Department of Physics
University of California San Diego

Modern Physics (2D)
Prof. V. Sharma
Quiz # 1 (Jan 17 2003)

Some Relevant Formulae, Constants and Identities

Speed of Light, c = 3.0×10^8m/s

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$x' = \gamma(x - vt)$$

$$t' = \gamma(t - \frac{xv}{c^2})$$

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}}$$

$$p = \frac{mu}{\sqrt{1 - u^2/c^2}}$$

$$E = \frac{mc^2}{\sqrt{1 - u^2/c^2}} = K + mc^2$$

$$f_{obs} = \frac{\sqrt{1 + v/c}}{\sqrt{1 - v/c}} f_{source}$$

Pl. write you answer in a Blue book in indelible ink. Make sure your code number is prominently displayed on each page

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Problem 1: Doppler Radar [8 pts]
If a police radar transmitter radiates at 10.0GHz, calculate the frequency shift observed by the police for a car traveling away from the police car at (a) 115 km/hr and (b) 130 km/hr (c) what measurement precision in frequency is required to distinguish between the two cars? State your answer as a fraction $\frac{\Delta f}{f}$.

Problem 2: Space talk [12 pts]
A observer on the Earth sees a rocket go by at a speed of v=0.6c. (a) An astronaut on the rocket sends an escape pod back towards the Earth. She measures the speed of the escape pod to be u=0.9c. What is the speed of the escape pod as measured by an observer on the Earth? (b) An observer on the escape pod measures the rocket to be 100 m long. What is the proper length of the rocket? (c) What is the length of the rocket as measured by an observer on Earth ?

Physics 2D: Quiz 1 Solutions

1] There are 2 Doppler shifts here: The one observed by the car, and the one the cop sees for the beam reflected from the car.

First, $f_{car} = \sqrt{\frac{1-(v/c)}{1+(v/c)}}\, f_{cop,original}$.

This has the minus sign on the top b/c the relative motion is away from each other.

Now, $f_{cop,final} = \sqrt{\frac{1-(v/c)}{1+(v/c)}}\, f_{car}$

↑ what the cop measures.

Thus $\boxed{f_{cop,final} = \left[\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right] f_{cop,original}}$

a] $v = 115\,\frac{km}{hr} = \frac{115\,km}{1\,hr}\left(\frac{1\,hr}{3600\,s}\right)\left(\frac{10^3\,m}{1\,km}\right) = 31.9\,\frac{m}{s}$.

So the freq. shift is

$\boxed{f_{cop,final} - f_{cop,original} = -2130\text{ Hz}}$

Note that you can get this either by just plugging in <u>or</u> using the Taylor series $\frac{1-\frac{v}{c}}{1+\frac{v}{c}} \simeq 1 - \frac{2v}{c}$, which implies $f_{cop,final} - f_{cop,orig} = -\frac{2v}{c} f_{cop,orig}$. Same answer.

b] Now $v = 130 \frac{km}{hr} = 36.1 \frac{m}{s}$

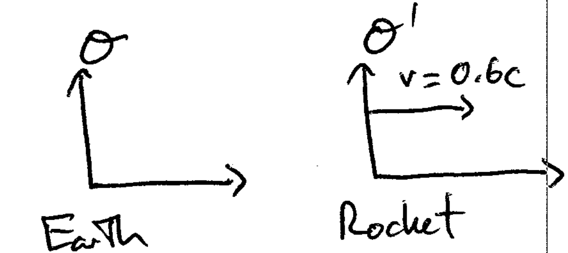
So $\boxed{f_{cop,final} - f_{cop,original} = -2407 \text{ Hz}}$

c] The difference between these shifts is

$\Delta F = 2407 - 2130 \text{ Hz} = 277 \text{ Hz}.$

So $\frac{\Delta F}{f} = \frac{277 \text{ Hz}}{10^{10} \text{ Hz}} = \boxed{2.77 \times 10^{-8} \simeq 3 \text{ parts in } 10^8}$

2a]



The observer in O' measures $u' = -0.9c$.

So using $u = \frac{u' + v}{1 + \frac{u'v}{c^2}}$, we see $u = \frac{(-0.9 + 0.6)c}{1 + (-0.9)(0.6)}$

$= \boxed{-0.65c}$

So the speed (the mag. of the velocity) is $\boxed{0.65c}$.

b) The observer in the escape pod moves with speed 0.9c with respect to the rocket, so

$$L_{pod} = \sqrt{1-(0.9)^2}\, L_{rocket} \qquad (\text{here, } v^2/c^2 = (0.9)^2)$$

L_{pod}: Length of rocket measured in pod frame

L_{rocket}: Proper length of rocket.

So using $L_{pod} = 100\text{ m}$, we see

$$\boxed{L_{rocket} = 229\text{ m}}$$

c) The observer on the Earth sees the rocket go by at 0.6c.

So $L_{earth} = \sqrt{1-(0.6)^2}\, L_{rocket}$

$$\boxed{L_{earth} = 184\text{ m}}$$