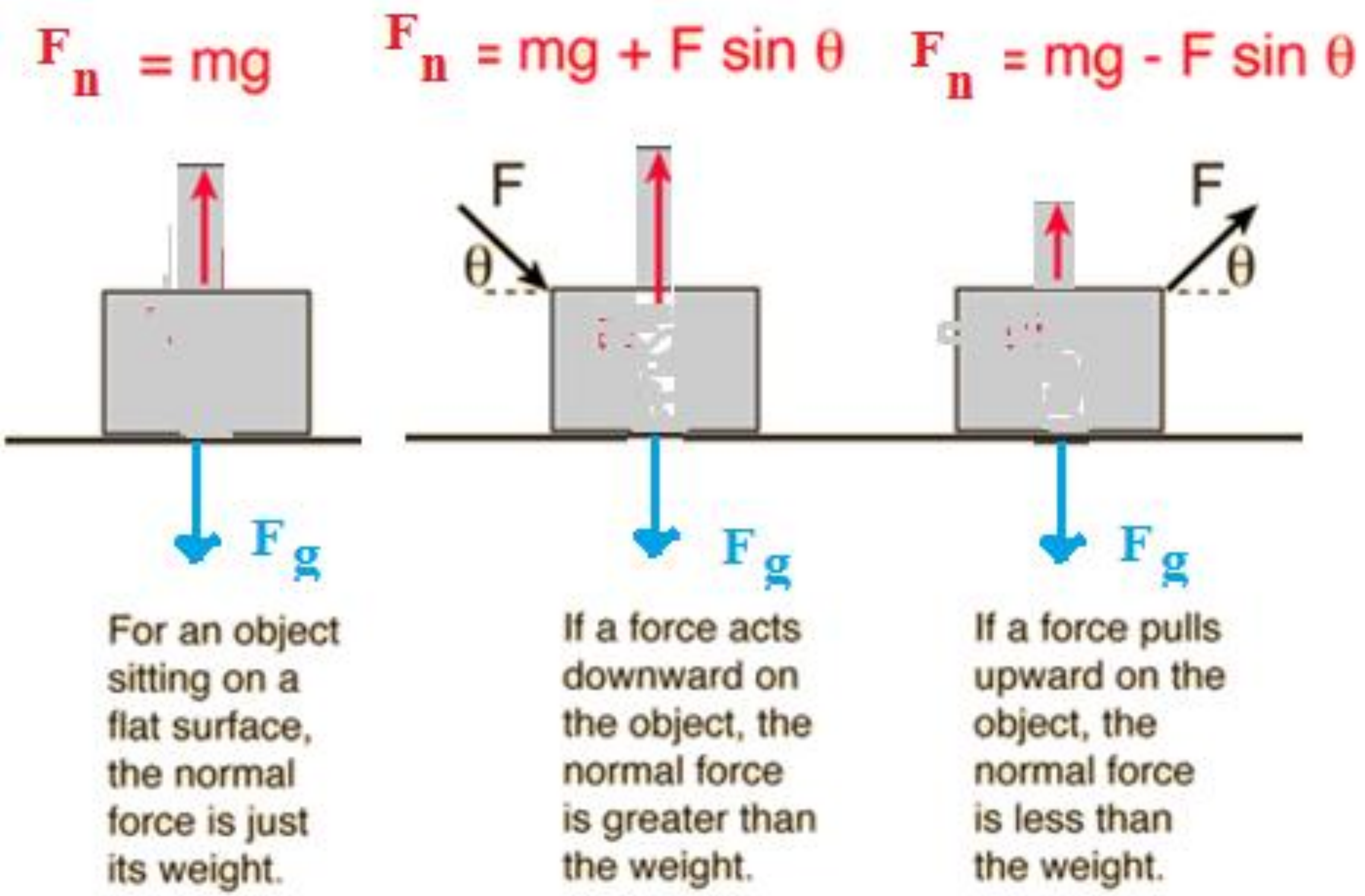
A) Determine the acceleration of the sled;

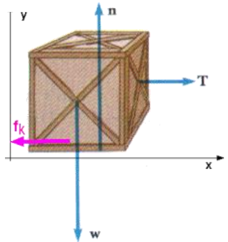
B) Its speed just as the team boards,

C) The distance that it was pushed.



Note: Three Ways to Calculate Normal Force

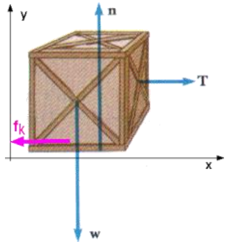


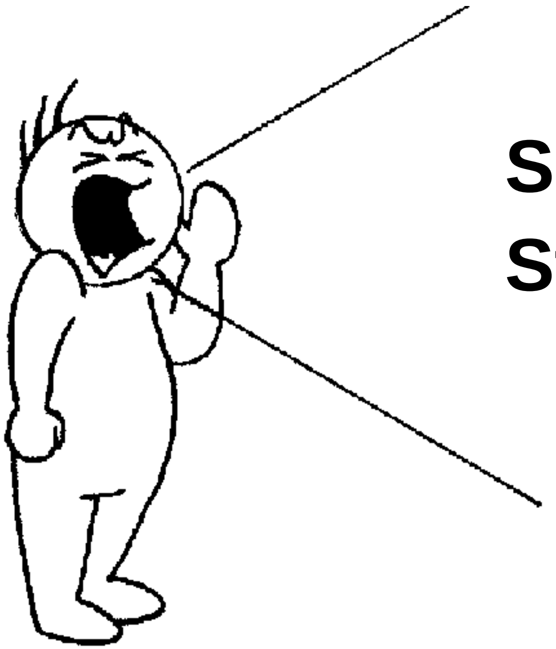


Activity

Questions:

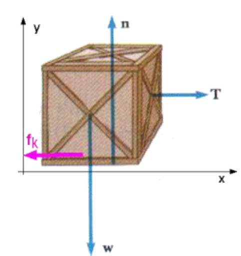
- Page 179, #3
- page 188, #36, #38, #39, #40, #44, #46, #49
- Worksheet 1“ Review of Physics 2204





Section 2 Topic 2
Strings and Pulleys

Text: 5.1 - 5.3

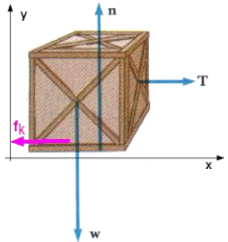


Newton's Laws: String and Pulley

- <u>Assumptions:</u>

- We will assume that all the pulley's are massless and frictionless.

- •We will assume that the strings are infinitely strong, massless, and never stretches



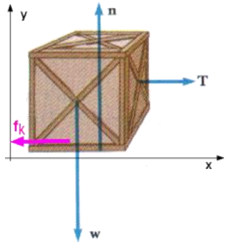
For these Problems:

•Always draw a Free Body Diagram for each object being considered.

