PH101: Physics I

Tutorial 7 _STR_01

Module2: Special Theory of Relativity

01 October 2018

Basic ideas

---

1. (Work within the framework of Galilean Relativity). Consider a ship traveling with speed of 36 km / hr due east.

   (i) A girl playing on the deck of the ship rolls a ball towards north (with respect to the deck) with a speed of 50 cm/s. Find the velocity relative to an observer on the shore.

   (ii) If the ball is rolled at 30° north of east, find the velocity relative to the earth.

2. A helicopter flying with a constant speed of 180 km/hr along the horizontal x-direction with respect an observer on the ground, at a height of 500 m. Consider the y direction vertically upwards. At certain time, the pilot releases a packet which drops down with zero initial vertical speed. Set the coordinates of the observer and the pilot so that at the time of release, the packet is at the origin in both the reference frames. Set this time to be $t = 0$. Consider acceleration due to gravity, $g = 9.8\ m/s^2$. Find the position and velocity of the packet in the two frames, 5 seconds after it is dropped, according to Galilean Relativity.

3. Compare the speeds of the following with that of light (express as fraction of *c*). In each of the cases find the pre-factor γ that appear in the Lorentz transformation.

   (i) Usain Bolt running at a speed of 100 m in 10 sec

   (ii) Japanese *Shinkansen* running at 600 km / hr

   (iii) Concord aircraft with ground speed 1800 km / hr

   (iv) Space-shuttle moving with a speed of 27000 km / hr

   (v) Earth orbiting around sun with a speed of 30 km per second

   (vi) Proton making one round of 27 km circumference of the Large Hadron Collider tunnel in 100 micro seconds.

4. A space rider, the captain on the deck of a ship sailing in the sea and an observer standing still on the shore are all watching a firecracker show. Both the space rider and the ship on the sea are moving along the same direction with constant speeds of

$v = 0.5c$ and 10 m/s, respectively. Set this direction to be x-axis for all the three. At a particular instant, a (firecracker) rocket set to fire shoots up. All the above three spectators set their coordinate system so that the spatial coordinates' origin coincide at this time with the firecracker at the origin, and the time itself is set to $t = 0$. The observer on the shore see that the firecracker bursts at time $t = 5$ seconds with spatial coordinates (x=100 m, y= 200 m, z=0). What are the time and spatial coordinates of the event as seen by the other two spectators:

(i) In Galilean Relativity?

(ii) In the Special Theory of Relativity?

5. Two events occur at $\left(t = \frac{X}{2c}, X, 0, 0 \right)$ and $\left(t = \frac{X}{c}, 3X, 0, 0 \right)$ in a frame S . What is the speed of frame S' (moving along x-axis with constant speed), so that the above two events occur at the same time in this frame? What is the value of this time, and what are the values of x-coordinate in S' ?