Gravitation

Improve your learning

Q. 1. What path will the moon take when the gravitational interaction between the moon and earth disappears?

Answer : Since the moon is in uniform circular motion with earth as the center. Therefore, when the gravitational interaction between the moon and the earth disappears the centripetal force due to which moon is revolving around the earth will become zero and it moves tangentially to the position it was present. Actually, gravitational force doesn't disappear, so these worries are useless.

Q. 2. A car moves with constant speed of 10 m/s in a circular path of radius 10m. The mass of the car is 1000 kg. Who or what is providing the required centripetal force for the car? How much is it?

Answer : The required centripetal force is provided by the normal reaction of the ground.

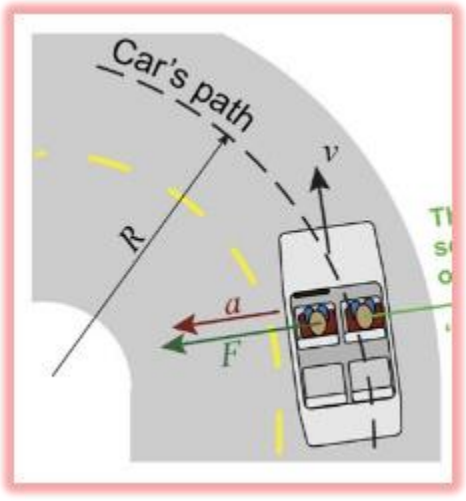
Now, according to the question;

Radius of circular path (r) = 10 m.

Mass of the car (m) = 1000 Kg.

Speed of the car (v) = 10 m/s.

The figure below describes the situation.



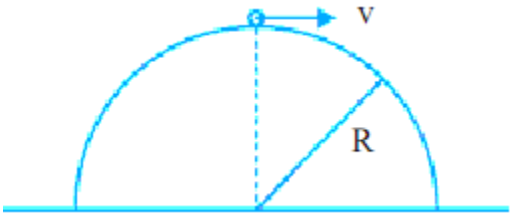
The required centripetal force is $F = \frac{mv^2}{r}$

$\Rightarrow F = \frac{1000 \times 10^2}{10}$ N

$\Rightarrow F = \frac{1000 \times 100}{10} = 10000$ N

The centripetal force required for the car is 10^4 N .

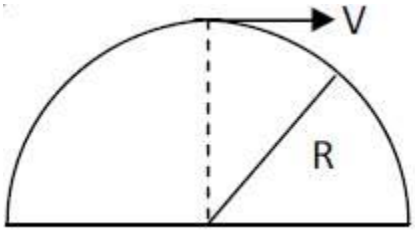
Q. 3. A small metal washer is placed on the top of a hemisphere of radius R. What minimum horizontal velocity should be imparted to the washer to detach it from the hemisphere at the initial point of motion? (See figure)



Answer : Given;

The radius of hemisphere = R.

The velocity of washer = V.



The centripetal force act on the washer is

$F = \frac{mv^2}{R}$ ..... (1)

Let the mass of washer is “m”

And acceleration by gravity is “g”

The force by hemisphere on the washer is

F = mg ……. (2)

By Newton’s law of motion every action has an equal reaction but in opposite direction.

∴ Centripetal force on washer = Force by hemisphere on the washer.

From (1) and (2).

$\frac{mv^2}{R}$ = mg;

⇒ v^2 = gR

⇒ v = $\sqrt{gR}$

Hence minimum horizontal velocity should be imparted to the washer to detach it from the hemisphere at the initial point of motion is $\sqrt{gR}$

Q. 4. Explain why a long pole is more beneficial to the tight rope walker if the pole has slight bending.

Answer : Carrying a pole helps the walker increase their rotational inertia (a measure of an object’s opposition/resistance to change in its direction of rotation), which aids in maintaining stability while walking over the narrow rope.

The pole also adds more weight below the center of gravity of the walker, which is another bonus for maintaining balance. By adjusting the place of the pole, one can balance easily their body and can walk on the rope. Finally, the line of the weight of total system must pass through a vertical line drawn to the rope.