•Determine the direction of the motion for each object.

•The direction of acceleration will be postive

•Use Newton's 2nd Law to write a an algebraic description



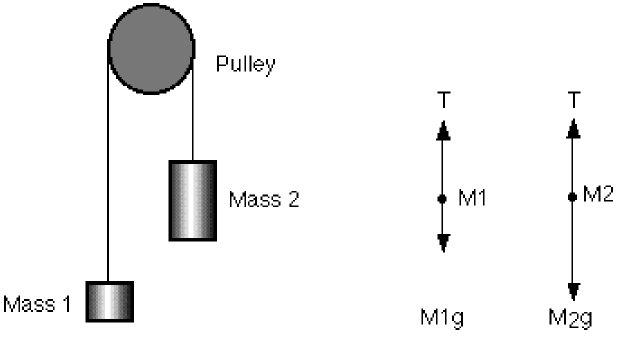
: Vertical string and Pulley Problems(Atwood's machine).

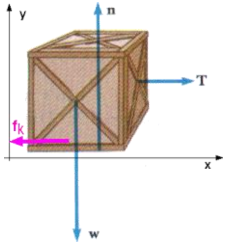
- Example 1.1:

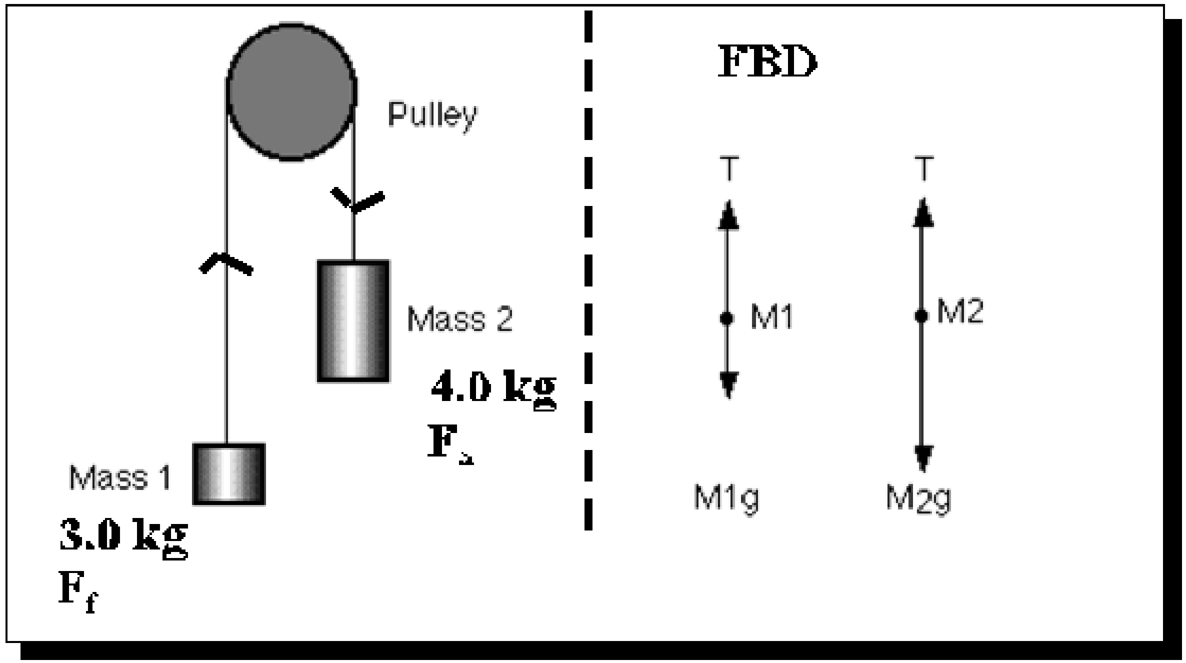
- A 3.0 kg mass and a 4.0 kg mass are suspended from a pulley as shown.

- A) Determine the acceleration of the system

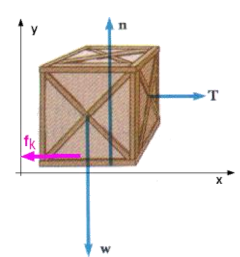
- B) Determine the Tension in the string







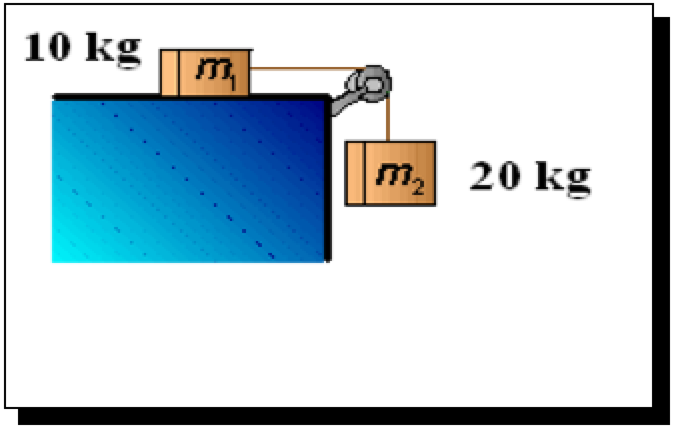
Note: m_2 (4.0 kg) is greater than m_1. As a result m_2 will go down because the gravitational force acting on it will be greater than the tension of the rope pulling it upwards. Therefore in the system you can consider force result from m_2 as the F_a and m_1 as the Frictional Force.



Block and Strings

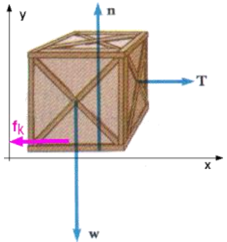
Example 2

A 10 kg block is connected to a 20 kg mass by a cord running over a frictionless pulley as shown below. The coefficient of kinetic friction between the table and the block is 0.10.

