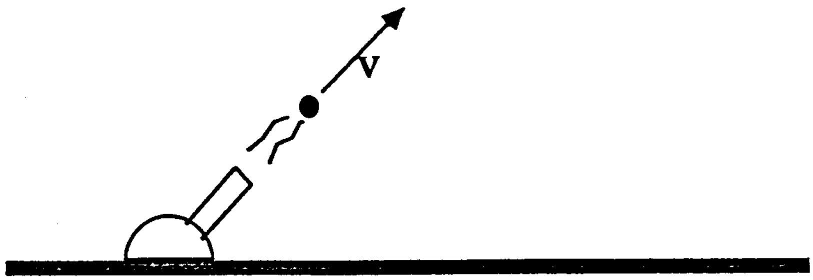
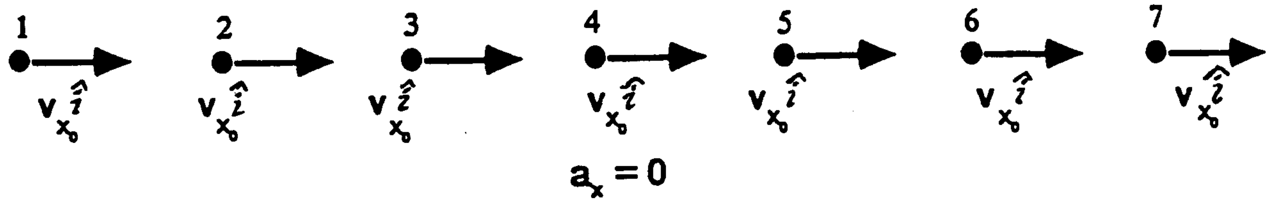
Projectile Motion



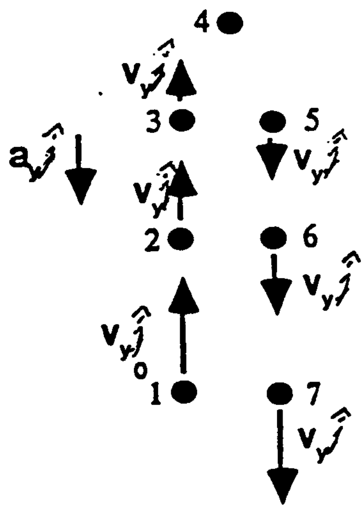
Motion Diagram for a Projectile

EXAMPLE 2.1 Construct a motion diagram for a projectile that initially moves in a diagonal direction above the horizontal—like a baseball after leaving a bat or a football after leaving the foot of the punter. To construct the motion diagram, combine step-by-step two motion maps—one for the horizontal motion and one for the vertical motion. Complete each step below before looking at the answer.

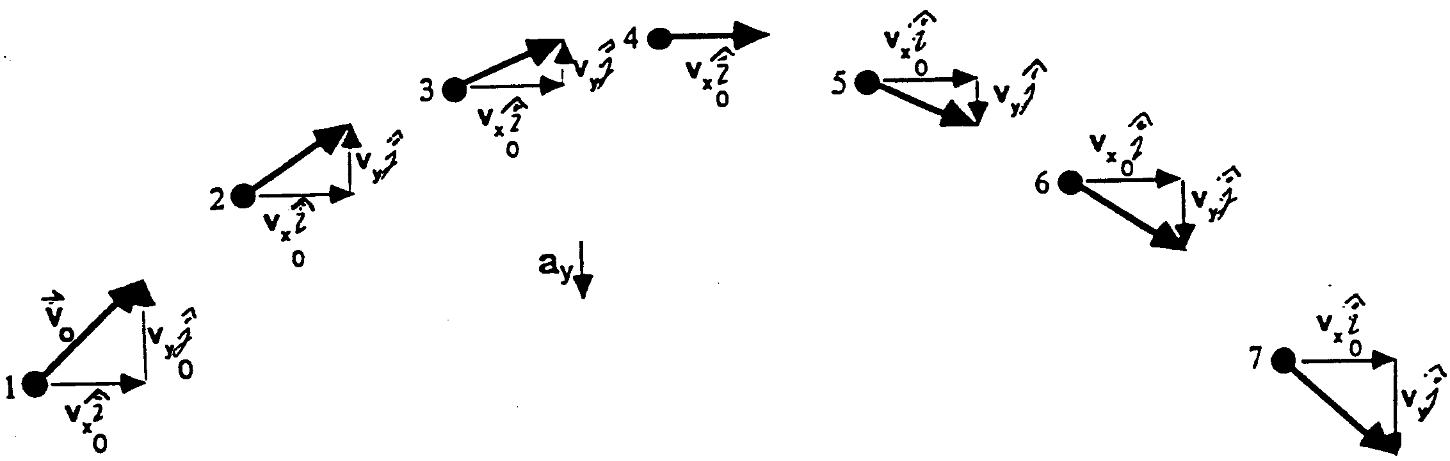
Construct a horizontal motion diagram for an object that moves at a constant speed in the horizontal direction (its horizontal speed is the horizontal component of its initial velocity).