The Figure below depicts the rope walker carrying the pole on tight rope.

Q. 5. Why is it easier to carry the same amount of water in two buckets, one in each hand rather than in a single bucket?

Answer : In both cases, you have the same amount of force in the vertical direction, but when we have a single bucket in hand there is a lot of force in the horizontal direction. With one bucket you are constantly leaning in the other direction so that the downward force is exerting directly on your center of gravity. Holding two buckets of water in each hand does not change the center of gravity of the person. But if the person holds a

bucket with the same quantity of water only in one hand, then the center of gravity moves towards the bucket (mass). Change in center of gravity causes instability of body as the gravitational force acts on it. So we feel hard to hold the bucket.

Q. 6. What is the speed of an apple dropped from a tree after 1.5 seconds? What distance will it cover during this time? Take g = 10m/s^2

Answer : Since Apple dropped from a tree.

∴ Initial speed (u) = 0 m/s

Given in question;

Time (t) = 1.5 s

Acceleration due to gravity (g) = 10 m/s^2

Now;

By Newton's equation of motion

V = u + at.

Here a = g = 10 m/s$^{2.}$

T = 1.5 s;

U = 0 m/s

⇒ Final speed (v) = u + gt.

⇒ v = 0 + 10 x 1.5.

⇒ v = 15 m/s

Hence the speed of an apple dropped from a tree after 1.5 second is 15 m/s

By Newton's equation of motion

$$S = ut + \frac{at^2}{2}$$

Here a = g = 10 m/s^2.

T = 1.5 s;

U = 0 m/s

$$\text{Distance (S)} = ut + \frac{gt^2}{2}$$

$$\Rightarrow s = 0 \times 1.5 + 10 \times \frac{1.5^2}{2}$$

$$\Rightarrow s = 0 + \frac{10 \times 2.25}{2}$$

$$\Rightarrow s = \frac{22.5}{2} = 11.25 \text{ m.}$$

Hence distance covered by an apple is 11.25 m.

Q. 7. A body is projected with a speed of 40 m/s vertically up from the ground. What is the maximum height reached by the body? What is the entire time of motion? What is the velocity at 5 seconds after the projection? Take g = 10m/s^2

Answer : A body is projected vertically up.

∴ According to the question;

The initial speed (u) = 40 m/s

Acceleration due to gravity (g) = 10 m/s^2.

From Newton's third equation of motion;

$V^2 = u^2 + 2as$;

In our question;

V = 0 (Velocity at maximum height is zero);

U = 40 m/s.

A = -g = -10 m/s^2. (When object will be going up the acceleration due to gravity will be acting downwards to make an object to fall. Hence by sign convention direction of motion and acceleration is opposite therefore a is negative)

S = Maximum Height (H).

Putting the values in the equation we get.

$0^2 = 40^2 – 2 \times 10 \times H$.

$\Rightarrow 0 = 1600 – 20H$.

$\Rightarrow 1600 = 20H$.

$\Rightarrow H = \frac{1600}{20} = 80\ m$.

Maximum height reached by the body is 80m.

Total time (T) = $\frac{2u}{g}$

$\Rightarrow T = \frac{2 \times 40}{10}$

$\Rightarrow T = \frac{80}{10} = 8\ s$

The entire time of motion is 8 s

Time is taken to reach maximum height = $\frac{\text{Entire time of motion}}{2}$

$= \frac{8}{2} = 4\ s$

Thus it takes 4 sec to reach the maximum height and returns with 0 initial speed.

∴ Speed after 1 sec in return = speed after 5 seconds of throwing the ball.

⇒ Speed (v) = u + at;

∵ u = 0 and t = 1sec; a = 10 m/s^2.

⇒ v = 0 + 10 x 1

⇒ v = 10 m\s.

Speed after 5 sec of throwing of the ball is 10 m/s.

Q. 8. A boy is throwing balls into the air one by one in such a way that when the first ball is thrown reaches maximum height he starts to throw the second ball. He repeats this activity. To what height do the balls rise if he throws twice in a second?

