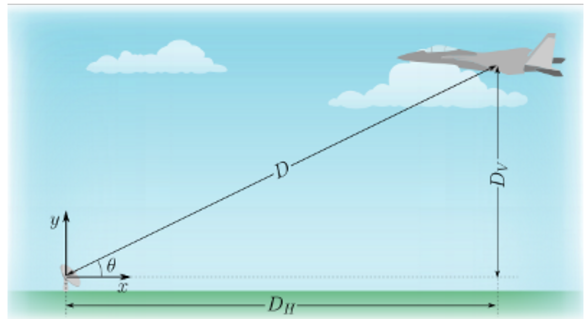
Problem 1: A plane flies towards a ground-based radar dish. Radar locates the plane at a distance $D = 25.3$ km from the dish, at an angle $\theta = 42.7°$ above horizontal.



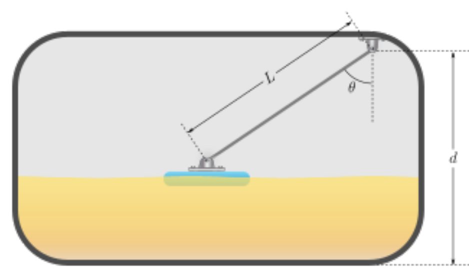
Part (a) What is the plane's horizontal distance, in meters, from the radar dish?
Numeric : A numeric value is expected and not an expression.
D_H = ____ m

Part (b) What is the plane's vertical distance, in meters, above the radar dish?
Numeric : A numeric value is expected and not an expression.
D_V = ____ m

Part (c) Write an expression for the position vector, $\vec{D}$, in rectangular Cartesian unit-vector form using the coordinate axes provided in the drawing in the problem statement.
Expression :
$\vec{D}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), γ, π, θ, i, j, D, g, m, n

Problem 2: The fuel tank on a car has a depth $d = 0.432$ m. The fuel level in the tank is detected by a sensor at the end of an arm with length $L = 0.703$ m. The arm is free to rotate about a pivot at an upper corner of the fuel tank. The angle between the arm and the vertical is θ, as indicated in the drawing.



Part (a) Derive an expression for the sensor height, h, above the horizontal tank bottom as a function of L, d and θ.
Expression :
h = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), tan(θ), α, β, d, g, h, L, m, t

Part (b) Use logic to deduce the value, in degrees, of the angle θ when the fuel tank is full. No computation is required.
Numeric : A numeric value is expected and not an expression.
θ_{full} = ____ °

Part (c) Calculate the angle, in degrees, associated with a half-full fuel tank.

Numeric : A numeric value is expected and not an expression.
θ_{half} = ____ $^\circ$

Part (d) Note that the arm is longer than the tank is deep, $L > d$. What angle, in degrees, is associated with an empty fuel tank?
Numeric : A numeric value is expected and not an expression.
θ_{empty} = ____ $^\circ$

Problem 3: The time-dependent position of a particle is given by

$$\vec{r} = (5.0\ \mathrm{m/s^2})t^2\ \hat{\imath} + (4.0\ \mathrm{m/s^2})t^2\ \hat{\jmath}$$

Part (a) What is the magnitude, in meters, of the particle's distance from the origin at $t = 0.0$ s?
Numeric : A numeric value is expected and not an expression.
$d(0.0\ \mathrm{s})$ = ____ m

Part (b) What is the magnitude, in meters, of the particle's distance from the origin at $t = 2.0$ s?
Numeric : A numeric value is expected and not an expression.
$d(2.0\ \mathrm{s})$ = ____ m

Part (c) Provide an expression in Cartesian unit-vector notation for the velocity vector of the particle. Do not include the units, but assume that units of length are meters, and units of time are meters.
Expression :
$\vec{v}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
î, ĵ, k̂, t

Part (d) What is the speed, in meters per second, of the particle when $t = 0.0$ s?
Numeric : A numeric value is expected and not an expression.
$v(0.0\ \mathrm{s})$ = ____ m/s

Part (e) What is the speed, in meters per second, of the particle when $t = 2.0$ s?
Numeric : A numeric value is expected and not an expression.
v(2.0 s = ____ m/s

Problem 4: A particle has a constant acceleration given by

$$\vec{a} = a_x\ \hat{\imath} + a_y\ \hat{\jmath}$$

and initially, at $t = 0$, the particle is at rest at the origin.

