PHYSICS 2204
Unit 4: Waves
Worksheet #7: DOPPLER EFFECT

Doppler effect When wave energy like sound or electromagnetic waves travels from two objects, the wavelength can seem to be changed if one or both of them are moving.

The Doppler effect causes the received frequency of a source (how it is perceived when it gets to its destination) to differ from the sent frequency if there is motion that is increasing or decreasing the distance between the source and the receiver. This effect is readily observable as variation in the pitch of sound between a moving source and a stationary observer.

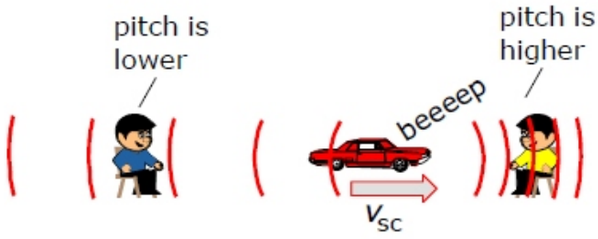
The Doppler effect may occur in all types of waves however we are most familiar with sound waves. Recall an instance in which a police car was traveling towards you on the highway. As the car approached with its siren blasting, the pitch of the siren sound was high; and then suddenly after the car passed by, the pitch of the siren sound was low.

It is important to remember that the source of sound always emits the same frequency.

The Doppler Effect is an apparent change of frequency due to the relative motion between an object listening to a sound and the source of the sound itself. The change of frequency depends on whether or not the listener is moving toward or away from the source or the source is moving toward or away from the listener

Equation 1: Moving Sound Source (Found on formula sheet)

$$f = \frac{f_o v_s}{v_s \pm v_0}$$



$\mathbf{f_O}$ = the frequency of the sound at the source
f = the observed frequency according to the Doppler Effect
$\mathbf{v_s}$ = Speed of sound
$\mathbf{v_o}$ = the speed of sound

When the source is moving toward the listener it is a (-) and when moving away it is (+).

Equation 2: Moving observer (Not found on formula sheet)

$$f = f_o \frac{(v_s \pm v_o)}{v_s}$$

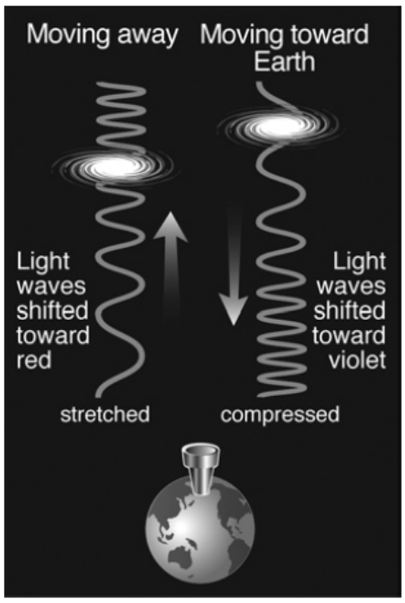
$\mathbf{f_O}$ = the frequency of the sound at the source
f = the observed frequency according to the Doppler Effect
$\mathbf{v_s}$ = Speed of sound
$\mathbf{v_o}$ = the speed of sound

When the listener is moving toward the sound it is a (+) and when moving away it is (-).

The Doppler effect and Electromagnetic Radation

The Doppler shift is also an important tool used by astronomers to study the motion of objects, such as stars and galaxies, in space. For example, if an object is moving toward Earth, the light waves it emits are compressed, shifting them toward the blue end (shorter wavelengths, higher frequencies) of the visible spectrum. If an object is moving away from Earth, the light waves it emits are stretched, shifting them toward the red end (longer wavelengths, lower frequencies) of the visible spectrum. In this skill sheet, you will practice solving problems that involve light and doppler shift.

Understanding Doppler shift



Astronomers use a spectrometer to determine which elements are found in stars and other objects in space. When burned, each element on the periodic table produces a characteristic set of spectral lines. When an object in space is moving very fast, its spectral lines show the characteristic patterns for the elements it contains. However, these lines are shifted.