Answer : Since the boy is throwing two balls per second

⇒ He is throwing one ball in half a second.

⇒ Ball takes half second to reach the maximum height.

WE know that time taken to reach maximum height = $\frac{u}{g}$

$$\Rightarrow \frac{1}{2} = \frac{u}{g}$$

$$\Rightarrow \frac{1}{2} = \frac{u}{10}$$

$$\Rightarrow 2u = 10$$

$$\Rightarrow u = \frac{10}{2} = 5$$

Hence initial velocity of ball is 5 m\s.

Also the maximum height (H) = $\frac{u^2}{2g}$

$\Rightarrow H = \frac{5 \times 5}{2 \times 10}$

$\Rightarrow H = \frac{25}{20} = \frac{5}{4}$

$\Rightarrow H = 1.25$ m

Maximum height reached by the ball is 1.25 m

Q. 9. A man is standing against a wall such that his right shoulder and right leg are in contact with the surface of the wall along with his height. Can he raise his left leg at this position without moving his body away from the wall? Why? Explain.

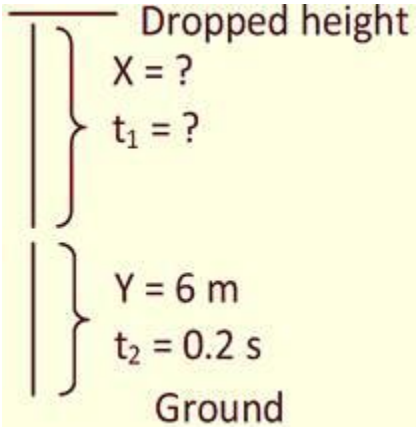
Answer : When the man is standing against the wall such that his right shoulder and right leg are along his height. Then the center of Gravity is nearly at the belly point. In this situation, he can't raise his left leg. Because if he raises the left leg, the center of gravity moves. Then he must move his body parts to maintain the center of gravity. Therefore as he raises his left leg he has to move his other body parts. The figure below depicts this.

Q. 10. A ball is dropped from a height. If it takes 0.2s to cross the last 6m before hitting the ground, find the height from which it is dropped. Take g = 10m/ s^2

Answer : Since ball takes 0.2 s to cross the last 6m before hitting the ground.

∴ Let velocity of the ball after time t_1 = u;

The figure below depicts the situation of the question.



By Newton's second equation of motion;

Distance (S) = $ut + \frac{gt^2}{2}$

Here S = 6m; t = 0.2s; g = 10m/s^2;

$\Rightarrow 6 = 0.2u + \frac{10 \times 0.2^2}{2}$

$\Rightarrow 6 = 0.2u + 5 \times 0.04$

⇒ 6 = 0.2u + 0.2

⇒ 0.2u = 6 – 0.2

⇒ 0.2u = 5.8.

⇒ u = 29 m/s.

Hence final speed (v) of the ball after it traveled ‘X’ distance is 29m/s.

By Newton’s first equation of motion

⇒ v = u + at;

Here v = 29 m/s (final velocity).

u = 0 (Initial velocity is zero);

A = g = 10 m/s^2.

T = t_1 (refer figure above);

Putting the values we get

29 = 0 + 10 t_1;

⇒ $t_1 = \frac{29}{10} = 2.9\ s$

Now finding the distance ‘X’ by newton’s second equation of motion

Distance (S) = $ut + \frac{gt^2}{2}$

Here S = X (refer figure); t = t_1 = 2.9s; g = 10m/s^2; u = 0 (initial velocity);

Putting the values we get;

$X = 0(2.9) + \frac{10 \times 2.9^2}{2}$

⇒ $X = 0 + 5 \times 2.9^2$

⇒ X = 5 x 8.41

⇒ X = 42.05 m

Now;

Total height from which ball was thrown = X + Y = 42.05 + 6

⇒ Total height = 48.05 m;

Q. 11. A ball is dropped from a balloon going up at a speed of 5 m/s. If the balloon was at a height 60 m. at the time of dropping the ball, how long will the ball take to reach the ground?

