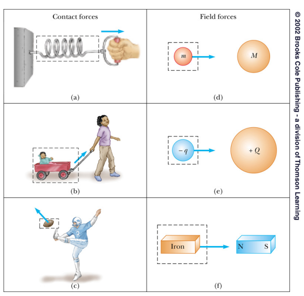
Chapter 4

Force and Motion

Forces

- Usually think of a force as a push or pull
- Vector quantity
- May be contact or field force

Contact and Field Forces



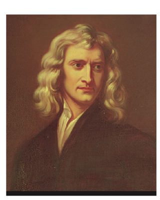
Fundamental Forces

- Types
  - Strong nuclear force
  - Electromagnetic force
  - Weak nuclear force
  - Gravity
- Characteristics
  - All field forces
  - Listed in order of decreasing strength

    - Cosmos 9 the first 20 minutes

Sir Isaac Newton

- Born in England within months of Galileo's Death
- Had not yet graduated from Cambridge when the Plague of 1665-1667 occurred.
- During this 2 years he accomplished more than an other person in History:
  - He laid the ground work for:
    - Differential calculus
    - Integral calculus
    - The Laws of Motion
    - Universal Gravitation
- In his later life he also pondered:
    - Harmonics
    - Fluids
    - Optics
  - "If I have seen farther then other men, it is only because I have stood on the shoulder of giants"



Classical Mechanics

- Describes the relationship between the motion of objects in our everyday world and the forces acting on them
- Conditions when Classical Mechanics does not apply
  - very tiny objects (< atomic sizes)
  - objects moving near the speed of light

Galileo's Preview of Newton's 1

- Galileo stated that an object on a curved path would return to its original height if the surface was very smooth

Newton's First Law

- If no forces act on an object, it continues in its original state of motion; that is, unless something exerts an external force on it, an object at rest remains at rest and an object moving with some velocity continues with that same velocity.
- i.e. - "An object in motion stays in motion and an object at rest stays at rest unless acted on by an outside force."

Newton's First Law, cont.

- External force
  - any force that results from the interaction between the object and its environment
- Alternative statement of Newton's First Law
  - When there are no external forces acting on an object, the acceleration of the object is zero.

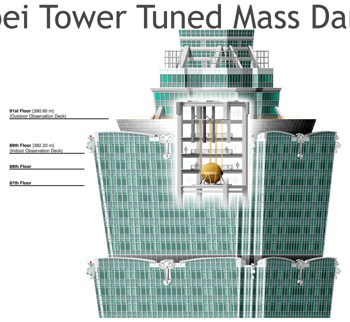
Inertia

- Is the tendency of an object to continue in its original motion

Mass

- A measure of the resistance of an object to changes in its motion due to a force
- Scalar quantity
- SI units are kg
- Inertia is an other name for mass

Taipei Tower Tuned Mass Damper



http://www.youtube.com/watch?v=NYSgd1XSZXc

Newton's Second Law

- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

$$a \propto \frac{\sum F}{m} \text{ or } \sum F = ma$$

  - F and a are both vectors
- Can also be applied three-dimensionally

- **All motion is caused by a force applying to a mass causing acceleration!**

Units of Force

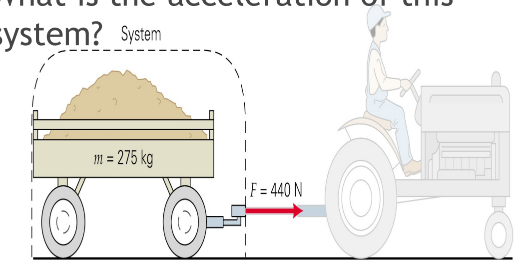
- SI unit of force is a Newton (N)

$$1\,\text{N} \equiv 1\frac{\text{kg m}}{\text{s}^2}$$

- US Customary unit of force is a pound (lb)
  - 1 N = 0.225 lb

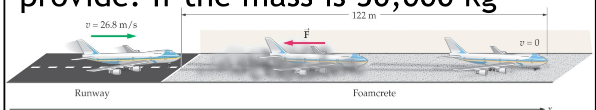
Newton's Second Law Example 1

What is the acceleration of this system?