Part (a) What is the particle's position in Cartesian unit-vector notation as a function of time?
Expression :
$\vec{r}(t)$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
î, ĵ, a_x, a_y, k̂, t

Part (b) What is the particle's velocity in Cartesian unit-vector notation as a function of time?
Expression :
$\vec{v}(t)$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
î, ĵ, a_x, a_y, k̂, t

Part (c) What is the particle's path, expressing the y coordinate as a function of x? Your expression will be independent of time.
Expression :
$y(x)$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
î, ĵ, a_x, a_y, k̂, x

Problem 5: Taking north to be the positive y direction and east to be the positive x direction, a particle's position is given by

$$r(t) = \left(31.7\ \mathrm{m/s}\right)t\,\hat{i} + \left(6.79\ \mathrm{m/s^2}\right)t^2\,\hat{j}$$

Part (a) In what direction is the particle traveling at $t = 0.0$ s?
MultipleChoice :

1) east
2) north
3) west
4) south

Part (b) At what time, in seconds, is the particle traveling *exactly* northeast?
Numeric : A numeric value is expected and not an expression.
t = ____ s

Problem 6: An airplane starts at rest and accelerates at *6.7* m/s^2 at an angle of *31*° south of west.

Part (a) After *9* s, how far, in meters, in the westerly direction has the airplane traveled?
Numeric : A numeric value is expected and not an expression.
x_{west} = ____ m

Part (b) After *9* s, how far, in meters, in the southerly direction has the airplane traveled?
Numeric : A numeric value is expected and not an expression.
y = ____ m

Problem 7: A boat leaves the dock at $t = 0.00$ s, and, starting from rest, maintains a constant acceleration of $(0.477\ \mathrm{m/s^2})\ \hat{\imath}$ relative to the water. Due to currents, however, the water itself is moving with a velocity of $(0.408\ \mathrm{m/s})\ \hat{\imath} + (2.43\ \mathrm{m/s})\ \hat{\jmath}$.

Part (a) How fast, in meters per second, is the boat moving at $t = 5.81$ s?
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Part (b) How far, in meters, is the boat from the dock at $t = 5.81$ s?
Numeric : A numeric value is expected and not an expression.
r = ____ m

Problem 8: A spaceship is traveling at a velocity of

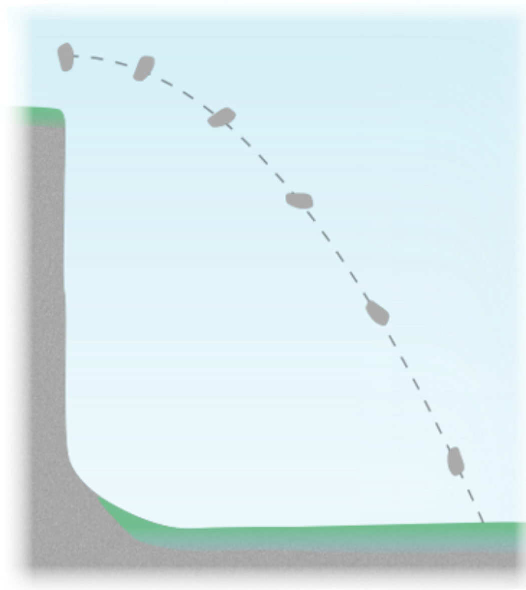
$$\vec{v}_0 = (21.9\ \mathrm{m/s})\ \hat{\imath}$$