Answer : According to question it is given;

Speed of balloon = 5m/s (upward)

⇒ Velocity of ball (u) = -5 m/s (because ball will fall downwards)

Height (S) = 60 m

Time to reach ground (t) = ?

By newton's second equation of motion

$$\text{Distance (S)} = ut + \frac{gt^2}{2}$$

$$\Rightarrow 60 = -5t + \frac{10 \times t^2}{2}$$

$$\Rightarrow 60 = -5t + 5t^2.$$

$$\Rightarrow \frac{60}{5} = -t + t^2.$$

$$\Rightarrow 12 = -t + t^2.$$

$$\Rightarrow t^2 - t - 12 = 0;$$

$$\Rightarrow (t - 4)\ (t - 3) = 0;$$

$\Rightarrow t = 4, -3;$

But time can't be negative;

$\therefore t = 4$ s

Hence Time taken by the ball to reach the ground is 4 s

Q. 12. A ball is projected vertically up with a speed of 50 m/s. Find the maximum height, the time to reach the maximum height, and the speed at the maximum height ($g = 10$ m/ s^2)

Answer : Since the ball is projected vertically up.

$\therefore$ The initial speed (u) = 50 m/s

Acceleration due to gravity (g) = 10 m/s^2.

$$\text{Maximum Height (H)} = \frac{u^2}{2g}$$

$$\Rightarrow H = \frac{50 \times 50}{20}$$

⇒ H = 125 m.

Maximum Height is 125 m.

$$\text{Time to reach maximum height } (t_1) = \frac{u}{g}$$

$$\Rightarrow t_1 = \frac{50}{10} = 5s$$

Time to reach maximum height is 5 sec.

Speed at maximum height (V) = 0 m/s.

Q. 13. Two cars having masses m1 and m^2 move in circles of radii r_1 and $r_2$respectively. If they complete the circle in equal time. What is the ratio of their speeds and centripetal accelerations?

Answer : According to the question given that;

Mass of first car = m_1.

The radius of first car = r_1.

Mass of second car = m_2.

The radius of second car = r_2.

Now let;

The speed of first car = V_1.

The speed of second car = V_2.

Time is taken for the first car to complete = $T_1 = \frac{2\pi r_1}{V_1}$

Time is taken for the second car to complete = $T_2 = \frac{2\pi r_2}{V_2}$.

According to question;

$T_1 = T_2$.

$$\Rightarrow \frac{2\pi r_1}{V_1} = \frac{2\pi r_2}{V_2}.$$

$$\Rightarrow \frac{r_1}{V_1} = \frac{r_2}{V_2}$$

$$\Rightarrow \frac{V_1}{V_2} = \frac{R_1}{R_2}.$$

Hence the ratio of speeds is $\frac{R_1}{R_2}$.

Centripetal acceleration of First car $a_1 = \frac{V_1^2}{R_1}$

Centripetal acceleration of Second car $a_2 = \frac{V_2^2}{R_2}$

$$\Rightarrow \frac{a_1}{a_2} = \frac{\frac{V_1^2}{R_1}}{\frac{V_2^2}{R_2}}$$

$$\Rightarrow \frac{a_1}{a_2} = \left(\frac{V_1^2}{V_2^2}\right) \times \left(\frac{R_2}{R_1}\right)$$

$$\Rightarrow \frac{a_1}{a_2} = \left(\frac{R_1^2}{R_2^2}\right) \times \left(\frac{R_2}{R_1}\right)$$

$$\Rightarrow \frac{a_1}{a_2} = \frac{R_1}{R_2}$$

Hence the ratio of centripetal acceleration is $\frac{R_1}{R_2}$

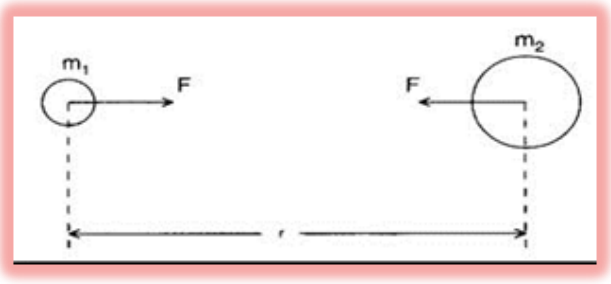
Q. 14. Two spherical balls of mass 10 kg each are placed with their centers 10 cm apart. Find the gravitationl force of attractdion between them.

