Q- Joan goes skydiving. As she is falling at terminal velocity, she screams very loudly with a frequency of 1500 Hz. If her friend on the ground directly below her measures the frequency of her scream to be 2000 Hz, how fast is she falling? She hears the echo of her scream as it bounces off the ground below her. What frequency does she measure the echo to have?

This phenomenon is called Doppler's effect.

When the source of sound is moving towards the listener the waves in the medium are getting compressed, wavelength decreases and hence the frequency of the waves increases. If the source is moving away from the listener the opposite effect will be there and the frequency of the waves will decrease. The frequency of the waves in the medium is given by the formula

$$n_1 = n\left(\frac{c}{c-v}\right)$$

Where c is the wave velocity and v is the velocity of approach of the source. If the source is moving away v will have negative sign and will be added to c.

Now the frequency heard is by her friend is n_1 = 2000 Hz hence

$$2000 = 1500\left(\frac{c}{c-v}\right)$$

Or $$1-\frac{v}{c}=\frac{1500}{2000}$$

Or $$v=\frac{c}{4}=\frac{340}{4}=85 \text{ m/s}$$

The wave of the same frequency n_1 is reflected by the ground which acts as stationary source.

Now when the source is stationary it produces the waves of same frequency in the medium. But if the listener is moving towards the source he will received some additional oscillation per second which are occupying the distance v traveled by him in one second.

Hence the frequency heard will be given by

$$n_2 = n+\frac{v}{\lambda}=n+\frac{nv}{c}=n\left(\frac{c+v}{c}\right)$$

If the listener is moving away the velocity will be negative and subtracted from c accordingly

Now as the frequency of the reflected waves is n_1 hence the frequency of the echo measured by Joan will be

$$n_2 = n_1\left(\frac{c+v}{c}\right)=n_1\left(1+\frac{v}{c}\right)=2000\left(1+\frac{1}{4}\right)=2500 \text{ Hz}.$$