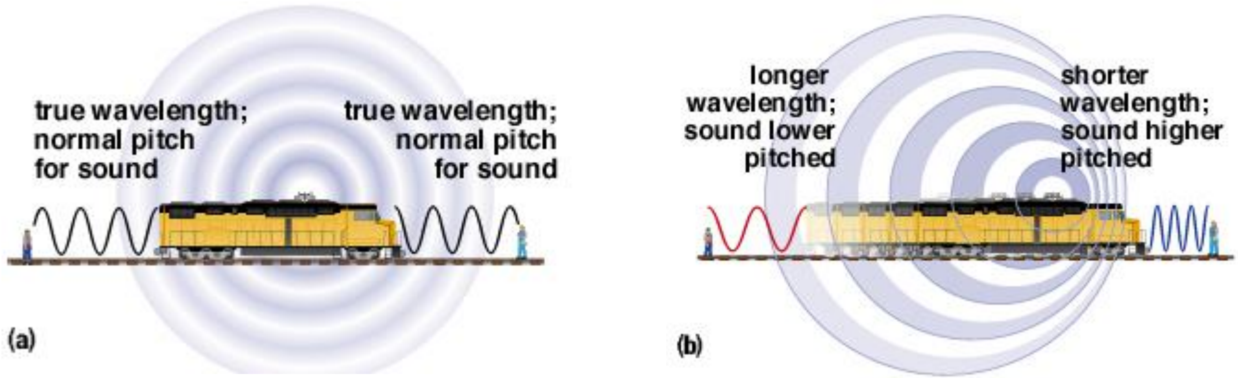
Name ____ Date ___________ Period ________

Lab: The Doppler Effect

CONCEPTUAL PHYSICS: SOUND WAVES

Background: Heard an ambulance go by recently? Remember how the siren's pitch changed as the vehicle raced towards, then away from you? First the ***pitch*** became higher, then lower. Originally discovered by the Austrian mathematician and physicist, Christian Doppler (1803-53), this change in ***pitch*** results from a shift in the ***frequency*** of the sound waves, as illustrated in the following pictures. In figure (a) the train is not moving. In figure (b), the train is moving at a constant velocity forward.



As the train approaches, the sound waves from its horn are compressed towards the observer. The intervals between waves diminish, which translates into an increase in ***frequency*** or ***pitch***. As the train recedes (moves away from you), the sound waves are stretched relative to the observer, causing the horn's ***pitch*** to decrease. By the change in pitch of the horn, you can determine if the train is coming nearer or speeding away. If you could measure the rate of change of pitch, you could also estimate the trains speed.

Materials:

- Doppler Ball
- String
- Stop watch
- Calculator
- Meter stick

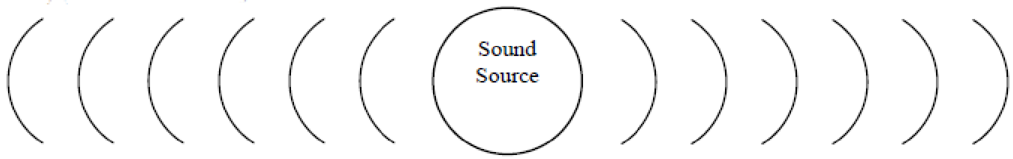
Procedure:

Part 1: Experiment with the Doppler ball and get a feel for what happens to the sound by throwing the Doppler ball back and forth with another lab partner (**please be careful**)

1. Start the Doppler ball buzzer and observe its pitch. Play catch. Throw the ball fast, and without spin. Describe the pitch (frequency) of the sound you hear when the ball is going away from you, and when it is coming toward you.

2. Tie a string tightly around the ball. Swing it in a circle above your head. Take turns listening to the buzzer from several feet away. Describe your observations.

3. The first diagram below shows a stationary ball emitting sound waves. Draw another identical ball moving to the right. Show how the sound waves would appear to stationary observers.



Part 2: In the next part of the lab you are going to calculate the difference in pitch (frequency) of the sound waves as the Doppler ball approaches you and as it moves away from you

4. Swing the Doppler ball overhead for 10 seconds at as consistent a rate as possible. You will need to be able to repeat this motion later.
5. Count the number of revolutions the ball completes in this 10 second time interval.
6. Now we can calculate the approximate **speed** of the ball.
   a. Remembering what we learned about circular motion, we will calculate the distance the ball travels around in a circle divided by the time it took to make one revolution.
   b. Since **v = d/t**, we can substitute the circumference of the circle (**2πr**) for the distance, and the period of rotation (**T**) for the time it took for one rotation. So, **v = 2πr/T**
   c. Measure the approximate **radius (r)** of rotation the ball makes. We will say 1 meter for this example.
   d. So that means the circumference of one revolution would be **2πr** or 6.28 meters.
   e. Now let's say your ball made a consistent 15 revolutions per 10 second time interval. That means your ball made 1.5 revolutions every second, or we could say it took 0.66 seconds to make one revolution (Its period (**T**) of rotation is 0.66 seconds).
   f. Use the following equation to calculate the ball's speed **v = 2πr/T**
   g. So for the example above, the ball traveled 6.28 meters (one revolution) in 0.66 seconds or 9.5 m per one second (9.5 m/s). You can probably get the ball moving faster than this.
   h. Fill out the information below for your group and calculate its average speed.