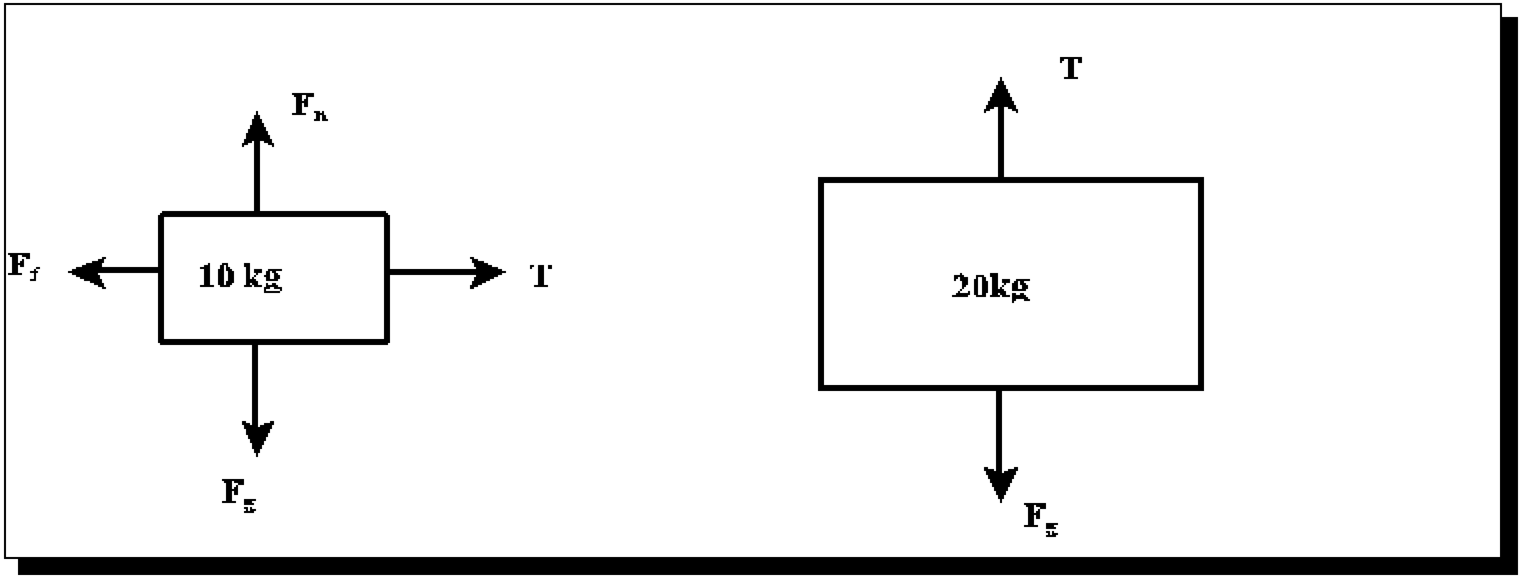


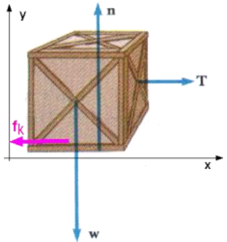
A) Determine the acceleration of the system

B) Determine the Tension in the string



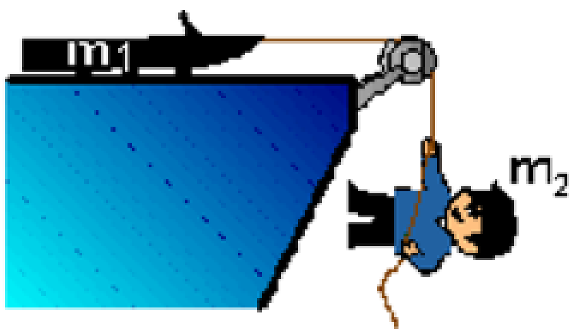
FBD for each mass

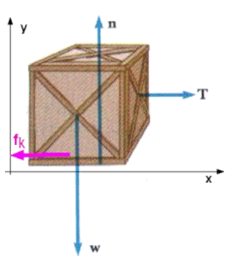




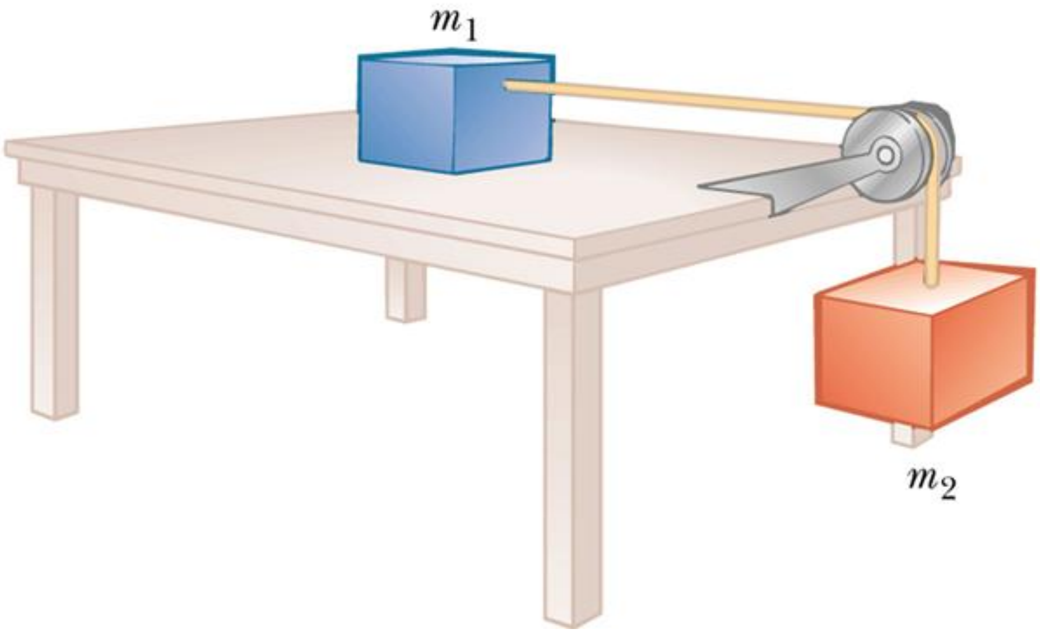
Example 3

The picture show our over-zealous physics student once again about to get himself in trouble. The mass of his boat is 120 kg and his own mass is 60.0 kg. The rollers reduce friction to 0.10. Determine the tension in the rope and the acceleration of the boat along the horizontal pier.





Example 4

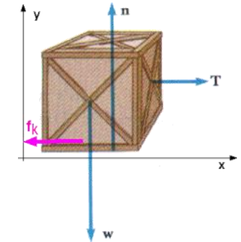


Given m_1 = 10 kg and m_2 = 5 kg:

a) What value of μ_s would stop the block from sliding?

b) If the box is sliding and μ_k = 0.2, what is the acceleration?

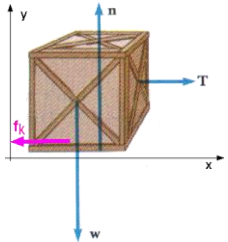
c) What is the tension of the rope?