Answer : The Gravitational force of attraction between two bodies of masses m_1 and $m_2$separated by a distance of R is given by;

$$F = \frac{Gm_1m_2}{R^2}$$

G = Gravitational constant;

The figure below illustrates the question well;



According to our question;

$m_1 = 10$ kg;

$m_2 = 10$ kg;

$R = 10 \text{ cm} = \frac{10}{100} \text{ m} = 0.1 \text{ m}$ (1 m = 100 cm).

$$F = \frac{6.67 \times 10^{-11} \times 10 \times 10}{0.1^2}$$

$$\Rightarrow F = \frac{6.67 \times 10^{-11} \times 10^2}{10^{-2}}$$

$$\Rightarrow F = \frac{6.67 \times 10^{-11} \times 10^4}{10^{-2}}$$

$$\Rightarrow F = 6.67 \times 10^{-11+4} = 6.67 \times 10^{-7} \text{ N}$$

Hence force between two spherical balls is 6.67×10^{-7} N

Q. 15. Find the free-fall acceleration of an object on the surface of the moon, if the radius of the moon and its mass are 1740 km and 7.4 x 1022 kg respectively. Compare this value with free-fall acceleration of a body on the surface of the earth.

Answer : According to the question given data is;

Mass of the moon (M) = 7.4×10^{22} Kg;

Radius of moon (R) = 1740 km = 1740×10^3 m (1km = 1000m).

Now;

$$\text{Acceleration due to gravity (g)} = \frac{GM}{R^2}$$

$$\Rightarrow g = \frac{6.67 \times 10^{-11} \times 7.4 \times 10^{22}}{(1740 \times 10^3)^2}$$

$$\Rightarrow g = \frac{6.67 \times 7.4 \times 10^{11}}{1740 \times 1740 \times 10^6}$$

$$\Rightarrow g = \frac{49.385 \times 10^5}{1740 \times 1740}$$

$$\Rightarrow g = \frac{49.385 \times 10^3}{174 \times 174}$$

$$\Rightarrow g = \frac{49358}{174 \times 174}$$

$$\Rightarrow g = 1.63 \text{ m\s}^2.$$

Free fall Acceleration at the surface of the moon is 1.63 m\s^2

Now;

Acceleration due to gravity on earth ag_e = 9.8 m\s^2.

Acceleration due to gravity on moon g_m = 1.63 m\s^2.

$$\frac{g_e}{g_m} = \frac{9.8}{1.63}$$

$$\Rightarrow \frac{g_e}{g_m} = 6$$

$$g_e = 6\, g_m.$$

Acceleration due to gravity on the moon is one-sixth of Acceleration due to gravity on earth.

Q. 16. Can you think of two particles which do not exert a gravitational force on each other?

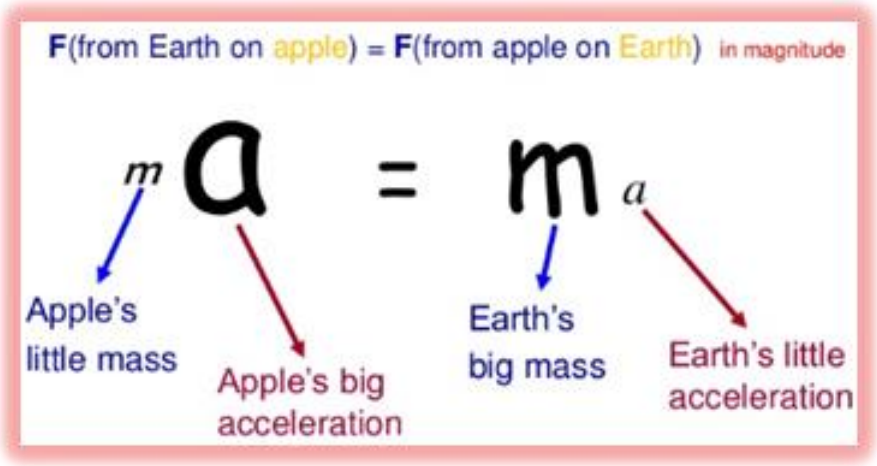
Answer : No, we cannot find any two particles which do not exert a gravitational force on each other. Because according to Newton's universal law of gravitation everybody can exert a gravitational force on another body. Hence there are no two bodies which do not exert a gravitational force on each other. If there would have been any such body than it would have violated the Newton's universal law of gravitation.