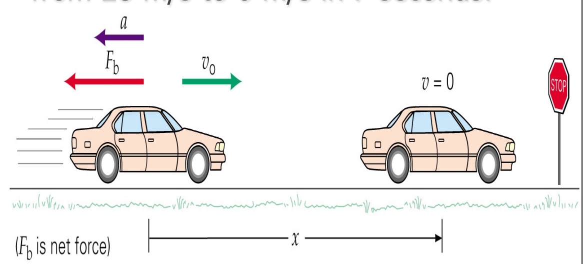
Newton's Second Law Example 2

What force does the foamcrete provide? If the mass is 30,000 kg



Newton's Second Law Example 3

If this car has a mass of 2000 kg what is the Force required to take if from 28 m/s to 0 m/s in 7 seconds!



Weight

- The magnitude of the gravitational force acting on an object of mass m near the Earth's surface is called the weight w of the object
  - $w = m\,g$ is a special case of Newton's Second Law
- g can also be found from the Law of Universal Gravitation which we will look at in a later chapter

More about weight

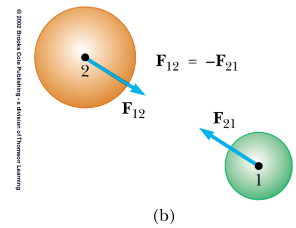
- Weight is **not** an inherent property of an object
  - mass **is** an inherent property
- Weight depends upon location

Newton's Third Law

- If two objects interact, the force F_{12} exerted by object 1 on object 2 is equal in magnitude but opposite in direction to the force F_{21} exerted by object 2 on object 1.
  - Equivalent to saying a single isolated force cannot exist

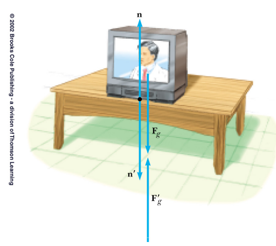
Newton's Third Law cont.

- F_{12} may be called the *action* force and F_{21} the *reaction* force
  - Actually, either force can be the action or the reaction force
- The action and reaction forces act on **different** objects



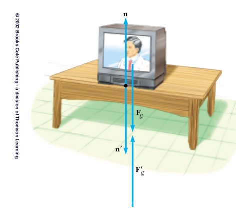
Some Action-Reaction Pairs

- n and n'
  - n is the *normal* force, the force the table exerts on the TV
  - n is always perpendicular to the surface
  - n' is the reaction – the TV on the table
    - In this case n' is weight
  - n = - n'



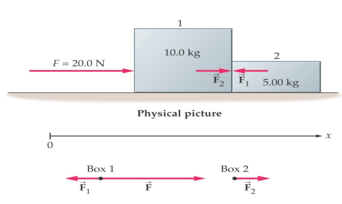
More Action-Reaction pairs

- F_g and F_g'
  - F_g is the force the Earth exerts on the object
  - F_g' is the force the object exerts on the earth
  - $F_g = -F_g'$



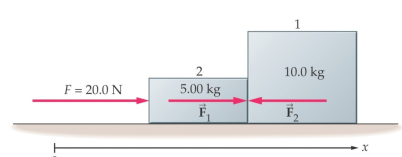
Action Reaction Example 1

What is the acceleration of the system? What is the force box 1 provides on box 2? What about box 2 on box 1?

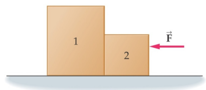


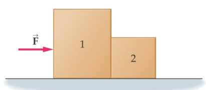
Action Reaction Example 1 part 2

What is the acceleration of the system? What is the force box 2 provides on box 1? What about box 1 on box 2?



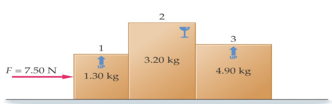
Action Reaction Example 2
Box 1 has a mass of 30kg
Box 2 has a weight of 196N
The force is 100 Newton's
What is the acceleration of the system?
What is the force between 1 and 2?





Action Reaction Example 3 Part 1
What is the acceleration of the system?
What is the force between 2 and 3?
What is the force between 1 and 2?