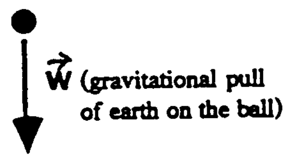
Construct a vertical motion diagram for an object with an initial upward velocity (its initial vertical speed is the vertical component of its initial velocity) and which experiences a constant, downward acceleration. Displace the position dots for the upward motion slightly to the left side of the position dots for the downward motion. Assume that the time interval separating each dot is the same for the vertical motion diagram as for the horizontal motion diagram.



Combine the two motion diagrams into a single projectile motion diagram. Place the vertical motion diagram on the left side along the y axis. Place the horizontal motion diagram at the bottom along the x axis. Remember that successive dots on the diagrams above indicate the horizontal and vertical positions of the projectile at the same times. Use this to place the position dots for the projectile on the two-dimensional motion diagram on the next page. The velocity at each position is the vector sum of the horizontal and vertical components of velocity. Also, the acceleration at each position is the vector sum of the horizontal and vertical components of acceleration at each point. Because there is no acceleration in the horizontal direction, the acceleration is constant in the downward direction for each point.



Finally, construct a free-body diagram for the projectile. Ignore air resistance. Does the direction of the resultant force acting on the object point in the same direction as the acceleration shown above?



The resultant force points down in the same direction as the acceleration.

Summary: If we ignore air resistance, a projectile moves at a constant speed in the horizontal direction while simultaneously moving in the vertical direction with a downward pointing acceleration. The only force acting on the projectile is the downward weight.

Pre-Newtonian physicists thought that a force must push the projectile in the direction of motion. There is no other object, however, that contacts the projectile to push in that direction. In Newtonian physics, the projectile continues to move in the horizontal direction at a constant speed because *NO* force is exerted on the projectile to change that horizontal motion.

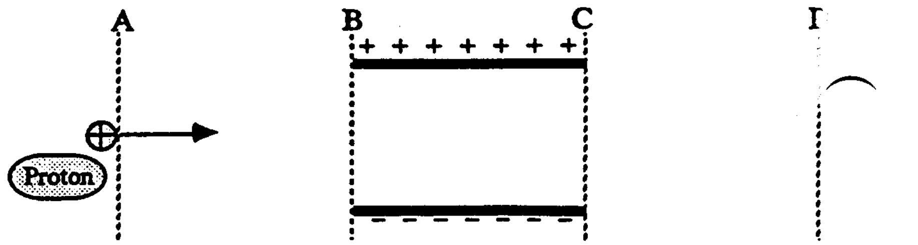
Problems

2.1 (a) Use the procedures discussed in Example 2.1 to construct a motion diagram for a projectile that initially moves in the horizontal direction. Ignore air resistance. (b) Construct a free-body diagram for the projectile. (c) Are the directions of the acceleration and the resultant force the same?