      ___________ **meters** (radius (**r**) of your swing)

      ___________ **meters** (one revolution or one circumference (**2πr**) of the ball's path)

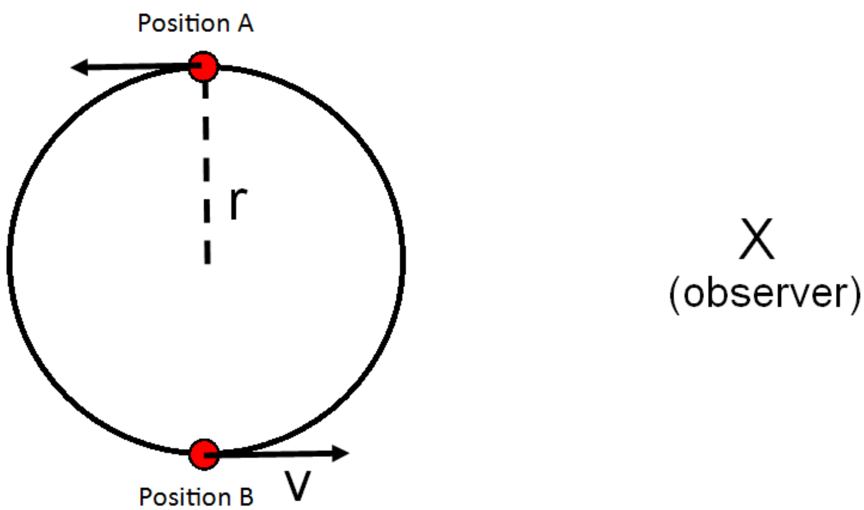
      ___________ **revolutions** (in a 10 second time interval)

      ___________ **seconds** (**Period** (**T**) of rotation: time for 10 rotations/number of rotations)

      ___________ **m/s** (the average speed of your ball: **v = 2πr/T**)

(SHOW WORK BELOW)

7. These beeping balls give off a frequency of approximately **120 Hz**. So as the ball approaches your ear as shown at **position A** below, the frequency emitted by the beeping ball should sound __________ (*higher or lower*) than the actual 120 Hz frequency. The ball while at **position B** should sound ________ (*higher or lower*) than 120 Hz.



Now let's calculate how much higher or lower using your Doppler effect equation.

Frequency (observed) = Frequency (actual) X shift factor.

Shift factor = $\dfrac{\textbf{speed of sound (345 m/s) + or – the speed of the observer}}{\textbf{speed of sound (345 m/s) + or – the speed of the source}}$

__________ **Hz observed frequency at position A.**

__________ **Hz observed frequency at position B**

(SHOW WORK BELOW)

Questions:

1. What is the definition of the Doppler Effect?

2. If the sound source began moving towards you at a faster speed, how would the frequency (pitch) be affected?

3. How does a “speed gun” used by police determine the speed of a vehicle?

4. Does the Doppler effect occur for only some types of waves or all types of waves?

5. How do astronomers use the Doppler Effect when looking at distant stars and galaxies?

6. How does the speed of a wave relate to its wavelength and frequency? (remember the equation for a waves speed is $\mathbf{v = \lambda f}$)

7. As the frequency of a sound wave is increased, does the wavelength increase or decrease? Give an example. (remember the equation for a waves speed is $\mathbf{v = \lambda f}$)

8. A fire engine’s siren emits a certain frequency. Rank from greatest to least the *apparent* frequency heard by the stationary listener in each scenario

a. The fire engine is traveling toward a listener at 30 m/s
b. The fire engine is traveling away from a listener at 5 m/s
c. The fire engine is traveling toward a listener at 5 m/s
d. The fire engine is traveling away from a listener at 30 m/s

9. When a wave source moves toward a receiver, does the receiver encounter an increase in wave frequency, wave speed, or both?

10. When a driver blows his horn while approaching a stationary listener, the listener hears an increase in the frequency of the horn. Would the listener hear an increase in the frequency of the horn if she were also in a car traveling at the same speed in the same direction as the first driver? Explain