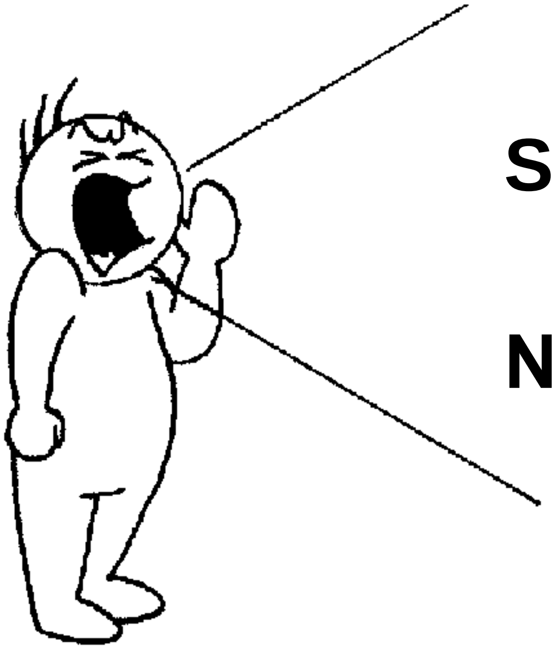


Activity

Questions:

- Worksheet 2“ Strings and Pulleys





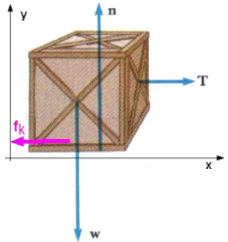
Section 2 Topic 3

Newton's Laws

and

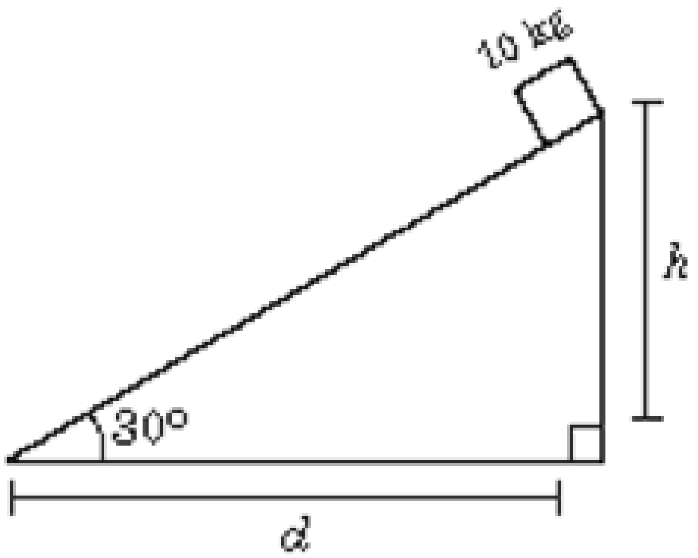
Inclines

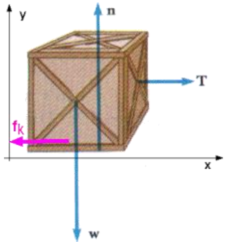
Text: 5.1 - 5.3



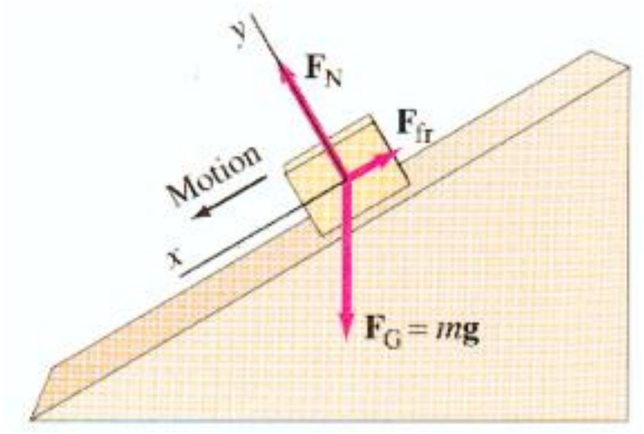
Newton's Law And the Incline Plane (Ramp)

- An object placed on a tilted surface will often slide down the surface. The rate at which the object slides down the surface is dependent upon how tilted the surface is; the greater the tilt of the surface, the faster the rate at which the object will slide down it. In physics, a tilted surface is called an inclined plane.





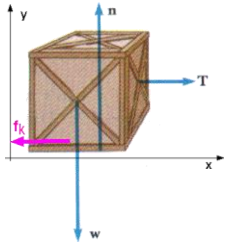
The picture below represents the forces acting on an object as it slides down an incline plane



Ff => is always parallel to surface and opposite the direction of the motion

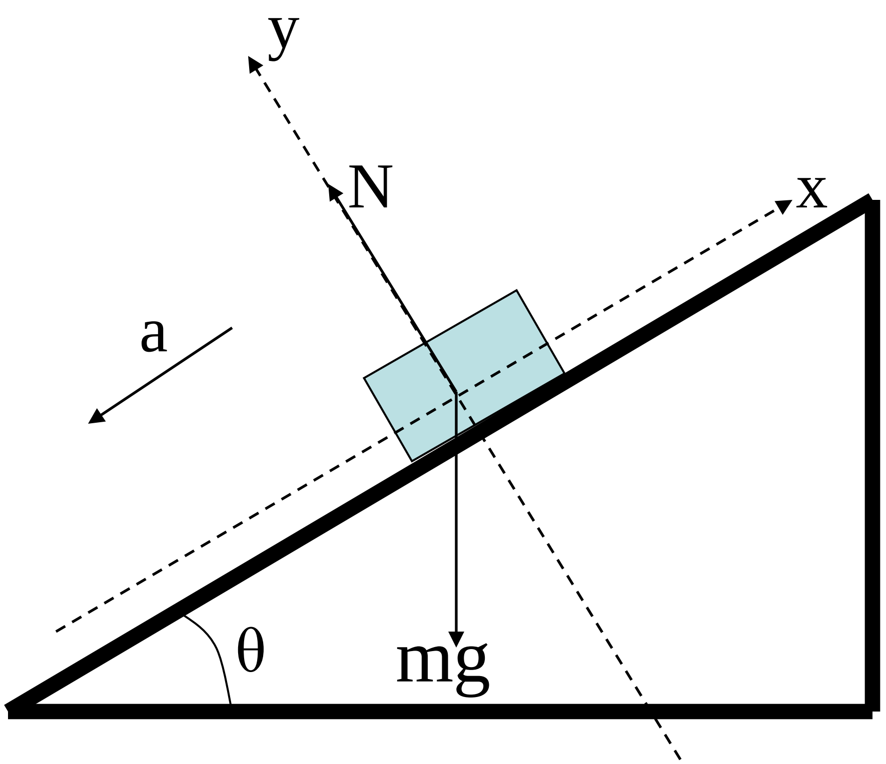
Fn => Normal force which is always perpendicular to the surface