when its rockets fire, giving it an acceleration of

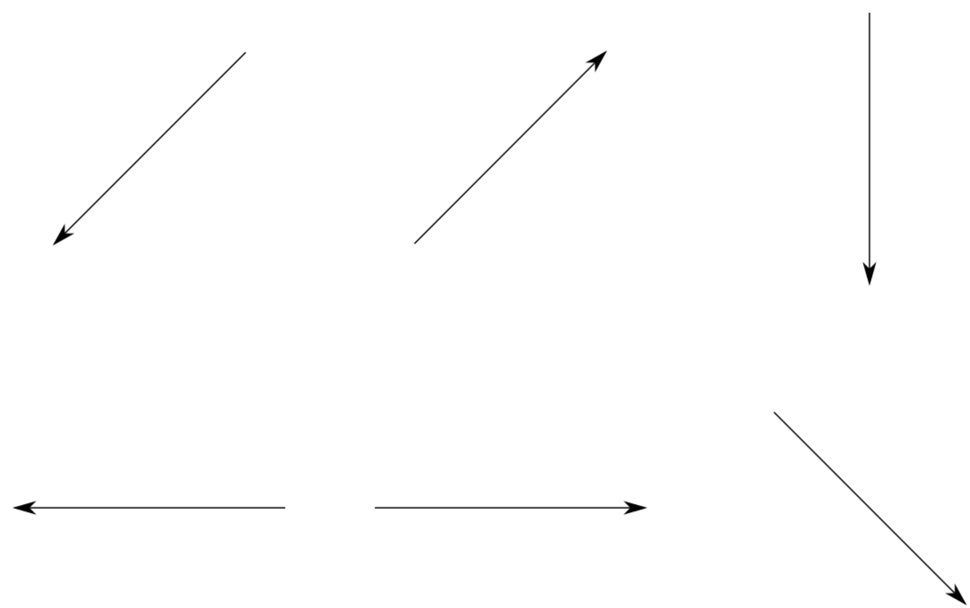
$$\vec{a} = (2.42\ \mathrm{m/s^2})\ \hat{\imath} + (5.45\ \mathrm{m/s^2})\ \hat{\jmath}$$

How fast, in meters per second, is the rocket moving 3.79 s after the rockets fire?
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Problem 9: A stone is thrown off of a cliff with an initial velocity that is horizontal. There is no air resistance, and it follows the path shown which is typical for projectile motion.



What direction is the acceleration of the stone?
SchematicChoice :



Problem 10: A projectile is launched from ground level at an angle of 30 degrees above the horizontal. Neglect air resistance and consider the motion from just after the moment it is launched to just before the moment it lands on the ground.

Part (a) When is the projectile's velocity equal to zero?
MultipleChoice :

1) At the highest point.
2) The projectile's velocity is never zero.
3) Just after launch.
4) Halfway to the highest point.
5) Just before landing on the ground.
6) Halfway back down to the ground.

Part (b) When does the projectile have the smallest speed?
MultipleChoice :

1) Halfway to the highest point.
2) The projectile's speed is constant.
3) At the highest point.
4) Just after launch.
5) Just before landing on the ground.
6) Halfway back down to the ground.

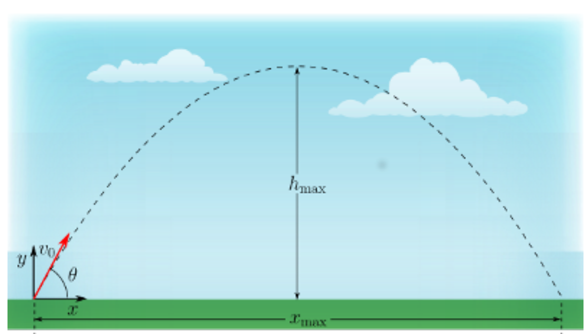
Part (c) When does the projectile's speed equal its launch speed?
MultipleChoice :

1) The projectile's speed is always equal to its launch speed.
2) Halfway back to the ground.
3) Halfway to the highest point.
4) At the highest point.
5) The projectile's speed is never equal to its launch speed.
6) Just before landing on the ground.

Part (d) After launch, when does the projectile's velocity equal its launch velocity?
MultipleChoice :

1) Just before landing on the ground.
2) Halfway to the highest point.
3) The projectile's velocity is always equal to its launch velocity.
4) The projectile's velocity is never equal to its launch velocity after launch.
5) At the highest point.
6) Halfway back to the ground.