Action Reaction Example 3 Part 2
What is the acceleration of the system?
What is the force between 1 and 2?
What is the force between 2 and 3?



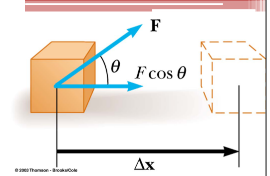
Applying Newton's Laws

- Assumptions
  - Objects behave as particles
    - can ignore rotational motion (for now)
  - Masses of strings or ropes are negligible
  - Interested only in the forces acting on the object
    - can neglect reaction forces

Free Body Diagram

- Must identify all the forces acting on the object of interest
- Choose an appropriate coordinate system
- If the free body diagram is incorrect, the solution will likely be incorrect

Component Forces



- Forces should be broken into x and y components to solve problems.
- Remember:

$$F_x = F * \cos(\theta) = ma_x$$

$$F_y = F * \sin(\theta) = ma_y$$

Equilibrium

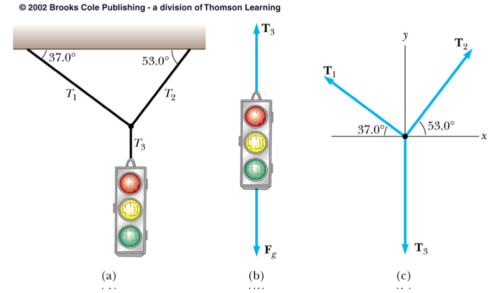
- An object either at rest or moving with a constant velocity is said to be in *equilibrium (Translational Equilibrium)*
- The net force acting on the object is zero

$$\sum F = 0$$

- Must work with the equation in terms of its components:

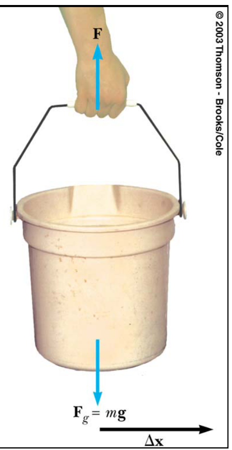
$$\sum F_x = 0 \qquad \sum F_y = 0$$

Equilibrium Example – Free Body



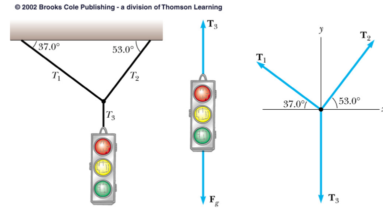
Static Example Problem 1

A girl holds a bucket of water that has 4 gallons in it. What force does she pull up with in mks? Water has a Fw of 8lbs per gallon.



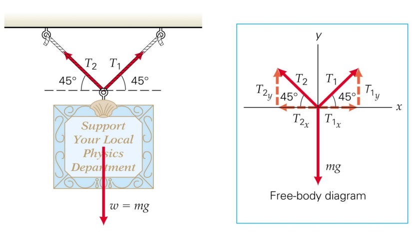
Static Example Problem 2

Assume the Light has a mass of 20 kg, what the force in T1 and T2?

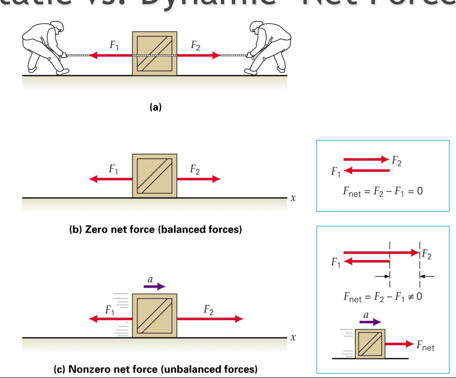


Static Example Problem 3

If the Picture has a mass of 10 kg how much force must each string provide?