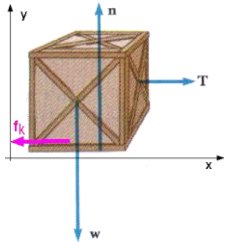
Fg => Is the gravitational force and is



Inclined Planes

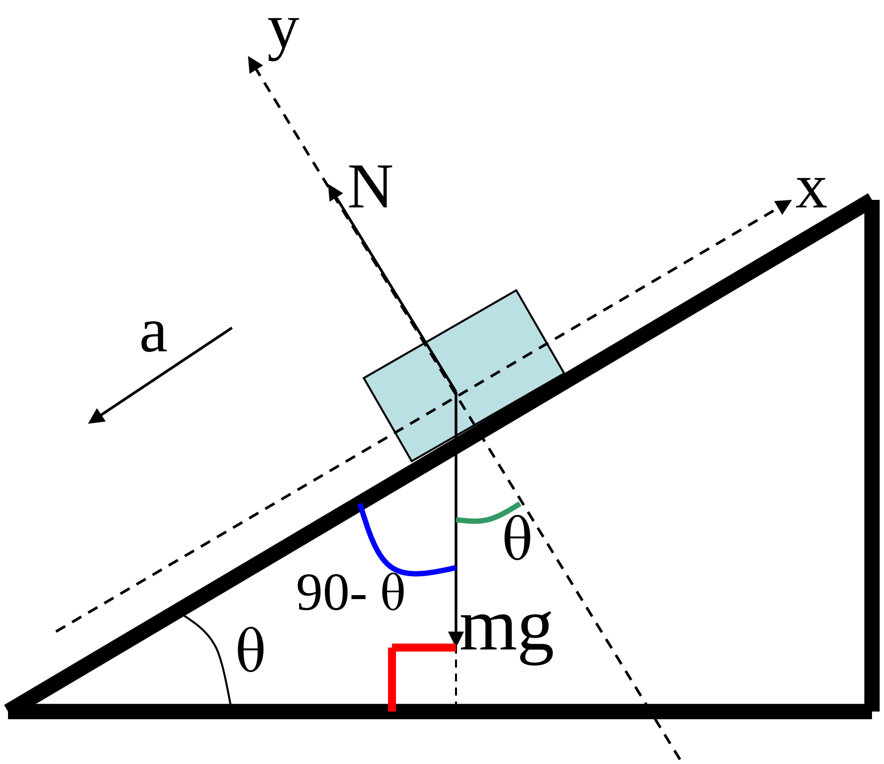
- Choose the coordinate system with x in the same or opposite direction of acceleration and y perpendicular to x.

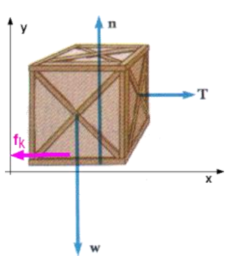




Inclined Planes

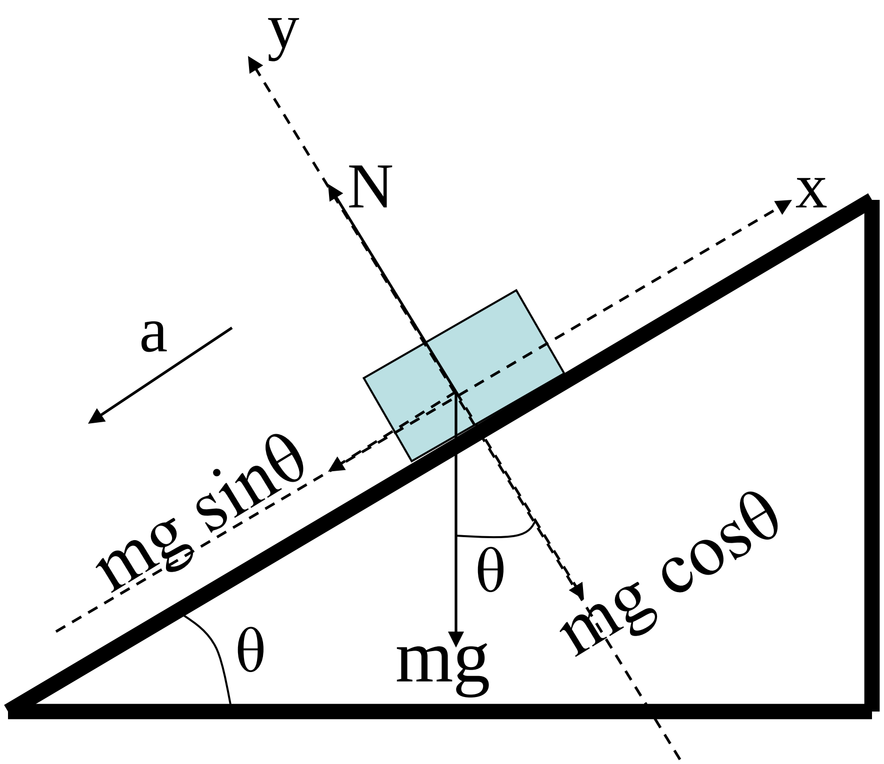
- Now some trigonometry

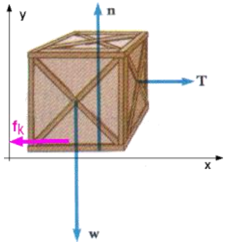




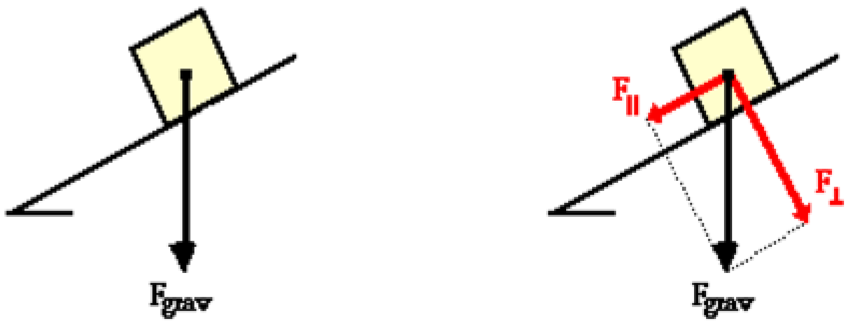
Inclined Planes

- Replace the force of gravity with its components.

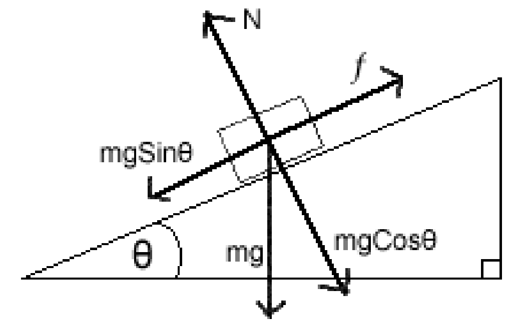




The force of gravity will be resolved into two components of force - one directed parallel to the inclined surface and the other directed perpendicular to the inclined surface.



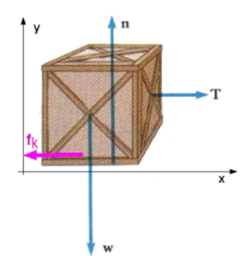
The force of gravity can be resolved into two components. Together, these two components replace the effect of the force of gravity.