Q. 17. An apple falls from a tree. An insect in the apple finds that the earth is falling towards it with an acceleration g. Who exerts the force needed to accelerate the earth with this acceleration?

Answer : According to Newton’s law ‘every action has an equal reaction but in opposite direction’. Therefore the apple applies gravitational force on earth which is equal to the force applied

By the earth apple. But the acceleration of earth due to the force of apple is very small. It is negligible due to the large mass of the earth.

The figure below depicts the more.



Q. 18. A scooter weighing 150kg together with its rider moving at 36 km/hr is to take a turn of radius 30 m. What force on the scooter towards the center is needed to make the turn possible? Who or what provides this?

Answer : According to the question;

Radius of circular path (r) = 30 m;

Velocity of scooter (v) = 36 km/hr;

$= 36 \times \left(\frac{5}{18}\right)$ m/s;

= 10 m/s.

Mass of scooter (m) = 150 kg;

For making the turn possible the scooter needs force equal to the centripetal force which is given by;

$F = \frac{mv^2}{r}$

$\Rightarrow F = \frac{150 \times 10 \times 10}{30}$

⇒ F = 5 x 10 x 10 = 500 N.

The force required is 500 N and it is provided by the normal reaction between the ground and the scooter.

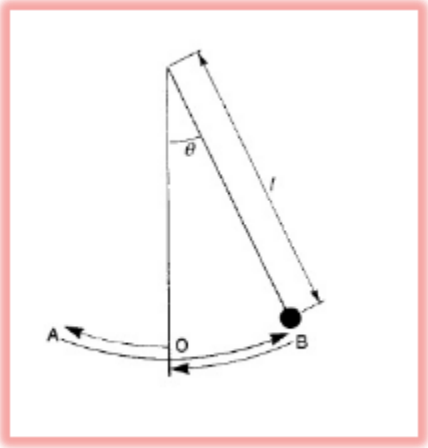
Q. 19. The bob of a simple pendulum of length 1 m has mass 100g and a speed of 1.4 m/s at the lowest point in its path. Find the tension in the string at this moment.

Answer : According to the question;

Length of pendulum (l) = 1 m;

Mass of pendulum (m) = 100g = $\frac{100}{1000} = 0.1\ \text{Kg}$

Velocity at lowest point (v) = 1.4 m/s.



Now;

The Tension in the string is equal to the sum of force in the circular path (centripetal force) and gravitational force..

⇒ Tension T = Centripetal force + gravitational force.

⇒ T = $\frac{mv^2}{r}$ + mg

⇒ T = $\frac{0.1 \times 1.4 \times 1.4}{1}$ + 0.1 × 9.8.

(Length of string (l) = radius of circle in which bob of pendulum moves (r))

⇒ T = 0.196 + 0.98

⇒ T = 1.176 N.