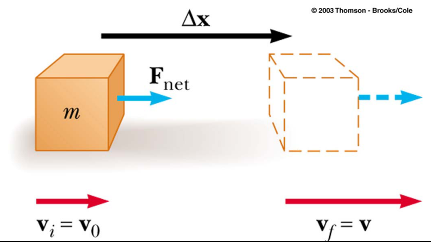


Static vs. Dynamic- Net Force



Dynamic 1D Example Problem 2

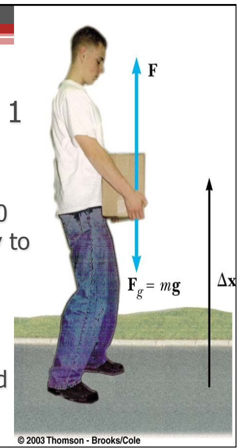
If the initial velocity is 0 m/s and the final is 20 m/s and the acceleration happens over 3 meters what is the force on this 10 kg box



Dynamic Example Problem 1

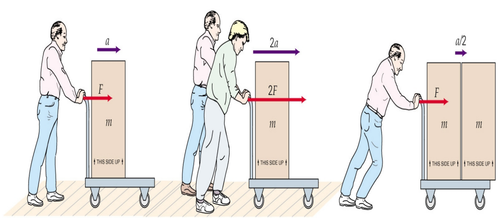
A boy raises a box 1 meter in .5 seconds. The box has a mass of 10 kg. How much force does he apply to lift it? (remember he has to overcome the acceleration downward!!)

How much force is required to hold it there?



Dynamic Example Problem 2

If the Mass of each of the boxes is 120 kg and each person pushes with 240 Newton's calculate the Acceleration in each of the cases

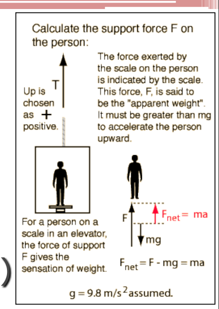


Elevators

In an elevator your weight changes based on the accelerations you are experience.

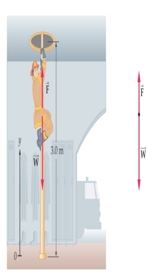
$T=F_n$=Apparent Weight (+)
F_w=True Weight (-)

$F_n+F_w = F_{net}$ as always $F_{net} / m = a$



Dynamic Example Problem 3

If the fire fighter has mass of 100 kg and provides a force up the poll of 300 Newton's how long does it take him to come down a 3 meter poll? What is his final speed?

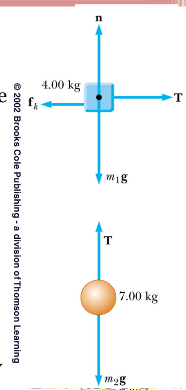


Dynamic Example Problem 4

Two people pull on a log with 1250 Newton's of force. 1 person pulls at 30 degrees P.C. The other pulls at 300 degrees P.C. What the Force each person applied to the log? What Direction does the log move in?

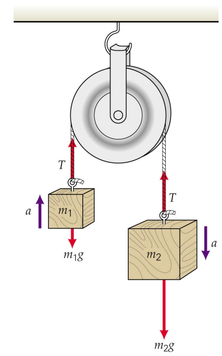
Connected Objects

- Apply Newton's Laws separately to each object
- The acceleration of both objects will be the same
- The tension is the same in each diagram
- Solve the simultaneous equations
- Treating the system as one object allows for an alternative method to check
  - Use only external forces
    - Not the tension – it's internal
  - The mass is the mass of the system
- Doesn't tell you anything about any internal forces



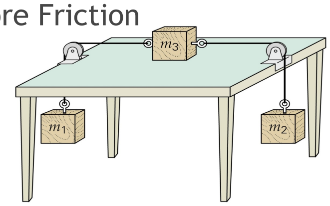
Connected Mass Example 1

If Block one has a mass of 20 kg and block 2 has a mass of 35 kg what is the acceleration of the system?



