PHYS 101 Lecture 5 Dynamics: Forces & Newton's Laws

Newton's 3 Laws of Motion

(We will cover the first two now and the third later)

- NEWTON'S FIRST LAW:
  - If there is zero net force on an object (body), then its speed and direction will not change. **Fred the Bear Demo**
  - Inertia (**Air track demo, dishes demo, ball on string**)
- NEWTON'S SECOND LAW:
  - If a *nonzero net force* acts on an object, its motion will change according to this equation:

$F_{Net} = ma$ ← Acceleration

↑ Net Force ↑ Mass

Newton's Laws of Motion

The one we will use all the time is:

NEWTON'S SECOND LAW (I will abbreviate as N#2)

If a nonzero net force is acting on an object its motion will change:

$\mathbf{F}_{Net} = m\boldsymbol{a}$ (F and a are vectors)

- The *net force* is the **vector sum** of all the individual forces acting on an *object*.
- **To apply N#2, you must**:
  - identify/isolate the *object* or *body* that you are analyzing.
  - identify *each individual force* acting on the object.
  - You then add (as vectors) the individual forces to get the *net force*.

There will only be two types of forces we will study in PHYS101

- *Type 1: Contact forces* (must touch object to exert force)
  - *Normal*: Perpendicular to surface
  - *Friction*: Parallel to surface (two types)
  - *Tension*: ropes & strings
  - *Springs*: $F = -kx$
  - Other forces that touch object (e.g., a hand pushing)

This is *the* list of contact forces. That's It!!

There will only be two types of forces we will study in PHYS 101

- *Type 2: Non-contact forces*: Action at a distance forces. Only one in Phys 101—gravitational force
  - In PHYS 101 we study the gravitational force (weight)
  - Near the earth's surface, $W = m_{object}\, g$
  - *Note: Any two masses will exert an attractive gravitational force on each other—more on that at a later lecture*

In Phys 102: electromagnetic force.

Applying Newton's Second Law: The Free-Body Diagram (FBD)

- A *free-body diagram:*
  - ➨isolates the object being analyzed
  - ➨has labeled arrows (vectors) *for each individual force acting on the object.*
- The vector length is the magnitude of the force
- The vector direction is the direction in which the force acts
- The *net force* is the **vector sum** of all the individual forces acting on an *object*.
- A FBD should NEVER show a **net force.**
  - ➨The net force is the sum of the forces in the FBD.
  - ➨Draw the forces with tail starting on object

Procedure for applying Newton's Second Law

How the game is played (or avoiding spooky rules)

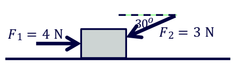
If you wish to memorize anything, memorize what's below.

- Identify/isolate *body* or *object* of interest.
- Draw a FBD (to identify all forces acting on body)
- Apply Newton's Law #2 (find F_{net} & do: $\mathbf{F}_{net}=m\boldsymbol{a}$)
- To apply Newton's Law #2:
  - ➨draw a coordinate system
  - ➨apply Newton's Law #2 in the x and y directions.
- $\mathbf{F}_{Net}= m\boldsymbol{a}$ is a vector equation.
  - ➨ It must be satisfied independently in the x and y directions.
- Use algebra to solve for the unknown quantity.
- Enjoy the experience!

Example

A block of mass $m = 0.4$ kg is being pushed by two different people with the forces shown. Consider the floor to be frictionless.

What is the acceleration of the block?

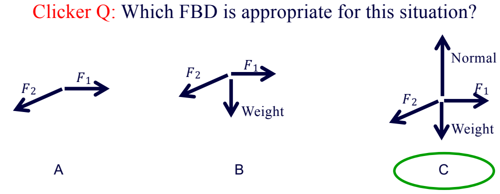


Isolate body: The block

N means *Newtons* for units of force

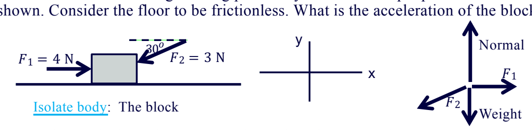
1 N = 1 kg m/s^2

Clicker Q: Which FBD is appropriate for this situation?



Example

A block of mass m=0.4 kg is being pushed by two different people with the forces shown. Consider the floor to be frictionless. What is the acceleration of the block?



Isolate body: The block

Using the standard coordinate system shown, let's decompose the forces in the x and y directions and apply Newton's Second Law.

x-direction

$F_1 - F_{2,x} = ma_x$

$4N - 3N(\cos 30^o) = ma_x$

$4N - 2.6N = (0.4kg)\,a_x$

Solve for a_x

$a_x = (4N - 2.6N)/0.4kg = 3.5\ m/s^2$

y-direction

$-F_{2,y} - W + N = ma_y$

$-3N(\sin 30^o) - mg + N = ma_y$

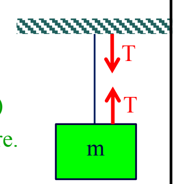
Note: N>mg=3.92N

Clicker Q: What can you say about a_y? A) $a_y < 0$ B) $a_y > 0$ C) $a_y = 0$

So normal force must be: $N = W + F_{2,y} = (0.4kg)(9.8m/s^2) + 1.5N = 5.42N$

Another Example of a Force: Tension

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



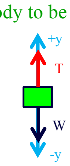
Newton's 2nd Law and Equilibrium Systems

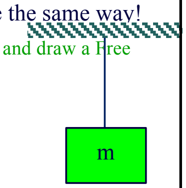
We suspend a mass m = 5 kg from the ceiling using a string. What is the tension in the string?

- Every single one of these problems is done the same way!

➨Step 1: Identify the object or body to be analyzed, and draw a Free Body Diagram,

(label your axes!)





➨Step 2: Identify and draw all force vectors Weight, W Tension, T

➨Step 3: Use your drawing to determine F_{Net} in Newton's 2nd law

$F_{Net} = ma$ What is the acceleration in this case? a = 0

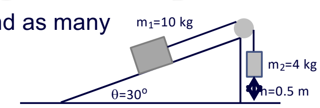
$T - W = 0$ $T = W = mg = (5\ kg)x(9.8\ m/s^2) = 49$ N

To avoid this sad situation in the future…don't apply "spooky rules"

- Resist resorting to "numerology," or to tempting but unfounded intuitions
- Look to physics laws and procedures to apply
- Check for consistency in answers
- In this last question many of you did not:
  - Isolate the body (the 2 kg block) and identify the forces acting on it (FBD)
  - Apply a physics law (Newton's Second Law, F_{net}=ma)
- But…you did it in the first question!!!!

Another great example

Incline is frictionless: Find as many things as you can

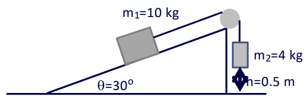


Direction of motion

N=

T=

a=



Summary of Concepts

- Newton's Law #1 and #2
- Contact forces (e.g., friction, tension)
- Action at a distance forces (gravity)
- Problem Solving Tips for Applying N#2
  - Isolate body to be analyzed
  - Draw FBD, pick a coordinate system
  - Apply physics laws: $\mathbf{F}_{net}=m\mathbf{a}$
  - Use algebra to solve for quantities in x & y directions
  - Avoid spooky rules (unfounded intuitions)