If the object is moving away from Earth, its spectral lines are shifted toward the red end of the spectrum to a longer wavelength.
If the object is moving toward Earth, its spectral lines are shifted toward the blue end of the spectrum to a shorter wavelength

When applying the Doppler effect to electromagnetic waves you only have to consider two formulas.

•This time use negative (–) for moving away and positive (+) for approaching

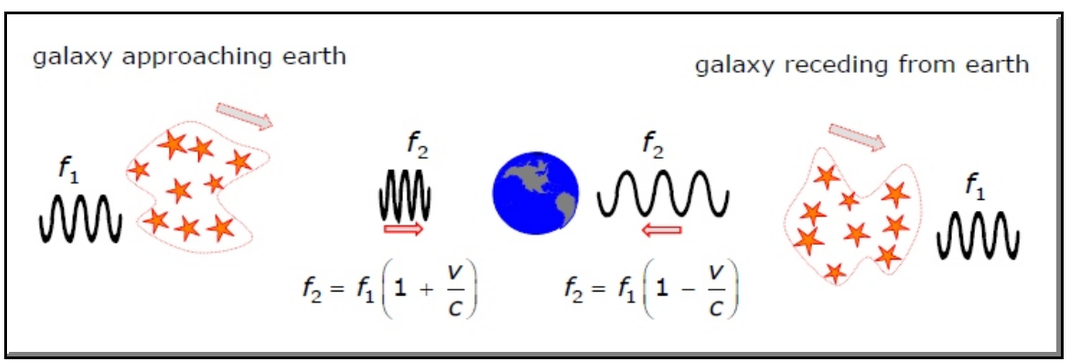
$$f_2 = f_1\left(1 \pm \frac{v}{c}\right)$$

f_2 = new (perceived) frequency, the frequency of electromagnetic wave that we observe

f_1 = actual frequency of the electromagnetic emitted from the source

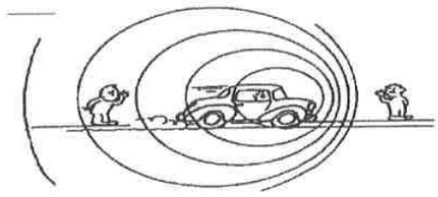
v = speed of source

c = speed of the electromagnetic wave emitted by the source (3.00×10^8 m/s)



PART A: MULTIPLE CHOICE

1. When an automobile moves towards a listener, the sound of its horn seems relatively



(A) low pitched
(B) high pitched
(C) normal
(D) No Change

2. When the automobile moves away from the listener, its horn seems

(A) low pitched
(B) high pitched
(C) normal
(D) No Change

3. A trumpet player is standing on a stage playing a single note. Which choice would result in you hearing a higher pitch than the trumpeter?

(A) Run very fast toward the trumpeter.
(B) Cover your ears.
(C) Play the sound much louder through a headphone.
(D) Get the trumpeter to point the horn at the sky.

4. Betty is running at 5 m/s toward a whistle, which is stationary. An identical whistle is approaching Bob at 5 m/s. Which statement about the pitch of the whistle is correct?

(A) Betty and Bob both hear a pitch which is higher than normal.
(B) Betty and Bob both hear a pitch which is lower than normal.
(C) Betty perceives the pitch to be higher and Bob perceives it to be lower than normal.
(D) Betty perceives the pitch to be lower and Bob perceives it to be higher than normal.

5. An aircraft is moving away from you at half the speed of sound, which, on that day is about 340 m/s. The jet engines make a sound that is primarily about 300 Hz. What is the apparent frequency of the jet engines?

(A) 150 Hz
(B) 200 Hz
(C) 470 Hz
(D) 600 Hz

6. A fast-moving car is sounding its horn as it moves by you. What will you observe just as the car passes by you?

(A) the pitch gets lower
(B) the pitch gets higher
(C) the pitch alternates behind high and low, repeatedly
(D) the pitch is unchanged

7. A trumpet player is standing on a stage playing a single note. Which choice would result in you hearing a higher pitch than the trumpeter?

