EEM 323

ELECTROMAGNETIC WAVE THEORY II

DOPPLER EFFECT

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Prof. S. Gökhun Tanyer

DEPARTMENT OF ELECTRICAL–ELECTRONICS ENGINEERING

FACULTY OF ENGINEERING, BASKENT UNIVERSITY

Önemli not: Ders notlarındaki şekillerin hazırlanmasında internet ortamından faydalanılmıştır. Özellikle belirtilmeyen tüm şekil, tablo, eşitlik ve denklemler vb. "D. K, Fundamentals of Engineering Electromagnetics, Addison-Wesley Inc." ile "D. K, Field and Wave Electromagnetics, Mc-Graw Hill Inc." kitabından taranarak elde edilmiştir. Alıntıların kaynağına kolay ulaşılabilmesi maksadıyla numarası ve altyazıları da gösterilmektedir.

DERS KİTABI

[1] David Keun Cheng, *Fundamentals of Engineering Electromagnetics*, Addison-Wesley Publishing, Inc., 1993.
veya David Keun Cheng, Çeviri: Adnan Köksal, Birsen Saka, *Mühendislik Elektromanyetiğinin Temelleri – Fundamentals of Engineering Electromagnetics*, Palme Yayınları.

KAYNAK / YARDIMCI KİTAPLAR:

[2] David Keun Cheng, *Field and Wave Electromagnetics*, Addison-Wesley Publishing, Inc. *veya* David Keun Cheng, Çeviri: Mithat İdemen, *Elektromanyetik Alan Teorisinin Temelleri – Field and Wave Electromagnetics*, Literatür Yayıncılık.

[3] Stanley V. Marshall, Richard E. DuBroff, Gabriel G. Skitek, *Electromagnetic Concepts and Applications*, Dördüncü Basım, Prentice Hall International, Inc., 1996.

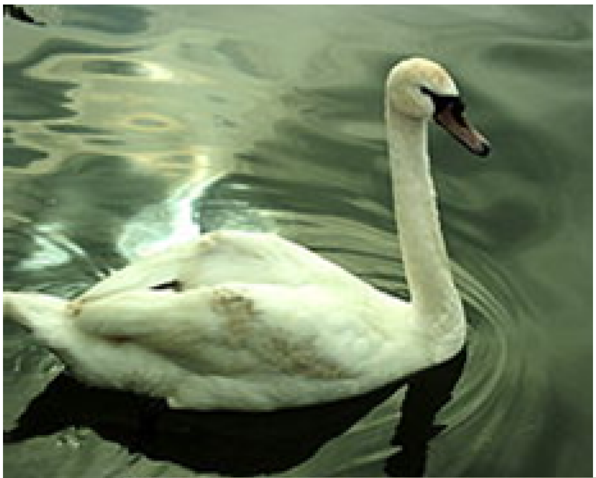
[4] Joseph A. Edminister, Elektromanyetik, 2. Baskıdan çeviri, Çevirenler: M. Timur Aydemir, E. Afacan, K. C. Nakipoğlu, Schaum's Outlines, McGraw Hill Inc., Nobel Yayın Dağıtım, Ankara, 2000.

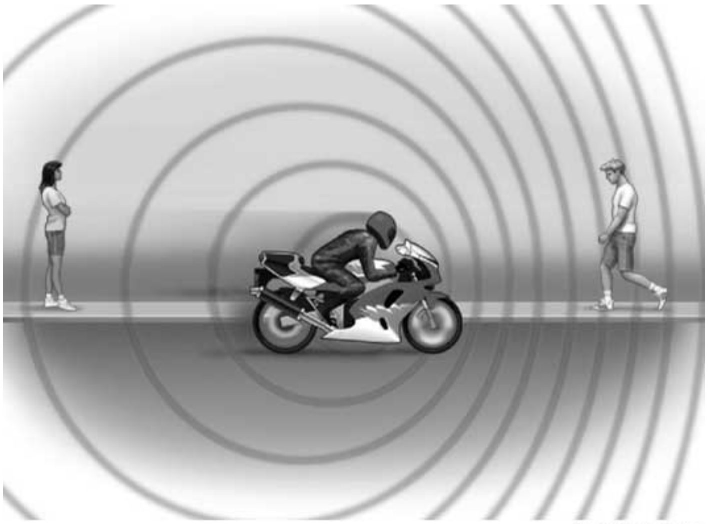
DOPPLER EFFECT

Christian Doppler
(1803 – 1853)