Connected Mass Example 2

If Block one has a mass of 10 kg, block 2 has a mass of 15 kg, and block 3 has a mass of 20kg what is the acceleration of the system? Ignore Friction



Connected Mass Example 3

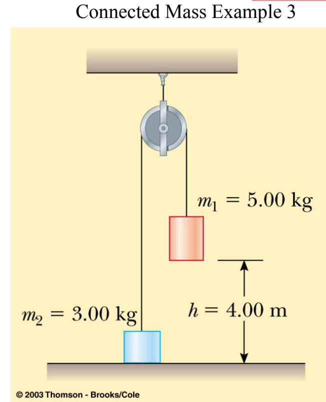
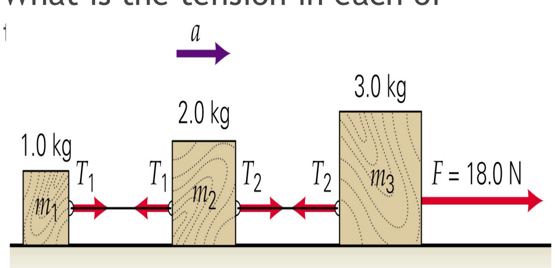


Fig. P5.63, p. 150

Slide 50

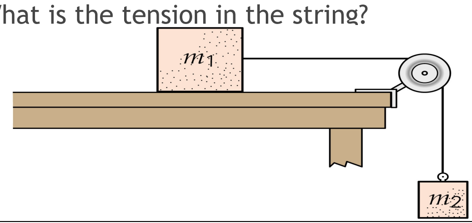
Tension Example Problem 1

What is the tension in each of



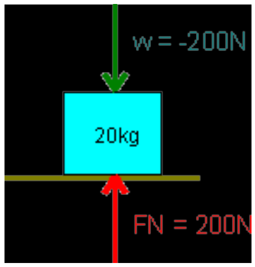
Tension Example Problem 2

If Block 1 has a mass of 50 kg and block 2 has a mass of 10 kg. What is the acceleration of the system? What Happens if the blocks change places. What is the tension in the string?



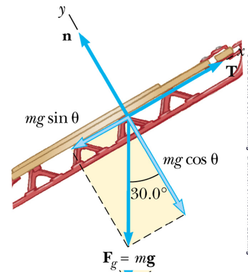
Equilibrium and Force Normal Recap

- The equilibrium is the force equal in magnitude and opposite in direction to the resultant force
- The Force normal is the force that is perpendicular to the contact between 2 surfaces. The point points out of the surface that is holding the objects



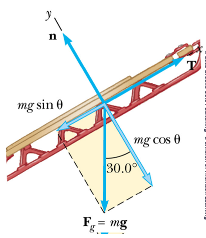
Incline Plane

- When we have an incline plane, the force weight still points downward
- The force normal however points perpendicular to the surface.
- This means there is unbalance in force!
  - This means there is an acceleration



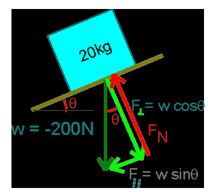
Inclined Planes

- Choose the coordinate system with x along the incline and y perpendicular to the incline
- Replace the force of gravity with its components



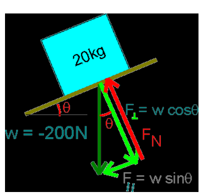
Force Normal

- The force normal is the force applied by the surface perpendicular to the surface of the incline. It equals the magnitude to the Fw *cos (theta)



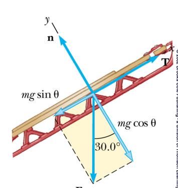
Force Parallel

- The force parallel is directional down the incline and equal in magnitude to the Fw *sin (theta)



Incline Example

- The mass of the sled shown is 15 kg. What is the Force Normal and the Force Parallel on the sled?

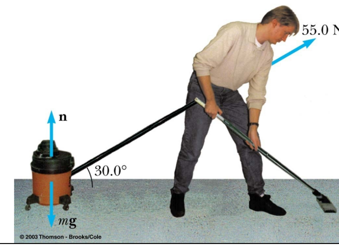


Applied forces

- A force caused by external source.
- The applied forces can add or subtract from the force normal, the force parallel, or both.
- Most challenging to solve for because they can be stated a number of different ways
- Draw a picture and use SOH CAH TOA
- Consider this in your calculations.

Applied Force Example Problem 1

What is the horizontal and vertical force on the vacuum cleaner?



Applied Force Example Problem 2

A person pushes a lawn mower with 100 Newton's of force on a handle that makes a 40 degree angle with the lawnmower. What is the horizontal and vertical force on the lawn mower?