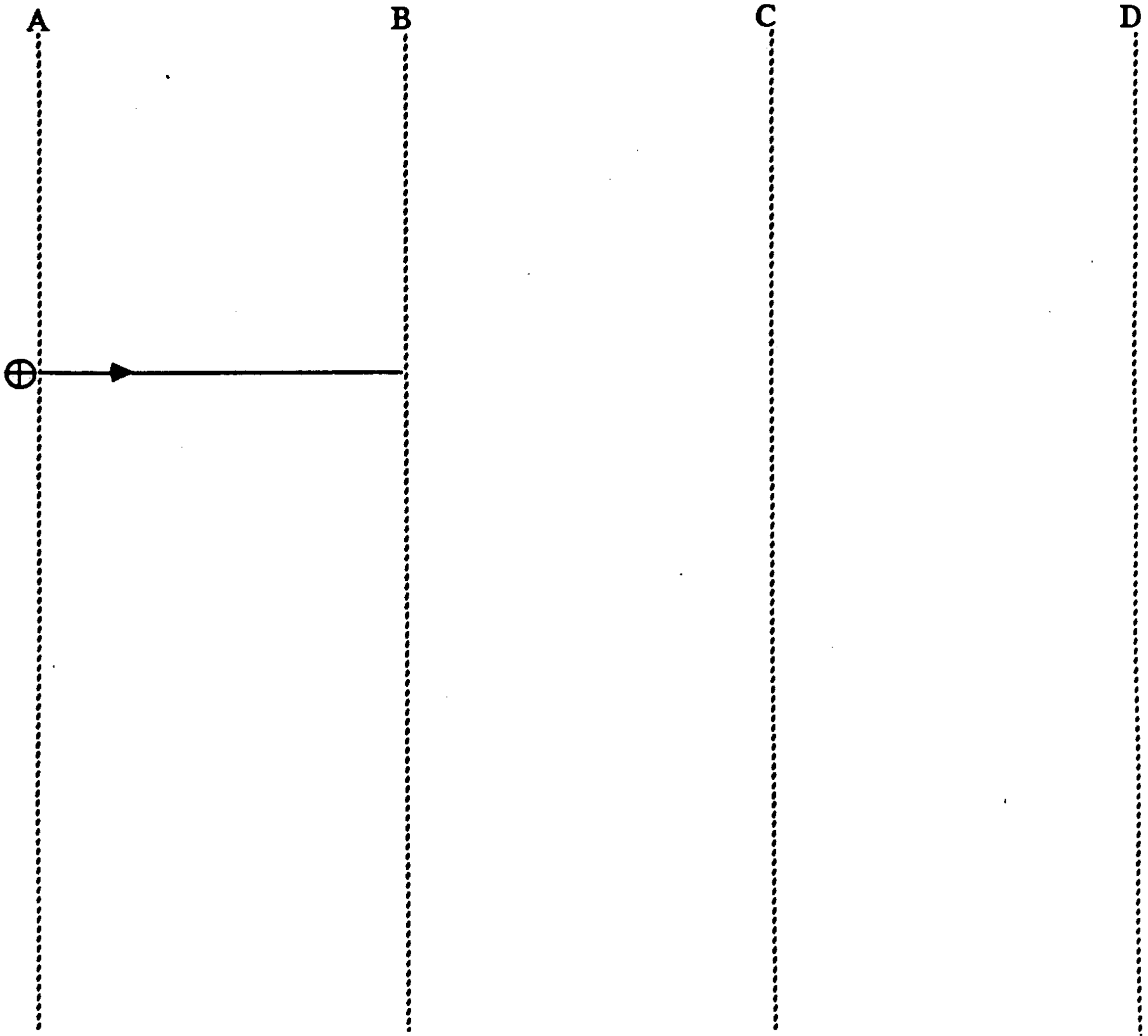
2.2 (a) Use the procedures dscussed in Example 2.1 to construct a motion diagram for a projectile that initially moves in a direction that is approximately 20° below the horizontal. Ignore air resistance. (b) Construct a free-body diagram for the projectile. (c) Are the directions of the acceleration and the resultant force the same?

A Proton as a Projectile

A proton with a small positive electric charge moves at constant velocity from A to B (no forces act on the proton). From B to C, the proton is in a region between two electrically changed plates that cause a constant downward electrical force on the proton. After C, no force acts on the proton.



(a) Draw the shape of the path of the proton between B and C (does it move horizontally, vertically, in a slanted path up or down, in a curved path up or down, or in some other path?).



(b) After C, the net force on the proton is again zero. In the sketch above, continue the line to indicate the direction and shape of the path followed by the proton from C to D.

(c) Check with two nearby students to see if you agree about the paths. If you disagree, try to reconcile any differences in opinion.

Projectile Motion and Initial Velocity

The initial velocity of several projectiles are listed below. For each case, determine the initial x and y velocity components and the velocity components two seconds after the projectile was launched. Assume g = $10 m/s^2$ and ignore air resistance.

Initial velocity	v_{0x} (0 s)	v_x (2 s)	v_{0y} (0 s)	v_y (2 s)
(a) 50 m/s 37° above horizontal				
(b) 50 m/s 30° above horizontal				
(c) 50 m/s horizontally				
(d) 50 m/s 30° below horizontal				
(e) 50 m/s 37° below horizontal				

(f) At what time does projectile (a), described above, reach its highest point?

