Problem 1: \text{NONELASTIC DOPPLER SHIFTS SOURCE AND OBSERVER IN MOTION (52 points)}

Consider the Doppler shift in the case where the source is moving with respect to the observer. Assume that the observer is at rest relative to the Earth. The source is moving with a speed \( v_s \) towards the observer, which is at rest. The observer measures the frequency of the source \( f_o \). The Doppler shift formula is given by:

\[
\frac{f_o}{f_s} = \frac{1 + \frac{v_o}{c}}{1 - \frac{v_s}{c}}
\]

where:
- \( f_o \) is the frequency observed by the observer.
- \( f_s \) is the frequency emitted by the source.
- \( v_o \) is the speed of the observer.
- \( v_s \) is the speed of the source.
- \( c \) is the speed of light.

(a) Derive the formula for the Doppler shift when the observer is moving towards the source. Explain your steps.

(b) Derive the formula for the Doppler shift when the source is moving towards the observer. Explain your steps.

(c) Explain why the Doppler shift formula is important in astrophysics and cosmology.

Problem 2: \text{THE TRANSVERSE DOPPLER SHIFT (52 points)}

Consider the Doppler shift in a medium other than air. Let the medium be a plasma. The plasma has a velocity \( v_p \) relative to the source. The Doppler shift formula for this case is given by:

\[
\frac{f_o}{f_s} = \frac{1 + \frac{v_o}{c}}{1 - \frac{v_s - v_p}{c}}
\]

where:
- \( f_o \) is the frequency observed by the observer.
- \( f_s \) is the frequency emitted by the source.
- \( v_o \) is the speed of the observer.
- \( v_s \) is the speed of the source.
- \( v_p \) is the speed of the plasma.
- \( c \) is the speed of light.

(a) Derive the formula for the transverse Doppler shift. Explain your steps.

(b) Discuss how the transverse Doppler shift differs from the longitudinal Doppler shift.

Note About Extra Credit: This problem can be extended into Chapters 3 and 4.

Due Date: Friday, September 16, 4:00 pm.

Problem Set 1
Total points for Problem Set I: 40, plus 15 points or extra credit.

(a) In the relativistic situation, where the wave is high, and the speed a may be comparable to c, what is the answer to the same three parts (i)-(iii) above?

(b) In the relativistic situation, where the wave is high, and the speed a may be comparable to c, and the speed u is very small compared to the speed of light, c, with what doppler shift does a given car escape the sound from (i) the car in front of it? (ii) the car in front of the one that escapes the sound from (i)?

(c) If the wave in question is sound, and both the source speed a and the wave speed u are high, what is the doppler shift? (This problem is not required, but can be done for 15 points extra credit.)