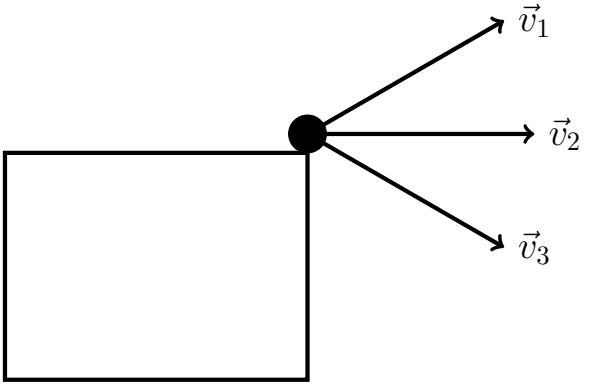
Studio 3: Motion and Forces



Warm-Up Activity

Which marble is in the air for the most time?

(A) Marble 1

(B) Marble 2

(C) Marble 3

(D) They are all in the air for the same amount of time.

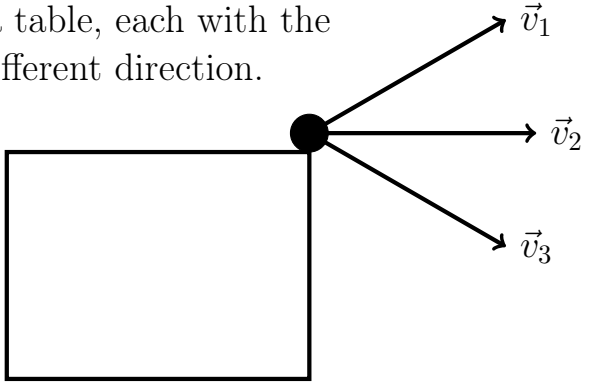
Projectile Motion

- Acceleration in the x-direction is equal to zero.
- Acceleration in the y-direction is only due to gravity.

$$
\begin{aligned}
a_x(t) &= 0 & a_y(t) &= -g \\
v_x(t) &= v_{ix} & v_y(t) &= v_{iy} - gt \\
x(t) &= x_i + v_{ix}t & y(t) &= y_i + v_{iy}t - \frac{1}{2}gt^2
\end{aligned}
$$

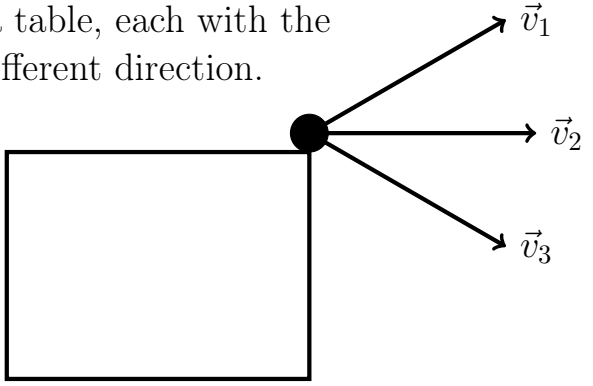
Three Marbles

- You throw three marbles off a table, each with the same initial speed, but in a different direction.
  - Which is in the air for the most time?
  - Which travels the most horizontal distance?
  - Which is moving fastest when it hits?



S3-1: Marble 2

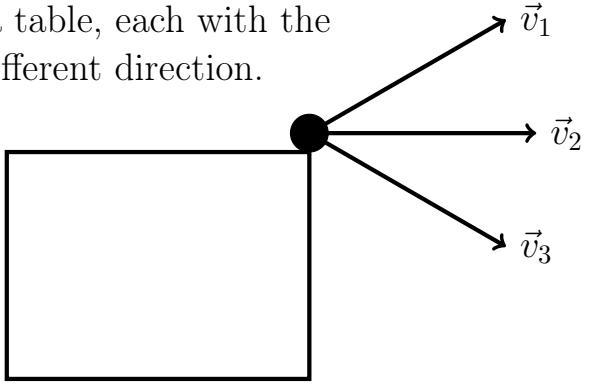
- You throw three marbles off a table, each with the same initial speed, but in a different direction.