Problem 11: During a baseball game, a baseball is struck, at ground level, by a batter. The ball leaves the baseball bat with an initial speed $v_0 = 46.7$ m/s at an angle $\theta = 36.5°$ above the horizontal. Let the origin of the Cartesian coordinate system be the ball's position the instant it leaves the bat. Ignore air resistance throughout this problem.



Part (a) Express the magnitude of the ball's initial horizontal velocity component, $v_{0,x}$, in terms of v_0 and θ.
Expression :
$v_{0,x}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), α, β, θ, d, g, h, m, t, v_0

Part (b) Express the magnitude of the ball's initial vertical velocity component, $v_{0,y}$, in terms of v_0 and θ.
Expression :
$v_{0,y}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), α, β, θ, d, g, h, m, t, v_0

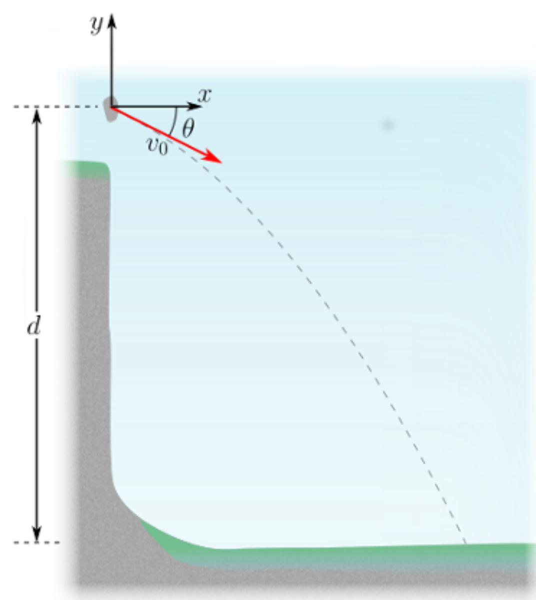
Part (c) Find the ball's maximum vertical height, h_{max}, in meters, above the ground.
Numeric : A numeric value is expected and not an expression.
h_{max} = ____ m

Part (d) Enter an expression in terms of v_0, θ, and g for the time it takes the ball to travel to its maximum vertical height.
Expression :
t_{apex} = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), α, β, θ, d, g, h, m, t, v_0

Part (e) Calculate the horizontal distance, x_{max}, in meters, that the ball has traveled when it returns to ground level.
Numeric : A numeric value is expected and not an expression.
x_{max} = ____ m

Problem 12: A student standing on a cliff throws a stone from a vertical height of $d = 8.0$ m above the level ground with velocity $v_0 = 25$ m/s at an angle $\theta = 29°$ *below* the horizontal, as shown. It moves without air resistance. Use a Cartesian coordinate system with the origin at the initial position of the stone.



Part (a) With what speed, in meters per second, does the stone strike the ground?
Numeric : A numeric value is expected and not an expression.
v_f = ____ m/s

Part (b) If the stone had been thrown from the clifftop with the same initial speed and the same angle, but *above* the horizontal, would its impact velocity be different?
MultipleChoice :

1) no

2) yes

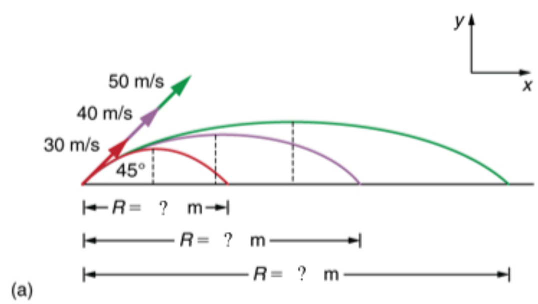
Problem 13: A quarterback can run with a speed of v_q = 15 miles per hour. He throws the football with a speed v_{ball} = 35 miles per hour at an unknown angle θ that is between 40 and 70 degrees, measured relative to horizontal plane. Neglect air resistance.

Part (a) Is it possible for him to catch his own pass?
MultipleChoice :

1) Yes
2) No

Part (b) In this part we'll assume the quarterback stops and throws the ball just as a receiver runs past just beside him running at 15 miles per hour. If the quarterback releases his pass at that instant, what would be the angle in degrees be that he would have to throw the ball for the receiver to catch it?
Numeric : A numeric value is expected and not an expression.
θ = ____ °

Problem 14: Find the ranges for the projectiles shown in the figure at an elevation angle of 45° and the given initial speeds.