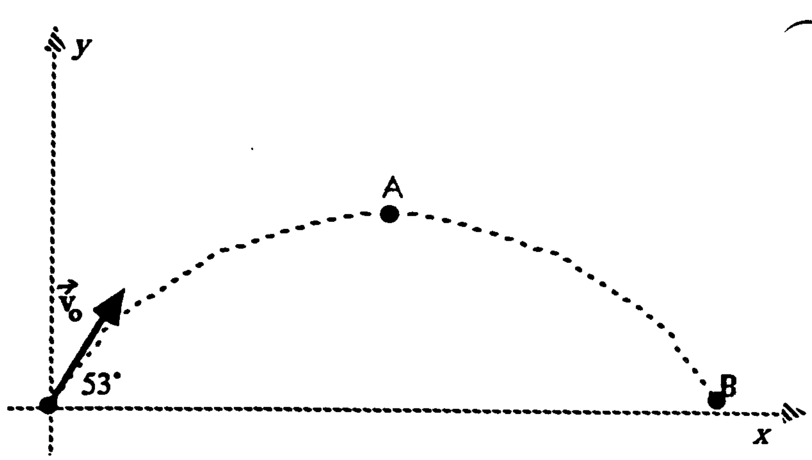
(g) What is the velocity (magnitude and direction) of projectile (a) at that point?

The components of the initial velocity for several projectiles are given below. Determine the magnitude and direction of the initial velocity.

	v_{0x} (m/s)	v_{0y} (m/s)	v_0 (m/s)	Direction
(h)	10	20		
(i)	20	10		
(j)	20	−10		

Projectile Motion Question 1

A ball is projected from the origin with initial velocity $\vec{v}_o$, as shown at the right. The initial speed of the ball is 50 m/s. Assume that. $g = 10 \text{ m/s}^2$.



(a) Determine the x component of the initial velocity?

(b) Determine the y component of the initial velocity?

(c) Determine the acceleration in the x direction. Ignore air resistance.

(d) Determine the acceleration in the y direction. Ignore air resistance.

(e) Complete the table below indicating the position components and the velocity components at one-secon time intervals beginning at time zero when the ball leaves the ground.

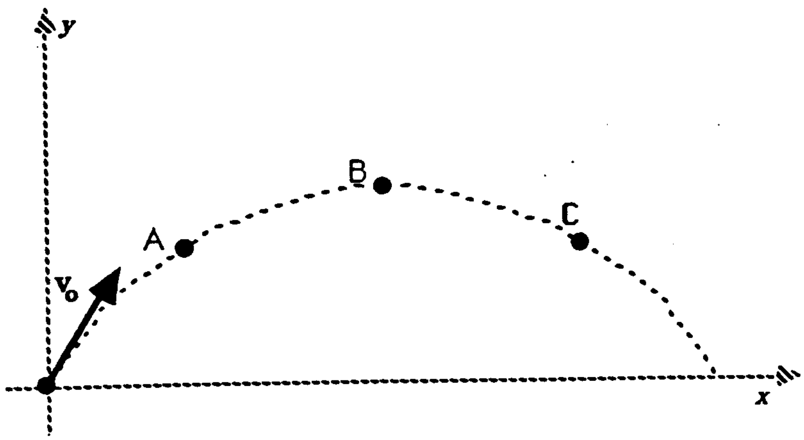
time (s)	x velocity (m/s)	x position (m)	y velocity (m/s)	y position (m)
0		0		0
1				
2				
3				
4				
5				
6				
8				

(f) Determine the ball's velocity (magnitude and direction) at position A.

(g) Determine the ball's velocity (magnitude and direction) at position B just before it hits the ground.

Projectile Motion Question 2

(a) A ball is projected from the origin with initial velocity $\vec{v}_o$, as shown at the right. Complete the table below indicating the signs (+, –, or 0) of the position components, velocity components, and acceleration components at positions A, B, and C. Ignore air resistance.



Position	x	v_x	a_x	y	v_y	a_y
A						
B						
C						

(b) For each position shown above, indicate in the table below if each quantity is:
I = increasing
D = decreasing
N = not changing

Position	x	v_x	a_x	y	v_y	a_y
A						
B						
C						

(c) If the initial velocity of the ball is 50 m/s directed 53° above the horizontal, what is the ball's velocity at position B?

pted from "Qualitative Problems for Introductory Physics," Robert E. Gibbs, p. 38 Kendall/Hunt Publisning Co., Dubuque Iowa (1989).

Projectile Motion Question 3

(a) A rock is thrown with an initial vertical velocity component of 30 m/s and an initial horizontal velocity component of 20 m/s. What will the velocity components be one second after the rock reaches the top of its flight? Ignore air resistance and assume that $g = 10\ m/s^2$.

(b) A ball is launched from ground level with initial velocity components v_{ox} and v_{oy}, and it travels over level ground. For each change proposed below, describe the change in the maximum height above the ground level, the time spent in the air, the range of the ball, and the launch angle. Ignore air resistance.

I = increases
D = decreases
N = no change

Proposed change	Maximum height	Time in air	Range of ball	Launch angle
Increase v_{ox} and do not change v_{oy}				
Increase v_{oy} and do not change v_{ox}				
Double both components				