Assignment-7

Satya Sangram Mishra

Download all python codes from

```
https://github.com/satyasm45/Summer−Internship/
    tree/main/Assignment−7/Codes
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and latex-tikz codes from

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https://github.com/satyasm45/Summer−Internship/
    tree/main/Assignment−7
```

1 Question No. 2.22

Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg,

(a) just after it is dropped from the window of a stationary train
(b) just after it is dropped from the window of a train running at a constant velocity of 36 km/h,
(c) just after it is dropped from the window of a train accelerating with $1ms^{-2}$
(d) lying on the floor of a train which is accelerating with $1ms^{-2}$, the stone being at rest relative to the train.

2 Explanation

For a body of constant mass the force **F** acting on it is given by mass(m) times its acceleration(**a**).

$$\mathbf{F} = m \times \mathbf{a} \tag{2.0.1}$$

The acceleration of a body under the influence of gravity is given by:

$$\mathbf{a} = \mathbf{g} = \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} \tag{2.0.2}$$

(a) The stone is dropped from stationary train

$$m = 0.1, \mathbf{a} = \mathbf{g} = \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} \tag{2.0.3}$$

$$\mathbf{F}_a = \begin{pmatrix} 0 \\ -0.98 \end{pmatrix} \tag{2.0.4}$$

$$\tag{2.0.5}$$

The magnitude of force is 0.98N and direction is vertically downwards.

(b) Since the train has a constant velocity **v** ,acceleration of stone is zero and force acting on it inside train is also zero.Just after it is dropped:

$$m = 0.1, \mathbf{a} = \mathbf{g} = \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} \tag{2.0.6}$$

$$\mathbf{F}_b = \begin{pmatrix} 0 \\ -0.98 \end{pmatrix} \tag{2.0.7}$$

The magnitude of force is 0.98N and direction is vertically downwards.

(c) The force acting on a body at an instant depends on that instant.So even if an additional force acted on the stone when it was inside, but once stone is dropped it ceases to act. The net force acting on it is again given by:

$$m = 0.1, \mathbf{a} = \mathbf{g} = \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} \tag{2.0.8}$$

$$\mathbf{F}_c = \begin{pmatrix} 0 \\ -0.98 \end{pmatrix} \tag{2.0.9}$$

The magnitude of force is 0.98N and direction is vertically downwards.

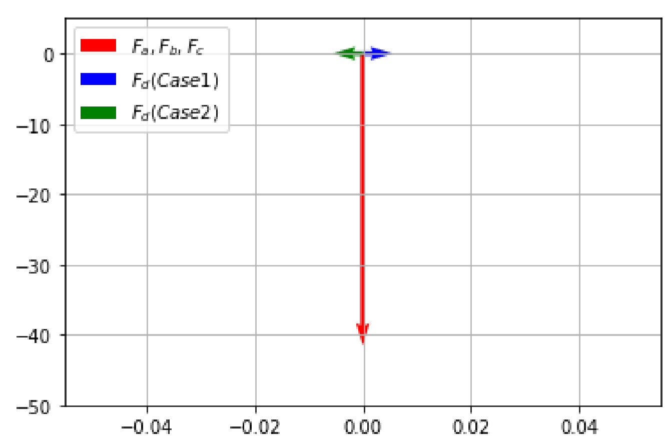

Fig. 2.1: The Force vectors

(d) The acceleration of stone will be same as the train.Hence,two possible values of force:

$$m = 0.1, \mathbf{a} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \begin{pmatrix} -1 \\ 0 \end{pmatrix} \tag{2.0.10}$$

$$\mathbf{F}_d = \begin{pmatrix} 0.1 \\ 0 \end{pmatrix}, \begin{pmatrix} -0,1 \\ 0 \end{pmatrix} \tag{2.0.11}$$

$\therefore$ magnitude of force is 0.1N and direction is along the direction of motion of train.