Part (a) Find the range, in meters, for the projectile with a speed of 30 m/s.
Numeric : A numeric value is expected and not an expression.
R = ____

Part (b) Find the range, in meters, for the projectile with a speed of 40 m/s.
Numeric : A numeric value is expected and not an expression.
R = ____

Part (c) Find the range, in meters, for the projectile with a speed of 50 m/s.
Numeric : A numeric value is expected and not an expression.
R = ____

Problem 15:
Great Problems in Physics Series

Dr. Jennifer Carter is an assistant professor at Susquehanna University where she teaches both astronomy and physics courses. Her main research interests are in astrophysics and data analysis. Currently her focus is on exoplanet research, in which she is using Bayesian data analysis techniques to test current models of reflected light and thermal emissions of exoplanets against novel models she is developing.

I chose this problem because many students struggle with the quadratic and symmetric nature of projectile motion. In particular, they may struggle in choosing which of the two possible solutions applies to a given situation. This problem will require students to use the context of the problem statement to determine which of two possible solutions to choose, but what makes this problem unique compared to many other problems is that there will be two positive solutions to the amount of time that has passed; therefore, students cannot rely on eliminating the negative time as being physically unreasonable and must instead carefully consider the context of the problem

Read more about Dr. Carter and her research here.

View Dr. Carter's LinkedIn profile here.

Some children are practicing baseball and accidentally throw a ball onto the roof of one of their houses. Suppose that the baseball was thrown at an angle of ***57***° above the horizontal at a speed of ***22*** m/s. The ball rises to its maximum height before falling onto the roof of the house ***3.9*** m above the level at which it was thrown.

Part (a) Determine the total amount of time, in seconds, the baseball spends in the air.
Numeric : A numeric value is expected and not an expression.
t = ____ s

Part (b) Calculate the horizontal distance, in meters, between the baseball's launch point and its landing point.
Numeric : A numeric value is expected and not an expression.
x = ____ m

Problem 16: You are the passenger in a car with your friend, who is driving. At one point in the journey, the your friend is following a curve on the highway. Concerned for your safety, you ask your friend how fast they are going.

Your friend responds, "I am going around this curve at a constant velocity of 55 mph." Is their statement physically correct?
MultipleChoice :

1) Yes, this statement is acceptable.
2) No, cars always slow down as they go around corners.
3) It might make sense, depending on extra information which is not being given in the problem?
4) No, the word "velocity" is being used incorrectly.

Problem 17: A particle is traveling along a circular path.

Part (a) Which of the following is associated with a change in the speed of the particle?
MultipleChoice :

1) Centripetal acceleration
2) Tangential acceleration
3) Both centripetal and tangential acceleration will change the speed.

Part (b) Which of the following is associated with a change in the velocity of the particle?
MultipleChoice :

1) Centripetal acceleration
2) Both centripetal and tangential acceleration will change the velocity.
3) Tangential acceleration

Problem 18: A particle travels in a circular path of radius ***11.9*** m at a constant speed of ***26.7*** m/s.

What is the magnitude of the acceleration of the particle in m/s^2?
Numeric : A numeric value is expected and not an expression.
a_c = ____

Problem 19: A propeller blade, measured from the rotational axis to the tip, has a length of 2.51 m. Starting from rest, the tip of the blade has a tangential acceleration of 2.97 m/s^2.

What is the magnitude of the total acceleration of the tip of the blade, in meters per squared second, 0.98 s after the blade begin to rotate?
Numeric : A numeric value is expected and not an expression.
a = ____ m/s^2

Problem 20: A race car entering the curved part of the track drops its speed from ***48*** m/s to ***36.3*** m/ s in ***2.75*** s.

If the radius of the curved part of the track is ***294*** m, calculate the magnitude of the total acceleration, in m/s^2, of the race car just after it has begun to reduce its speed.
Numeric : A numeric value is expected and not an expression.
a = ____