  - If the height of the table is h, how much time does it take for marble 2 to hit the ground?
  - How far has the marble traveled horizontally in that amount of time?
  - What is the marble's speed when it hits the ground?

S3-2: Marble 1

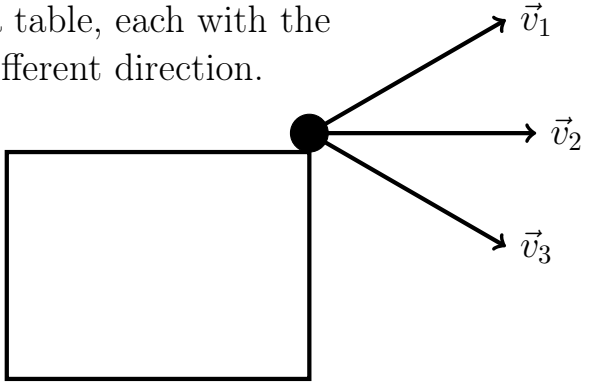
- You throw three marbles off a table, each with the same initial speed, but in a different direction.



  - If the angle is θ, how long does it take for marble 1 to hit the ground?
  - How far has the marble traveled horizontally in that amount of time?
  - What is the marble's speed when it hits the ground?

Three Marbles

- You throw three marbles off a table, each with the same initial speed, but in a different direction.



  - If h is the height of the table, v is the initial speed, and θ is the angle up from the horizontal:

$$t_f = \frac{v}{g}\sin\theta + \sqrt{\frac{v^2}{g^2}\sin^2\theta + \frac{2h}{g}} \qquad d = vt_f\cos\theta \qquad v_f = \sqrt{v^2 + 2gh}$$

What are Interactions/Forces?

- What does it mean to say that two objects are interacting?
- What happens to objects when they interact?
- What if multiple objects interact with the same object?
- **What different kinds of interactions are there?**

Types of Forces

- Gravity: $\vec{F}^g$
- Normal: $\vec{F}^N$
- Tension: $\vec{F}^T$
- Spring: $\vec{F}^{sp}$
- Friction: $\vec{F}^f$ ($\vec{F}^{kf}$, $\vec{F}^{sf}$)
- Electric: $\vec{F}^E$
- Magnetic: $\vec{F}^M$

Normal Forces

- Normal forces are contact forces that act perpendicular to the surface of contact.
- There is no formula for determining normal forces—the magnitude can change depending on the circumstances.
- Too much normal force can cause objects to break!

Tension Forces

- Tension forces are kind of like normal forces, except they pull in the direction of the rope.
- There is no formula for determining tension forces—the magnitude can change depending on the circumstances.
- Too much tension force can cause a rope to break!
- Tension is uniform throughout a single rope.
  - . . . if the rope is massless, inextensible, and the middle of the rope isn't in contact with anything.

Free-Body Diagrams and Systems

- Choose a system.
  - Make sure you know what is internal to your system and what is external to your system.
- Identify and describe each external force:
  - Say what kind of force it is.
  - Determine the object the force is being acted on.
  - Determine the object that is exerting the force.
  - Write a symbolic version of the force that includes the information above.
  - Represent all the forces acting on a single object or system using a **free-body diagram**.

$$\vec{F}_{\text{on,by}}^{\text{type}}$$

S3-3: The Bag of Groceries

For each situation to the right:

(1) Sketch a picture of the object of interest.

(2) Make a strobe or motion diagram.

(3) Identify and describe the forces acting on the object.

(4) Draw a free-body diagram for the object.

(A) You hold a bag of groceries in your hand.

(B) You lower the bag of groceries; the bag moves downward faster and faster.

(C) You lift the bag of groceries; the bag moves upward at constant speed.

Main Ideas

- Motion in 2 dimensions can be broken down into independent motion in each dimension.
- Solving a problem symbolically allows you to solve many problems with one set of algebra.
- Forces arise from interactions between objects.
- There are many different kinds of forces that we can analyze differently.
- Objects can only change their motion when acted upon by an external force.