DEPED - GENERAL SANTOS CITY
SIMPLIFIED
SELF-LEARNING MODULE
(S S L M)

GENSAN's ProTUNA
General Santos City's Pro-Active Response in Turbulent, Uncertain, New and Ambiguous Environment

GENERAL PHYSICS 1 – GRADE 12 STEM

Name: ____________________ Date: ____________

Grade: ____________________ Section: ____________

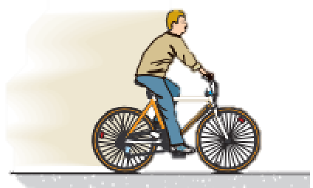
Quarter: _1_ **Week:** _3_ **SSLM No.** _3_ **MELC(s):** Describe motion using the concept of relative velocities in 1D and 2D **(STEM_GP12KIN-Ic20).** Deduce the consequences of the independence of vertical and horizontal components of projectile motion **(STEM_GP12KIN-Ic22).** Calculate range, time of flight, and maximum heights of projectiles **(STEM_GP12KIN-Ic23).** Infer quantities associated with circular motion such as tangential velocity, centripetal acceleration, tangential acceleration, radius of Curvature **(STEM_GP12KIN-Ic25).** Solve problems involving two dimensional motion in contexts such as, but not limited to ledge jumping, movie stunts, basketball, safe locations during firework displays, and Ferris wheels **(STEM_GP12KIN-Ic26).**

- **Objectives:**
  - Describe motion using the concept of relative velocities in 1D and 2D.
  - Deduce the consequences of the independence of vertical and horizontal components of projectile motion.
  - Calculate range, time of flight, and maximum heights of projectiles.
  - Infer quantities associated with circular motion such as tangential velocity, centripetal acceleration, tangential acceleration, radius of Curvature.
  - Solve problems involving two dimensional motion in contexts such as, but not limited to ledge jumping, movie stunts, basketball, safe locations during firework displays, and Ferris wheels.
- **Title of Textbook/LM to Study**: You and the Natural World – Physics 3rd Ed.
- Chapter: _4_ Pages: _62-_ Topic: Kinematics

Let Us Discover

RELATIVE MOTION

Speed, v is a scalar quantity that represents the rate at which an object moves. For instance, imagine a cyclist moving on a straight road, we can compute his speed by dividing the distance he has travelled by the time it took him to reach that distance, also called elapsed time. In equation, $\vec{v} = d/t$



To discuss relative motion in one or more dimensions, we first introduce the concept of reference frames. When we say an object has a certain velocity, we must state it has a velocity with respect to a given reference frame. If you say a person is sitting in a bus moving at 10 m/s east, then you imply the person on the bus is moving relative to the surface of the Earth at this velocity, making Earth as the reference frame.

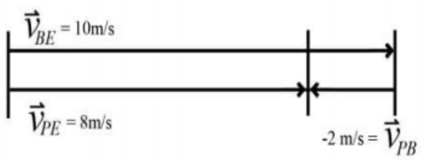
Example #1: Relative Motion in 1D

The person is sitting in a bus moving east. If we choose east as the positive direction and the Earth as the reference frame, then we can write the velocity of the bus with respect to the Earth v⃗ BE = 10m/s î east, where the subscript BE refer to the bus and earth. Let's now say the person gets up out of his seat and walks toward the back of the bus at 2 m/s. This tells us he has a velocity relative to the reference frame of the bus. Since the person walking west, in the negative direction, we write the velocity with respect to the bus as v⃗ PB = -2m/s î west. We can add the two velocity vectors to find velocity of the person with respect to Earth. This relative velocity is written as

$$\overrightarrow{v_{PE}} = \overrightarrow{v_{PB}} + \overrightarrow{v_{BE}}$$

Given: $\overrightarrow{v_{BE}} = 10\frac{m}{s}\hat{\imath}\ E$ $\qquad = \left(-2\frac{m}{s}\right) + \left(10\frac{m}{s}\right)$

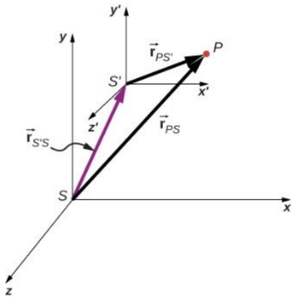
$\overrightarrow{v_{PB}} = -2\frac{m}{s}\hat{\imath}\ W$ $\qquad = 8\frac{m}{s}\hat{\imath}$



Therefore, the person is moving 8 m/s east with respect to Earth.

Relative Motion in 2D

Consider a particle P S is and reference frames $r_{PS'}$ S and S',as shown in is the figure.