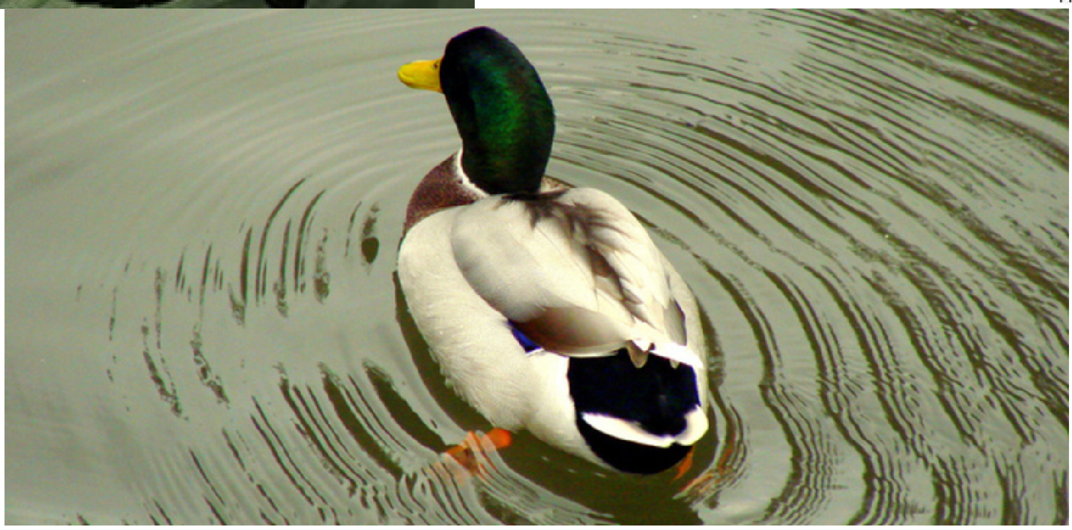
When the source of the waves is moving toward the observer, each successive wave crest is emitted from a position closer to the observer than the previous wave. Therefore each wave takes slightly less time to reach the observer than the previous wave. Therefore the time between the arrival of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are travelling, the distance between successive wave fronts is reduced; so the waves "bunch together". Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wave fronts is increased, so the waves "spread out".

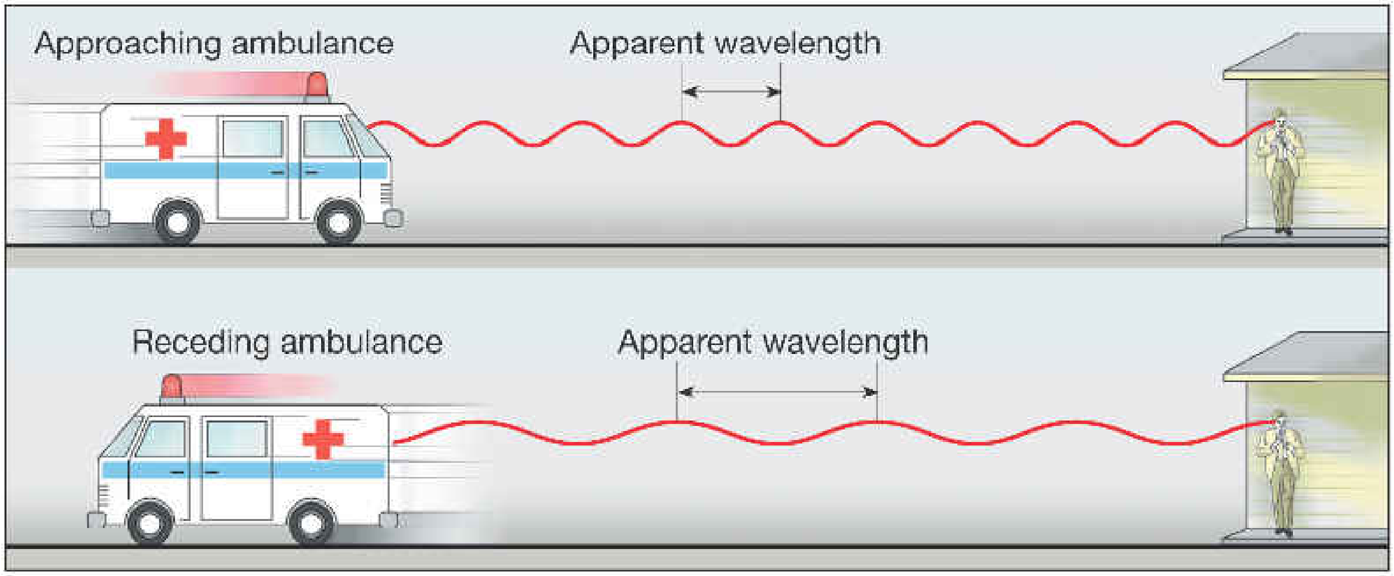
OBSERVATIONS:





Precision Graphics





http://www.google.com.tr/imgres?imgurl=http://mail.colonial.net/~hkaiter/aa_newest_images/doppler.effect.diagram.jpg&imgrefurl=http://mail.colonial.net/~hkaiter/Doppler_Effect_Shift.html&h=332&w=792&sz=32&tbnid=puppu2LAGTW1pM:&tbnh=90&tbnw=215&zoom=1&usg=__TjIncK-NZ63jMFh6RMr3Pak-F5o=&docid=0S00zZDk2ZatkM&sa=X&ei=I7diUvufE83FswaC8IGIBA&ved=0CCsQ9QEwAA

QUESTION:

Draw the wavefronts of a wave originating from a point source of;

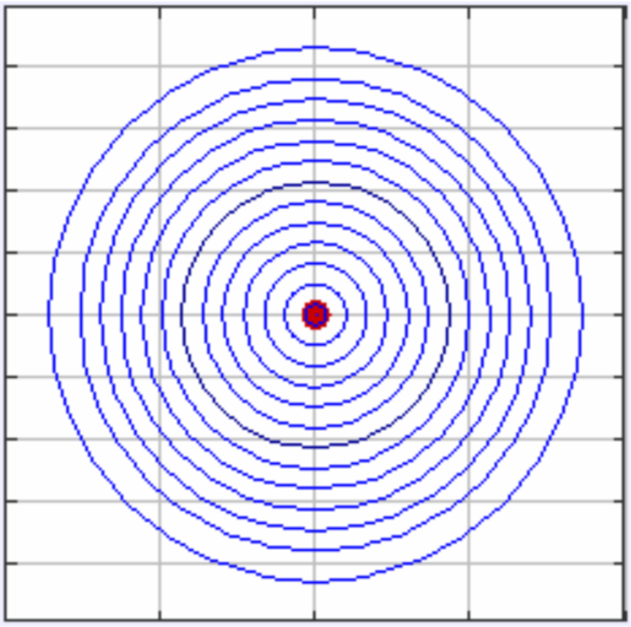
a) Zero velocity (stationary),

Source traveling right with a speed of;