(A) Run very fast toward the trumpeter.
(B) Cover your ears.
(C) Play the sound much louder through a headphone.
(D) Get the trumpeter to point the horn at the sky.

8. A police car travelling at 30.0 m/s sounds its 525 Hz siren as it approaches a person standing on the side of the road. If the speed of sound is 344 m/s, what frequency is heard by the person?

(A) 483 Hz
(B) 525 Hz
(C) 555 Hz
(D) 575 Hz

9. An ambulance approaches an observer at 31.5 m/s on a day when the speed of sound is 341 m/s. If the frequency heard is 525 Hz, what is the actual frequency of the siren?

(A) 477 Hz
(B) 481 Hz
(C) 573 Hz
(D) 578 Hz

10. High frequency sound waves are directed at an artery. Reflected waves have a different frequency than the incident waves due to the movement of blood cells in an artery. From this difference the speed of blood cells can be determined. This is an application of which wave property?

(A) Diffraction
(B) Doppler Effect
(C) Interference
(D) Refraction

11. The Doppler effect produces apparent changes in

(A) loudness
(B) frequency
(C) amplitude
(D) velocity

12. A distant star is known to produce a frequency of $6.00\times?10^{-14}$Hz. If it is moving away from the Earth at 5.35×10^{-6}m/s, what wavelength is observed on Earth?

(A) 8.92×10^{-9} m
(B) 4.91×10^{-7} m
(C) 5.09×10^{-7} m
(D) 5.73×10^{-7} m

13. A car horn has a frequency of 400 Hz. The car is moving away from an intersection at 20 m/s. The frequency heard by a woman standing at the intersection could be:

(A) 390 Hz
(B) 400 Hz
(C) 410 Hz
(D) 420 Hz

14. An observer approaches a stationary 1000 Hz sound source at twice the speed of sound. What frequency does the observer hear?

(A) 4,000 Hz
(B) 3,000 Hz
(C) 2,000 Hz
(D) none of these

15. What frequency do you hear if you are traveling at 15 m/s toward a train with a 750 Hz whistle? The train is moving away from you at 25 m/s and the temperature is 15˚ C.

(A) 668 Hz
(B) 729 Hz
(C) 774 Hz
(D) 845 Hz

16. What is the frequency heard by a stationary observer when a train approaches with a speed of 30 m/s? The frequency of the train horn is 600 Hz and the speed of sound is 340 m/s.

(A) 570 Hz
(B) 630 Hz
(C) 653 Hz
(D) 658 Hz

PART B: WRITTEN RESPONSE

1. An ambulance siren emits a frequency of 440 Hz. If the air temperature is 22^{O}, calculate the frequency heard by an observer if the ambulance is coming toward him at 26 m/s.

2. A car is moving towards a stationary observer at 15.1 m/s when the driver blows the horn with a frequency of 870 Hz. If the speed of sound is 344 m/s what is the frequency of the sound perceived by the observer?

3. A burglar alarm is wailing with a frequency of 1200 hertz. What frequency does a cop hear who is driving towards the alarm at a speed of 40.0 m/s? **Answer is 1340 Hz**

4. With reference to the above problem, what frequency would the burglar hear, if he was running away from the alarm at a speed of 10 m/s? **Answer is 1170 Hz**

5. A cop cars siren has a frequency of 700. hertz. If you are standing on the sidewalk as the cop car approaches you at a speed of 15.0 m/s, what frequency would you hear? **Answer is 732 Hz**

6. In the previous problem, what frequency would you hear if the cop were driving away from you at a speed of 25 m/s? **Answer is 652 Hz**

7. An alarm clock is dropped off the edge of a tall building. You, standing directly under it, hear a tone of 1350 Hz coming from the clock at the instant it hits the ground (you jumped out of the way at the last moment- whew!) Since you know the building is 25.0 m tall, you can find out what the frequency of the alarm would be if you had just held it in your hands. What would that frequency be? **Answer is 1260 Hz**

8. A siren of frequency of 570 Hz is moving toward a driver in a car at 45 m/s. What is the apparent frequency of the siren as it moves toward the driver and away from the driver?