3 Appendix

For (c) let us assume height from ground is 'h' and the instantaneous velocity of train is $\mathbf{v} = \begin{pmatrix} v \\ 0 \end{pmatrix}$.Just after ball is dropped,from the ground frame of reference the ball has initial velocity $\mathbf{v}$ and:

$$\mathbf{a} = \mathbf{g} = \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} \tag{3.0.1}$$

This is because as soon as the ball loses contact with the train its horizontal acceleration due to train becomes zero. If $\mathbf{X}$ is instantaneous position of ball:

$$\mathbf{X} = \begin{pmatrix} 0 \\ h \end{pmatrix} + \mathbf{v}t + \frac{1}{2}\mathbf{g}t^2 \tag{3.0.2}$$

$$\mathbf{X} = \begin{pmatrix} 0 \\ h \end{pmatrix} + \begin{pmatrix} v \\ 0 \end{pmatrix} t + \frac{1}{2} \begin{pmatrix} 0 \\ -9.8 \end{pmatrix} t^2 \tag{3.0.3}$$

Assuming h=490m and v=1.5m/s and using (3.0.3) the motion of ball as seen by an observer from ground found out by varying 't' is given as :

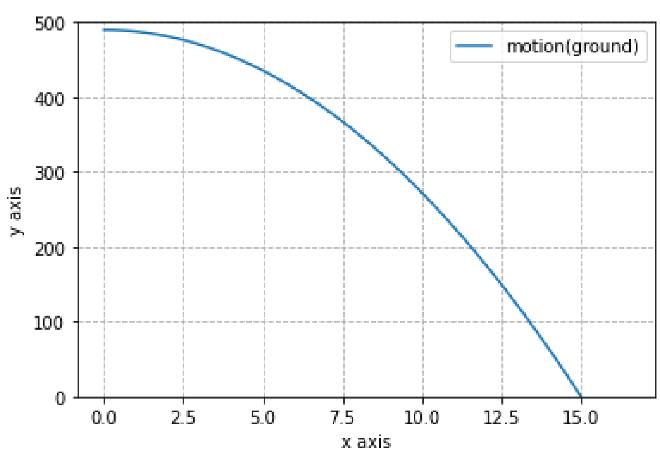

Fig. 3.1: Motion as seen from ground

From the train frame of reference,let $\mathbf{a_t}$ be acceleration of train w.r.t ground $\mathbf{a_r}$ be the relative acceleration of ball w.r.t to train,and let $\mathbf{v_r}$ be the relative velocity of ball w.r.t to train:

$$\mathbf{a_r} = \mathbf{g} - \mathbf{a_t} = \mathbf{g} - \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} -1 \\ -9.8 \end{pmatrix} \tag{3.0.4}$$

$$\mathbf{v_r} = 0 \tag{3.0.5}$$

If $\mathbf{X}$ is instantaneous position of ball from train frame of reference:

$$\mathbf{X} = \mathbf{v_r}t + \frac{1}{2}\mathbf{a_r}t^2 \tag{3.0.6}$$

$$\mathbf{X} = \frac{1}{2} \begin{pmatrix} -1 \\ -9.8 \end{pmatrix} t^2 \tag{3.0.7}$$

Assuming h=500m and using (3.0.3) the motion of ball as seen by an observer from train found out by varying 't' is given as:

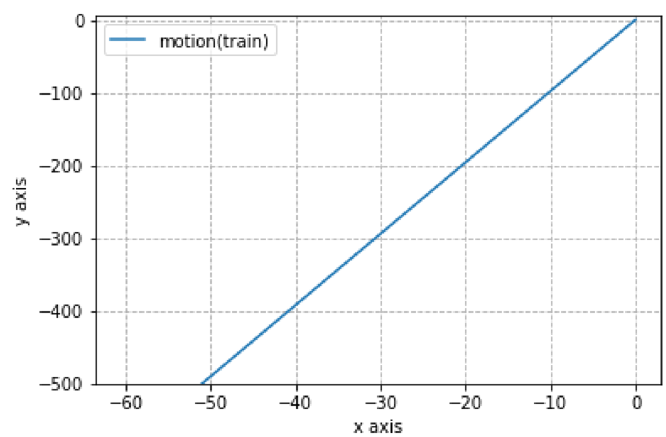

Fig. 3.2: Motion as seen from train

Similar trajectories can be found out for the case $\mathbf{a} = \begin{pmatrix} -1 \\ 0 \end{pmatrix}$