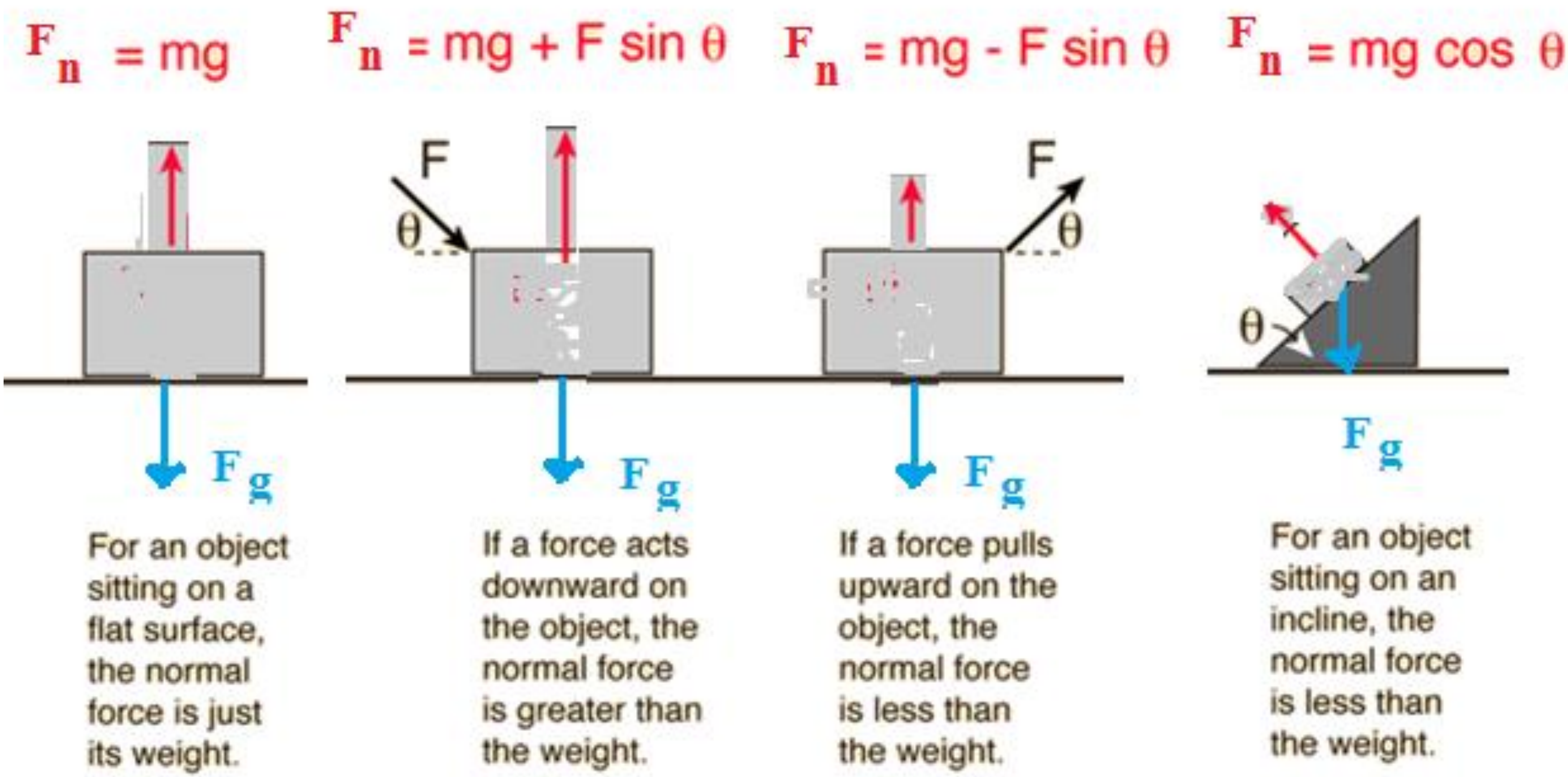
$$F_x = F_a = F_{II} = F_g \text{Sin}\,\theta$$

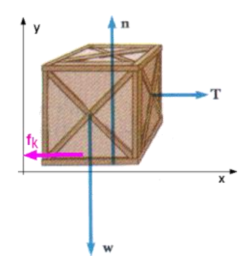
$$F_y = F_n = F_{\perp} = F_g \text{Cos}\,\theta$$

Note: Always let the direction of the motion to be positive



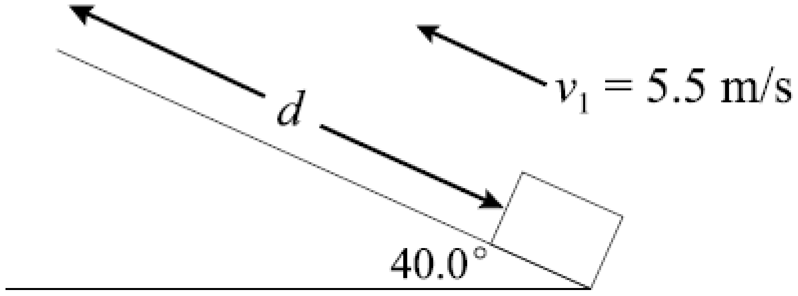
Now We Have Four Ways to Calculate Normal Force

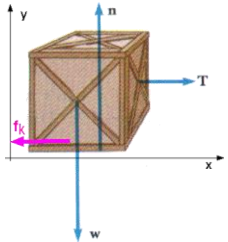




Example 1:

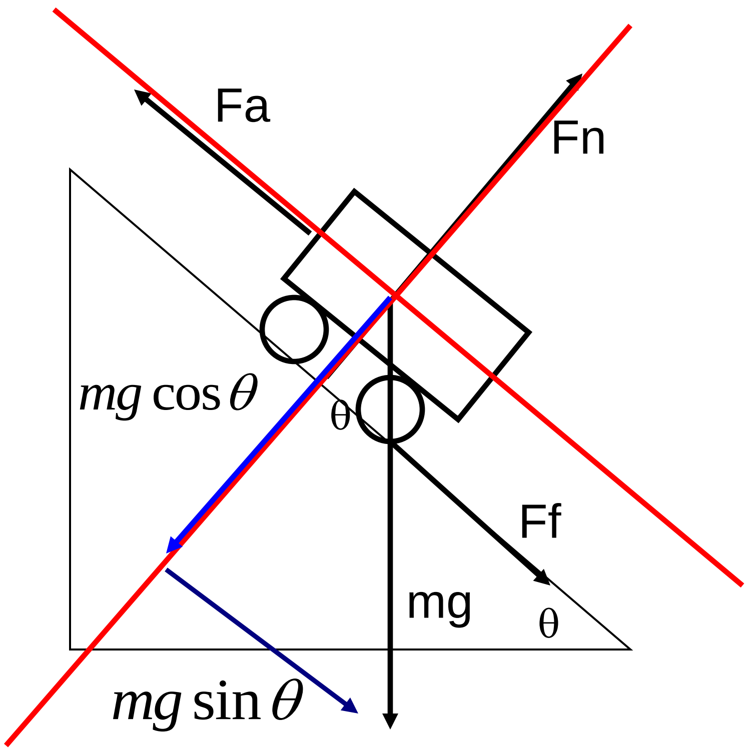
A block is launched up a frictionless incline with an initial speed of 5.5 m/s as shown.   What is the maximum displacement, d, of the block up the incline?