The position of origin of S' as measured in $r_{S'S}$, the position P as measured in S' is and the position of P as measured in S r_{PS}.

$$\mathbf{r_{PS} = r_{PS} + r_{S'S}}$$

The relative velocities are $\overrightarrow{v_{PS}} = \overrightarrow{v_{PS'}} + \overrightarrow{v_{S'S'}}$

Example #2: Relative Motion in 2D

A truck is travelling south at a speed of 70 km/hr toward an intersection. A car is traveling east toward the intersection at a speed of 80 km/hr. What is the velocity of the car relative to the truck?

Solution:

$$\vec{v}_{CT} = \vec{v}_{CE} + \vec{v}_{ET}\ , \quad \text{where } \vec{v}_{ET} = -\vec{v}_{TE}$$

$$\vec{v}^2{}_{CT} = \vec{v}^2{}_{CE} + \vec{v}^2{}_{ET}$$

$$|\vec{v}_{CT}| = \sqrt{\left(80.0\frac{km}{hr}\right)^2 + \left(70.0\frac{km}{hr}\right)^2}$$

$$= \sqrt{\left(6400\frac{km^2}{hr^2}\right) + \left(4900\frac{km^2}{hr^2}\right)}$$

$$= \sqrt{11300\ \frac{km^2}{hr^2}}$$

$$= 106.3\ \frac{km}{hr}$$

and

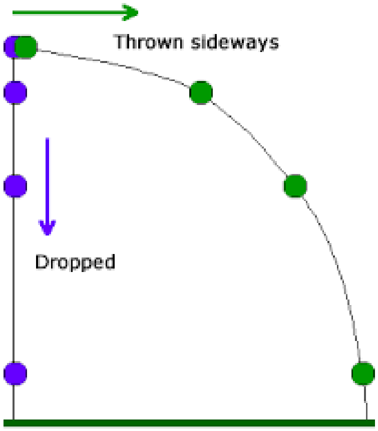
$$\theta = \tan^{-1}(\vec{v}_{ET}/\vec{v}_{CE})$$

$$\theta = \tan^{-1}(70.0/80.0)$$

$$= 41.2°N\ of\ E$$

PROJECTILE MOTION

In a laboratory experiment, a ball was projected in a horizontal direction at the same time a second ball was released to fall freely from the same height. It was found that the balls reached the floor at the same time. This was based on the fact that a single sound was heard as they struck the floor. This result suggests that the vertical motion of the projected ball is not affected by its horizontal motion. Therefore, projectile motion is a combination of vertical and horizontal motions that are completely independent to each other.



Horizontal (x) component

The horizontal component of the velocity of an object along the horizontal is constant or the same anywhere on the trajectory which means that there is no acceleration. The first two kinematic equations should be written as;

$$v_{fx} = v_{ix} = v_x = v\cos\theta$$
$$x = v_x t$$

where; v_{fx} is the final horizontal velocity
v_{ix} is the initial horizontal velocity
v_x is the horizontal velocity

Where θ is the angle from the horizontal. This also assumes that the initial position is zero.

Vertical (y) component

Projectile motion, when viewed along a vertical, accelerates at a rate of –g. Note also that when a projectile reaches its maximum height, the velocity along the vertical is zero. From this assumption, you can write the first two kinematic equations as;

$$v_y = v\sin\theta$$
$$v_{ymax} = 0 \ at \ y_{max}$$
$$v_{yf} = v_{yi} - gt$$
$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$$

where; v_y is the vertical velocity
v_{ymax} is the maximum vertical velocity
v_{yf} is the final vertical velocity
v_{yi} is the initial vertical velocity
g is the acceleration due to gravity
t is the time
y_f is the final vertical displacement
y_i is the initial vertical displacement

Time of flight, t the entire duration while the projectile is at its trajectory;
Range, R is the horizontal distance covers by a projectile;
Maximum height, y_{max} is the maximum vertical displacement travelled by the projectile

$$v_{yi} = gt \qquad R = v_x\left(2\frac{v_{yi}}{g}\right)$$

$$t = \frac{v_{yi}}{g} \qquad R = \frac{v^2\sin 2\theta}{g}$$

Example #3

A bullet is fired from gun mounted at an angle of 30º. If the muzzle velocity is 400 m/s. Calculate:

a. Vertical velocity component
b. Horizontal velocity component
c. Maximum height reach
d. Time of flight
e. Range

Given: θ = 30º
v_i = 400 m/s

Solution:

a) Vertical velocity component

$$v_y = v_i \sin\theta$$

= (400m/s) (sin 30º)

= 200 m/s

b) Horizontal velocity component

$$v_x = v_i \cos\theta$$

= (400m/s) (cos 30º)

