Vectors have both *magnitude* and *direction*
displacement, velocity, acceleration
Scalars have *magnitude* only
distance, speed, time, mass

Unit vectors
Specify direction only.
Used to represent a vector in terms of components.
$\mathbf{a} = a_x\mathbf{i} + a_y\mathbf{j} + a_z\mathbf{k}$

Kinematic Equations (in 3 dimensions)
$\mathbf{v} = \mathbf{v}_o + \mathbf{a}t$
$\mathbf{r} = \mathbf{r}_o + \mathbf{v}_o t + \frac{1}{2}\,\mathbf{a}\,t^2$
$\mathbf{v} \bullet \mathbf{v} = \mathbf{v}_o \bullet \mathbf{v}_o + 2\mathbf{a}\bullet\Delta\mathbf{r}$

Projectile Motion
Horizontal velocity is constant.
$x = v_{xo}t$
Vertical velocity is accelerated at -g.
$v_y = v_o - gt$
$y = y_o + v_{yo}t - {}^1/_2gt^2$
$v_y^2 = v_{yo}^2 - 2g(y - y_o)$
The trajectory is defined mathematically by a parabola.

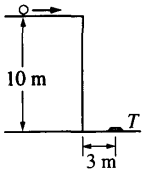
Problem: Projectile (CM-1998)

2. The velocity of a projectile at launch has a horizontal component v_h and a vertical component v_v. Air resistance is negligible. When the projectile is at the highest point of its trajectory, which of the following show the vertical and horizontal components of its velocity and the vertical component of its acceleration?

	Vertical Velocity	*Horizontal Velocity*	*Vertical Acceleration*
(A)	v_v	v_h	0
(B)	v_v	0	0
(C)	0	v_h	0
(D)	0	0	g
(E)	0	v_h	g

Justify your answer:

Problem: Projectile (CM-1998)



26. A target *T* lies flat on the ground 3 m from the side of a building that is 10 m tall, as shown above. A student rolls a ball off the horizontal roof of the building in the direction of the target. Air resistance is negligible. The horizontal speed with which the ball must leave the roof if it is to strike the target is most nearly

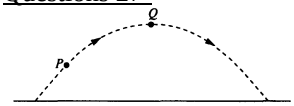
(A) 3/10 m/s (B) $\sqrt{2}$ m/s (C) $\frac{3}{\sqrt{2}}$ m/s

(D) 3 m/s (E) $10\sqrt{\frac{5}{3}}$ m/s

Show your work:

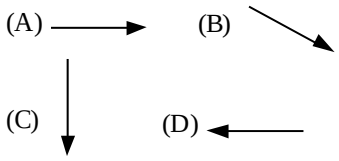
Problem: Projectile (CM-1993)

Questions 27-



A ball is thrown and follows a parabolic path, as shown above. Air friction is negligible. Point Q is the highest point on the path.

27. Which of the following best indicates the direction of the acceleration, if any, of the ball at point Q ?



(E) There is no acceleration of the ball at point Q.

Justify your answer:

Problem: Projectile (CM-1988)

10. A projectile is fired from the surface of the Earth with a speed of 200 meters per second at an angle of 30° above the horizontal. If the ground is level, what is the maximum height reached by the projectile?

(A) 5 m (B) 10 m (C) 500 m
(D) 1,000 m (E) 2,000 m

Show your work:

<u>Justify your answer:</u>

<u>Relative Motion</u>
Usually requires vector addition.
You may make any observer the "stationary" observer.

Problem: Relative Motion (CM-1993)

3. At a particular instant, a stationary observer on the ground sees a package falling with speed v_1 at an angle to the vertical. To a pilot flying horizontally at constant speed relative to the ground, the package appears to be falling vertically with a speed v_2 at that instant. What is the speed of the pilot relative to the ground?