Example 2:

A person pushes a 30-kg shopping cart up a 10 degree incline with a force of 85 N. Calculate the coefficient of friction if the cart is pushed at a ***constant speed.***



$$F_a = F_f + mg\sin\theta \qquad F_f = \mu_k F_N$$

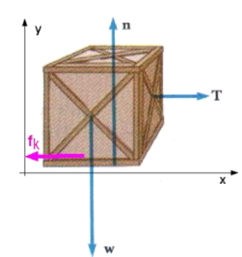
$$F_a = \mu_k F_N + mg\sin\theta \qquad F_N = mg\cos\theta$$

$$F_a = \mu_k mg\cos\theta + mg\sin\theta$$

$$F_a - mg\sin\theta = \mu_k mg\cos\theta$$

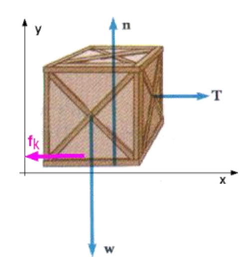
$$\mu_k = \frac{F_a - mg\sin\theta}{mg\cos\theta}$$

$$\mu_k = \frac{85 - (30)(9.8)(\sin 10)}{(30)(9.8)(\cos 10)} = \textbf{0.117}$$



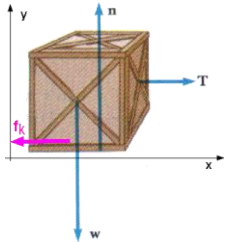
Example 3:

A skier starting from rest begins descending a 30^{o} slope. Assume the coefficient of kinetic friction is 0.10. What is the acceleration of the skier? Include a free
body diagram.



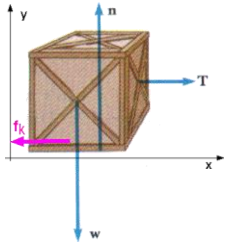
Look at the following link

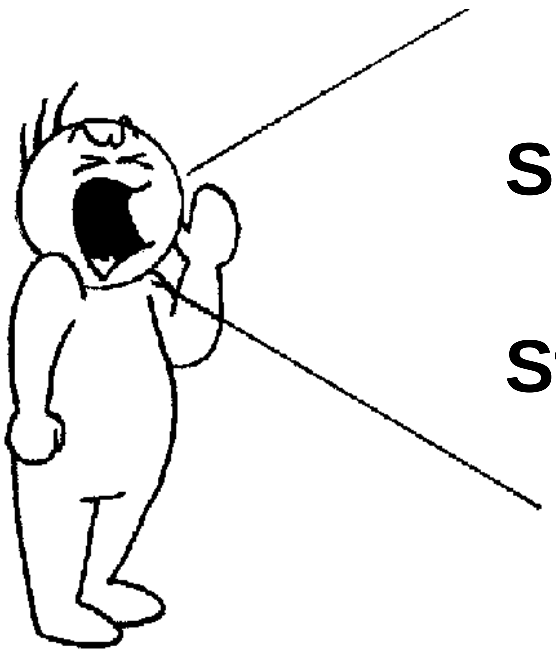
http://lectureonline.cl.msu.edu/~mmp/kap4/cd095a.htm



