Consider the following the simulation (you can access the simulation by typing the link in the internet browser of you cell-phone or laptop):

http://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html

A. Open the simulation.

Select the option “Pulse” from the top left. You can select “Fixed End” or “Loose End” from the top right.

Compare the shape of the incident and reflected waves. To do so send a V-pulse towards the end and see whether the crest is reflected as a crest or a trough.

1. When the end is loose: .................................................................
2. When the end is fixed: .................................................................
3. When is the amplitude reversed, when the end is loose or when it is fixed?

B.

1. Use different colors to sketch the following:
   (i) Draw the graph of a sine wave
   (ii) In the same graph draw the same graph with inverted (negative) amplitude
   (iii) In the same graph draw the same wave (as in (i)) shifted by π.

2. Compare the graphs in (ii) and (iii).

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
3. For a sinusoidal wave what is the difference between inverting the amplitude and shifting the phase by $\pi$?


________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

C. Recall the following situation with travelling waves on ropes (from first year physics):

![Image of travelling waves on ropes]

1. Does the transmitted wave has the same phase or not? [Hint: See part B.]

D. Imagine you have a rope with one end tied to a pole. Now you hold onto the other end of the rope and try to shake the rope. Now answer the following questions:

1. Consider two ropes of equal length and thickness. One rope has a higher density compared to the other one. Which rope is easier to shake?

________________________________________________________________________

________________________________________________________________________

2. Based on the above analogy which one is closer to the “fixed end” scenario in the simulation in part A? Select the correct answer and explain. [Hint: The disturbance is in a sense trying to shake the second rope into which it is trying to move in! If we make the second rope infinitely dense (thus infinitely heavy) will the disturbance be able to move the second rope?]  

   (a) When a wave travels from a lighter rope to a denser rope

   (b) When a wave travels from a denser rope to a lighter rope
3. Which one is closer to the “loose end” scenario in the simulation in part A? Select the correct answer and explain.

(a) When a wave travels from a lighter rope to a denser rope

(b) When a wave travels from a denser rope to a lighter rope

C. Under what conditions does the incident and reflected wave

1. Have the same phase? ____________________________________________________________

2. Have opposite phases? __________________________________________________________

The situation with light is similar to the situation with rope. The transmitted / refracted wave has the same phase as the incident wave. The reflected wave has the same phase going from a higher refractive index medium (optically denser medium) to a lower refractive index medium (optically less dense medium), but the opposite phase when going from a lower refractive index medium to a higher refractive index medium.

Opposite phase implies a $\pi$ phase shift and same phase means 0 phase shift. Therefore the extra phase due to reflection from a lower refractive index medium to a higher refractive index medium gives rise to a half-cycle reflection phase shift and otherwise there is no half-cycle reflection phase shift.