(A) $v_1 + v_2$ (B) $v_1 - v_2$ (C) $v_2 - v_1$
(D) $\sqrt{v_1^2 - v_2^2}$ (E) $\sqrt{v_1^2 + v_2^2}$

Show your work:

Problem: Relative Motion (CM-1988)

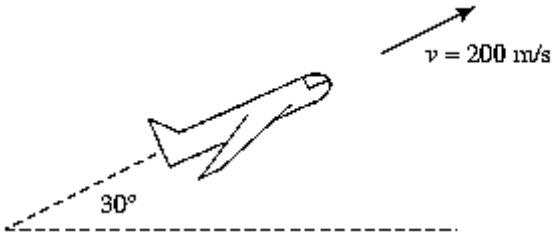
6. Two people are in a boat that is capable of a maximum speed of 5 kilometers per hour in still water, and wish to cross a river 1 kilometer wide to a point directly across from their starting point. If the speed of the water in the river is 5 kilometers per hour, how much time is required for the crossing?

(A) 0.05 hr (B) 0.1 hr (C) 1 hr (D) 10 hr
(E) The point directly across from the starting point cannot be reached under these conditions.

Show your work:

FREE RESPONSE 1

An airplane attempts to drop a bomb on a target. When the bomb is released, the plane is flying upward at an angle of 30° above the horizontal at a speed of 200 m/s, as shown below. At the point of release, the plane's altitude is 2.0 km. The bomb hits the target.



a. Determine the magnitude and direction of the vertical component of the bomb's velocity at the point of release.
b. Determine the magnitude and direction of the horizontal component of the bomb's velocity at the point when the bomb contacts the target.
c. Determine how much time it takes for the bomb to hit the target after it is released.
d. At the point of release, what angle below the horizontal does the pilot have to look in order to see the target?

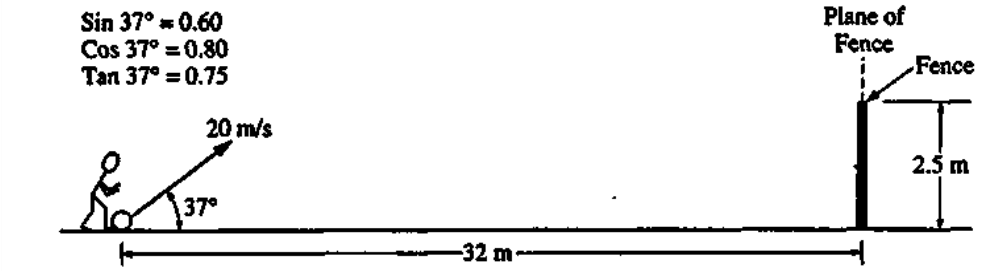
FREE RESPONSE 2

A projectile is launched from the top of a cliff. The cliff is 30 m high, and the projectile is launched from the cliff in the direction of the level plane below. At launch, the projectile has a velocity of 35m/s at an angle 30° above the horizontal. Air resistance is negligible.

a. Draw a representation of the trajectory of the projectile.
b. Calculate the total time from launch until the projectile hits the ground.
c. Calculate the horizontal distance that the projectile travels before it hits the ground
d. Calculate the speed at points A, B, and C, where A is maximum height, B is point at which projectile returns to its original height, and C is just before impact.

FREE RESPONSE 3. 1994 AP Test.

A ball of mass 0.5 kilogram, initially at rest, is kicked directly toward a fence from a point 32 meters away, as shown below. The velocity of the ball as it leaves the kicker's foot is 20 meters per second at an angle of 37° above the horizontal. The top of the fence is 2.5 meters high. The kicker's foot is in contact with the ball for 0.05 second. The ball hits nothing while in flight and air resistance is negligible.



Note: Diagram not drawn to scale.

a. Determine the time it takes for the ball to reach the plane of the fence.
b. Will the ball hit the fence? If so, how far below the top of the fence will it hit? If not, how far above the top of the fence will it pass?
c. On the set of axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.