Activity

- Worksheet 3“ Newton’s Laws and Inclines

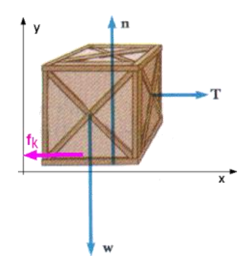




Section 2 Topic 4

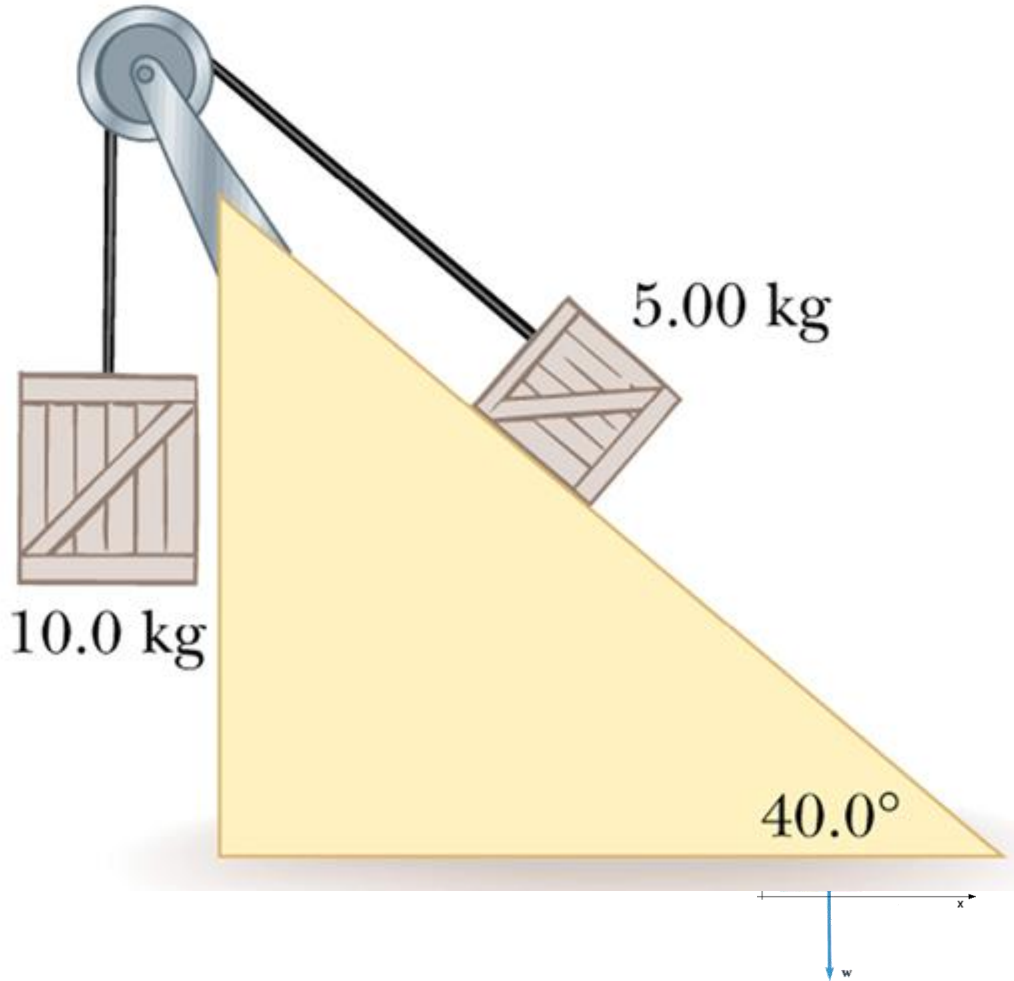
Strings and Pulleys on an Incline

Text: 5.1 - 5.3



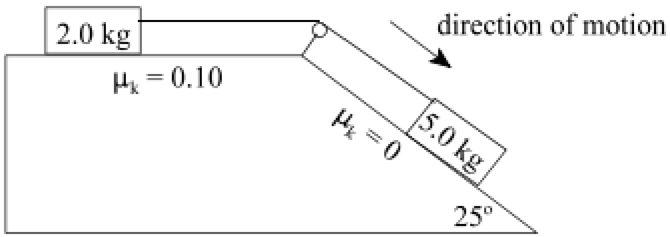
Example 1:

For the frictionless system shown determine the acceleration of the blocks and the tension in the string.



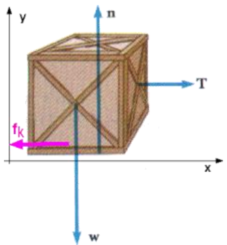
Example 2

The diagram below shows two blocks connected by a massless string over a frictionless pulley. What is the acceleration of the system of blocks? Show workings.



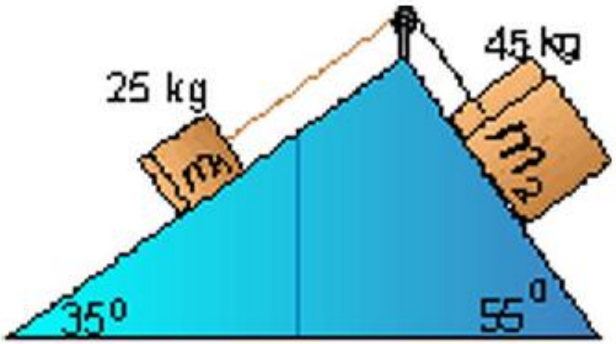
A) Determine the acceleration of the system

B) Determine the Tension in the string



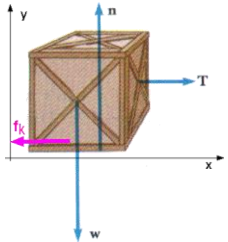
Example 3:

The blocks in the picture are sitting inclined surfaces where the coefficient of sliding friction on the left-hand incline is 0.12, and on the right-hand incline is 0.21.



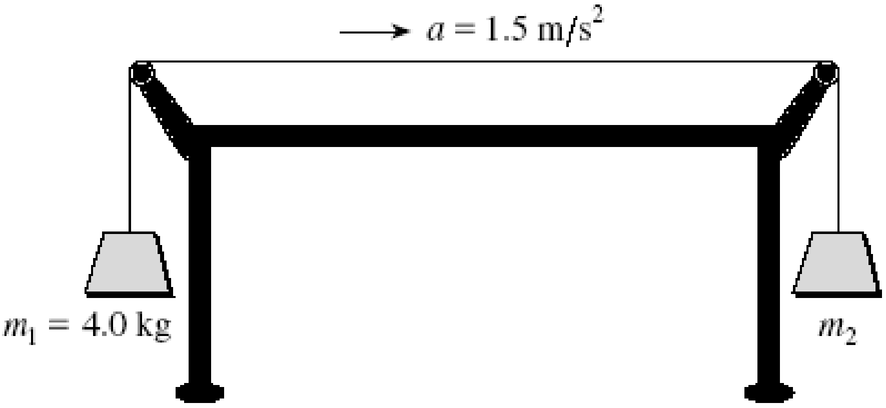
A) Determine the acceleration of the system

B) Determine the Tension in the string

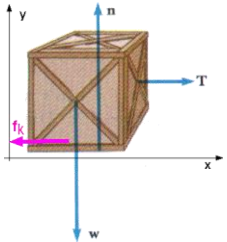


Example 4:

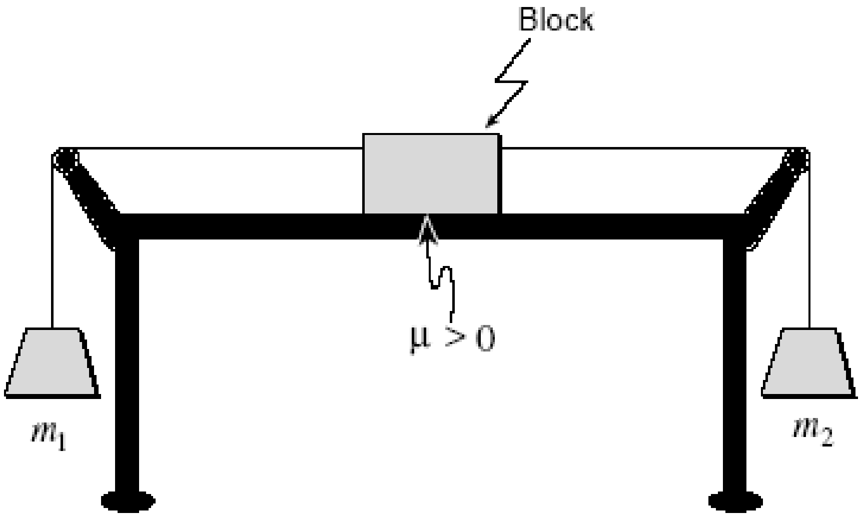
Two masses are connected by a light cord passing over frictionless pulleys as shown in the diagram below.
m_1 = 4.0 kg



a) What is m_2 if the system accelerates as shown?

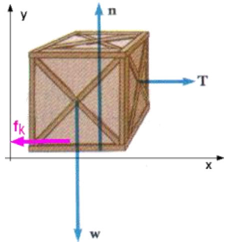


A block is then added to the system.



b) Adding the block decreases the acceleration of the system. Identify and explain two reasons for this decrease.

Since the system mass has increased, the acceleration must decrease $a = F_{net}/m_{total}$. Since there is friction, the net force will decrease and the acceleration will be smaller yet. (4 marks)



Activity

Questions:

- Page 179, #3
- page 188, #36, #38, #39, #40, #44, #46, #49
- Handout on " Newton's Second Law