9. A runner is jogging along the sidewalk when a little baby starts crying at a frequency of 400 Hz. If the running is traveling at 25 m/s, what is the apparent change in frequency he hears as he approaches and passes the baby?

10. A police car is chasing a bad guy down the road. The police car has its siren on which is at a frequency of 800 Hz. If the police car is traveling at 65 m/s and the bad guy is in front of the police car traveling 80 m/s, what frequency does the bad guy hear?

11. A train is approaching a station at 30 m/s when it sounds its 800 Hz whistle. To a person standing on the train platform what will be the perceived frequency of the whistle?

12. The referee is skating down the ice, away from you, at 15 m/s, blowing his whistle. The frequency of the whistle is 1000 Hz. What will you perceive it to be? **Answer is 958 Hz**

13. The engine of a race car produces a sound with a frequency of 350 Hz. The car is moving at 85 m/s.

a. If the car is coming towards you, what will you perceive its frequency to be? **Answer is 470 Hz**
b. If the car is moving away from you, what will you perceive its frequency to be?
c. Suppose that the car approaches you and passes you by. Describe the sound that you hear.

14. Two fire trucks with sirens on speed towards and away from an observer as shown below.

a) Which truck produces a higher than normal siren frequency? **Answer is left truck**
b) Which truck produces a lower than normal siren frequency? **Answer is right truck**

15. What is the frequency heard by a person driving at 15 m/s toward a blowing factory whistle (800. Hz) if the speed of sound is 340.6 m/s? **Answer is 835 Hz**

16. From the previous problem, what frequency would he hear after passing the factory if he continues at the same speed? **Answer is 765 Hz**

17. A car approaching a stationary observer emits 450. Hz from its horn. If the observer detects a frequency of 470. Hz, how fast is the car moving? The speed of sound is 343 m/s. **Answer is 15 m/s**

18. While standing near a railroad crossing, a person hears a distant train horn. According to the train's engineer, the frequency emitted by the horn is 440 Hz. The train is traveling at 20.0 m/s and the speed of sound is 346 m/s.

a) What would be the frequency of the train's horn if the train were at rest? **Answer is 440 Hz**
b) What is the adjusted frequency that reaches the bystander as the train approaches the crossing? **Answer is 467 Hz**
c) What is the adjusted frequency that reaches the bystander once the train has passed the crossing? **Answer is 416 Hz**

19. A burglar alarm is wailing with a frequency of 1200. hertz. What frequency does a cop hear who is driving towards the alarm at a speed of 40.0 m/s? The air temperature is 35.0 ºC. **Answer is 1336 Hz**

20. With reference to the previous problem, what frequency would the burglar hear, if he was running away from the alarm at a speed of 10 m/s? **Answer is 1166 Hz**

21. A cop car's siren has a frequency of 700. Hz. If you are standing on the sidewalk as the cop car approaches you at a speed of 15.0 m/s, what frequency would you hear? The speed of sound is 343 m/s. **Answer is 732 Hz**

22. In the previous problem, what frequency would you hear if the cop were driving away from you at a speed of 25 m/s? **Answer is 652 Hz**

23. An alarm clock is dropped off the edge of a tall building. You, standing directly under it, hear a tone of 1350. Hz coming from the clock at the instant it hits the ground. Since you know the building is 25.0 m tall, you can find out what the frequency of the alarm would be if you had just held it in your hands. What would that frequency be? The speed of sound is 343 m/s. **Answer is 1263 Hz**

24. Two identical cars are driving toward one another and sounding their horns. You're the driver of one of the cars. You measure your car's horn to be sounding at 512 Hz, but you measure the horn of the other car to be sounding at 600. Hz. The speed of sound is 345 m/s. If you are traveling at 26.8 m/s , how fast is the other car traveling? **Answer is 27.7 m/s**

25. A galaxy is moving away from the earth at 1.8×10^7 m/s. What frequency of light is observed on earth if the galaxy is emitting a frequency of 6.2×10^{14} Hz? X