= 346.4 m/s

c) Maximum Height, v_{ymax}

$$v_{ymax} = \frac{v_{y^2}}{2g} = \frac{(200m/s)^2}{2(9.8\,m/s^2)} = 2040.82m$$

d) Total time of flight, t_T

$$t_T = \frac{2\,(v_y)}{g}$$

$$= \frac{2\,(200m/s)}{9.8m/s^2}$$

= 40.82 s

e) Range or Horizontal distance, R

$$R = \frac{v^2 \sin 2\theta}{g}$$

$$= \frac{(400\frac{m}{s})^2 \sin 60°}{9.8m/s^2}$$

$$= \frac{138{,}560\frac{m^2}{s^2}}{9.8m/s^2}$$

= 14,138.78m

CIRCULAR MOTION

Tangential velocity, $\overrightarrow{v_t}$ is the linear speed of any object moving along a circular path. The equation used to compute is:

$$\overrightarrow{v_t} = \frac{2\pi r}{T}$$

Centripetal acceleration, $\overrightarrow{a_c}$ is a property of the motion of a body traversing a circular path. It can be computed using:

$$\overrightarrow{a_c} = \frac{v^2}{r}\ or\ \overrightarrow{a_c} = rw^2$$

Tangential acceleration, $\overrightarrow{a_t}$ is a measure of how quickly a tangential velocity changes. It always acts perpendicular to the centripetal acceleration of a rotating object. To compute for tangential acceleration, the formula for centripetal acceleration will be used.

$$\overrightarrow{a_t} = \frac{v^2}{r}\,or\,\overrightarrow{a_t} = rw^2$$

Radius of curvature is the reciprocal of the curvature. For a curve, it equals the radius of the circular arc which best approximate the curve at that point.

It was observed that as the radius increases, the tangential velocity and centripetal acceleration also increase, while the period decreases. Hence, radius is inversely proportional to period and directly proportional to tangential velocity and centripetal acceleration.

Example #4: Acceleration of a revolving ball.

A 150-g ball at the end of a string is revolving uniformly on a horizontal circle of radius 0.600m. The ball makes 2.00 revolutions in a second. What is its centripetal acceleration?

Given: $r = 0.600\ m$

Find:

Period: $T = \frac{1}{frequency\ (f)} = \frac{1}{2.00\ revolutions} = 0.500\ s$

$a_r = ?$

Solution:

Determine, first, the speed of the ball. $v = \frac{2\pi r}{T} = \frac{2\ (3.14)\ (0.600\ m)}{(0.500\ s)} = 7.54\ m/s$

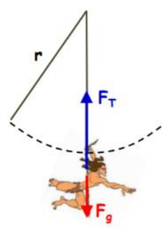
The centripetal acceleration is $a_r = \frac{v^2}{r} = \frac{(7.54\ m/s)^2}{(0.600\ m)} = 94.8\ m/s^2$

Let Us Try

1) A cannon ball on the ground is fired at 35° with an initial velocity of 250 m/s. (a) how long will it take to hit the ground? (b) How far from the cannon ball will it hit the ground? (c) Compute for maximum height to be reached by the cannon ball.
2) An arrow is launched at a velocity of 20 m/s in a direction making an angle of 25° upward with the horizontal. (a) How long will it take to hit the ground? (b) How far from the cannon ball will it hit the ground? (c) Compute for maximum height to be reached by the cannon ball.

Let Us Do

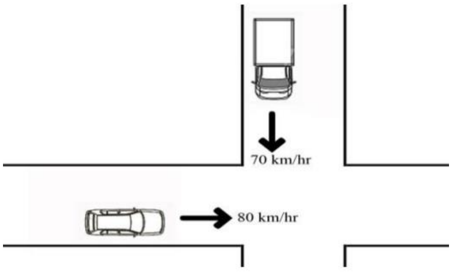
1) Tarzan (m = 85 kg) tries to cross a river by swinging from a 10-m-long vine. His speed at the bottom of the swing (as he just clears the water) is 8.0 m/s. Tarzan doesn’t know that the vine has a breaking strength of 1000 N. Does he make it safely across the river? Justify your answer



2) A swimmer heads directly across a river swimming at 1.6 m/s relative to still water. She arrives at a point 40 m downstream from the point directly across the river, which is 80 m wide. Determine: (a) the speed of the current (b) the magnitude of the swimmer's resultant velocity (c) the direction of the swimmer's resultant velocity (d) the time it takes the swimmer to cross the river.

Let Us Apply

(1) Study the illustration below and perform the given task.



a) What is the direction of the car relative to the truck?
b) What is the direction of the truck relative to the car?
c) Do you think the car and the truck will meet at common point? Explain your answer.
d) Plot a vector diagram of the motion of the two vehicles and label it.

(2) Meldrick is playing foot jump. The ball in his foot jump is in uniform circular motion and makes 10 revolutions in 4.0 seconds.

a) What is its period?
b) If the length of the plastic cord that holds the ball is 0.8 meter, what is its tangential velocity?
c) If the ball has a mass of 3 grams, how much force is acting the ball to keep it in uniform circular motion?
d) What is the centripetal acceleration of the ball?

References

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