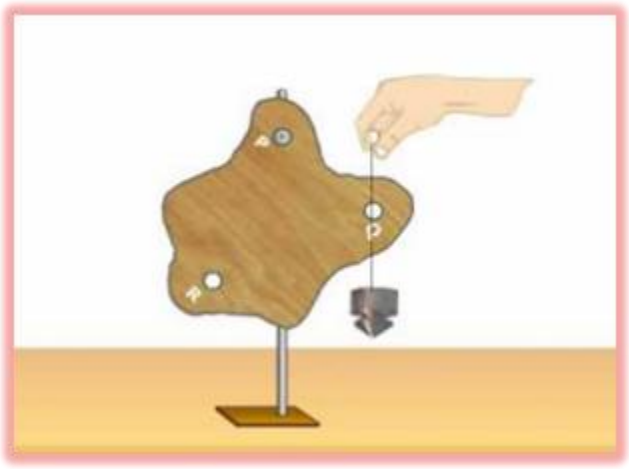
The tension in the string is 1.176 N.

Q. 20. How can you find the center of gravity of an India map made of steel? Explain.

Answer : The map of India is irregular in shape its center of gravity can be found out in following way

1. Take the map and make three holes along its edge.

2. Suspend the map freely from one hole by using the thread as shown in the figure below.



3. Take a plumb bob and suspend it from the same hole.

4. Draw a line along the thread. It indicates the line of weight at that point. As shown in the figure below.

5. Repeat the same from remaining holes and draw other two lines of weight.

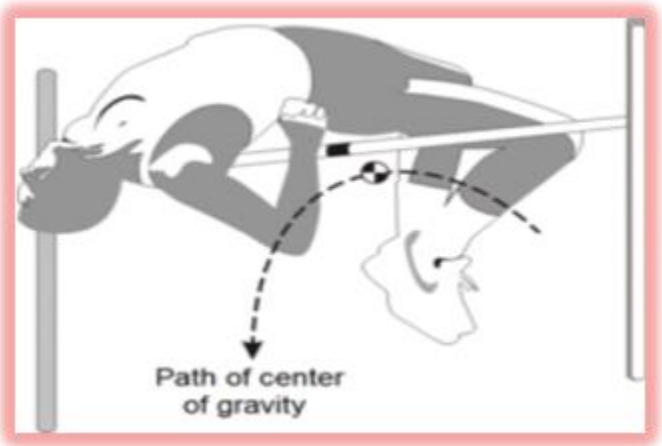
6. The concurrent point of the three lines is the Center of gravity of the map.

Q. 21. Explain some situations where the center of gravity of man lies outside the body.

Answer : Some of the situations where the center of gravity of man lies outside the body are as follows.

i. While doing Yogasanas, if we bend our body in inverted “V” shape. Then the center of gravity may lie out side of the body. The figure below illustrates the point.

ii. The athletes while doing the high jump, bend their body as arc. In that situation, the center of gravity may lie outside of the body. The figure below shows the center of gravity of athlete doing the high jump.



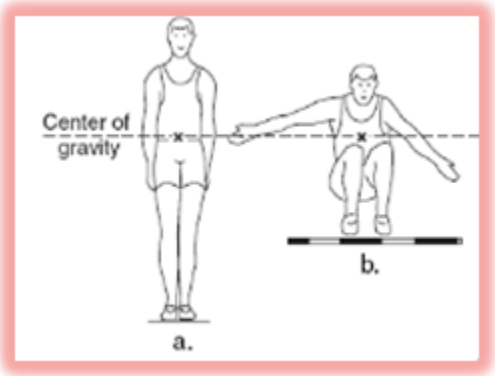
Q. 22. Where does the center of gravity of the atmosphere of the earth lie?

Answer : Since the earth is surrounded by the atmosphere with nearly equal thickness and. The center of gravity of Earth lies at the center of Earth because, at that point, the mass of the Earth is equally distributed in all the directions. Therefore center of gravity

of the atmosphere of the earth coincides the center of gravity of the earth. As shown in the figure below.

Q. 23. Where does the center of gravity lie, when a boy is doing sit-ups? Does weight vector pass through the base or move away from the base? Explain.

Answer : The center of gravity of an object is the point you can suspend the object from without there being any rotation because of the force of gravity .when a boy is doing sit-ups the center of gravity move up and down, thus it is not fixed it keeps changing with the upward and downward movement of the boy. The figure below illustrates it.



The weight vector passes through the base but the move slightly with respect to the previous position.