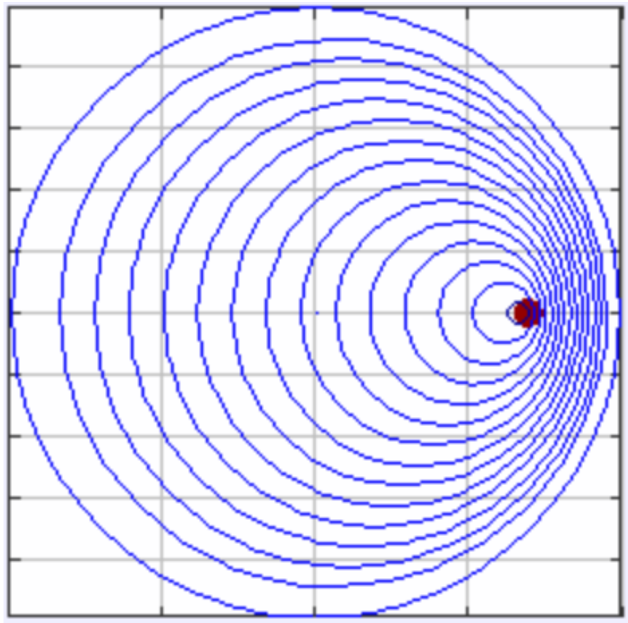
b) 3/4 of the speed of wave,

c) equivalent to the speed of wave,

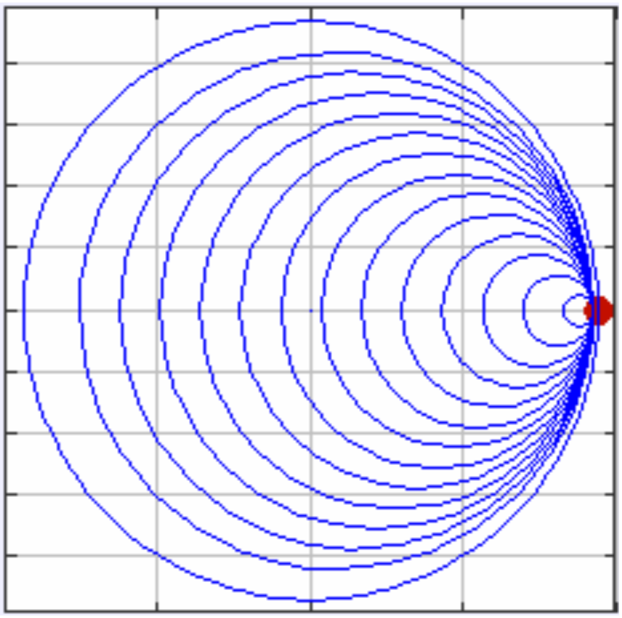
d) 4/3 of the speed of wave



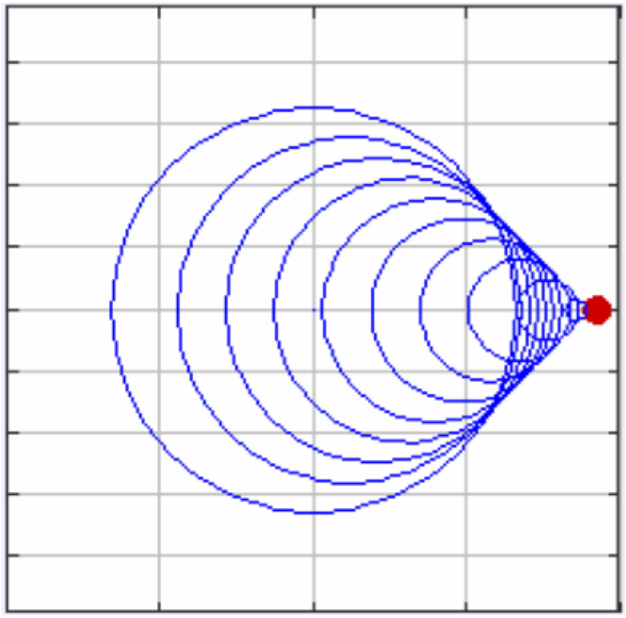
Stationary source



Source traveling right with a speed 3/4 of the speed of the wave

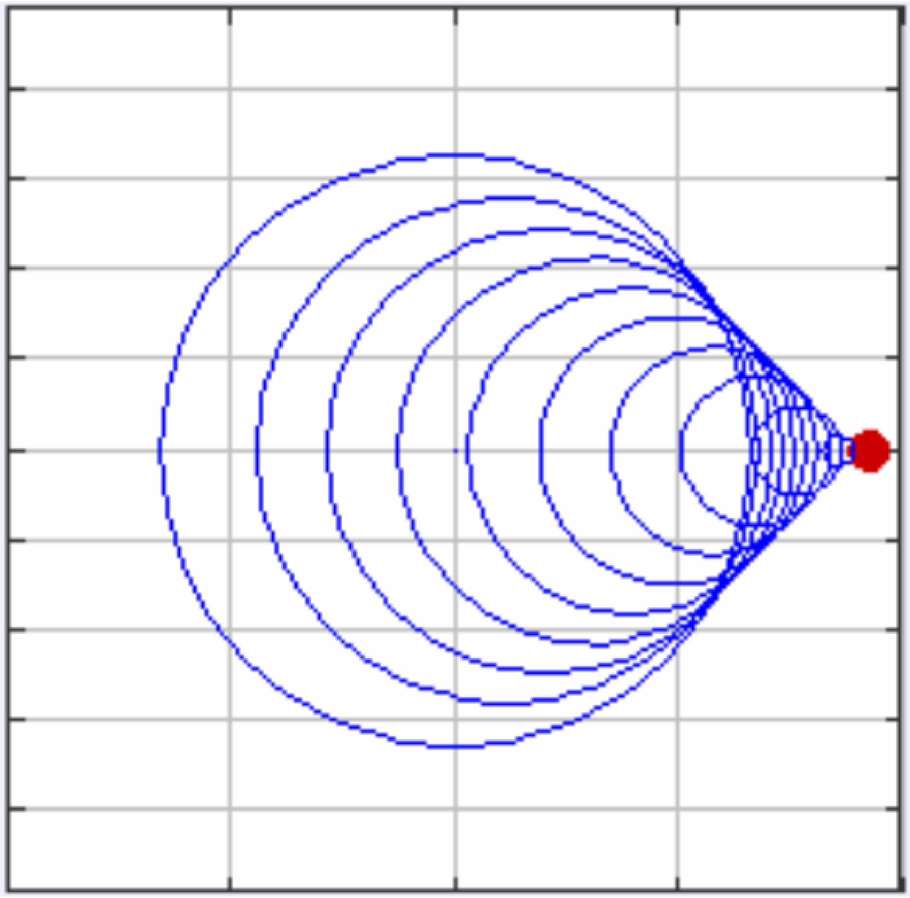


Source traveling right with the speed of wave

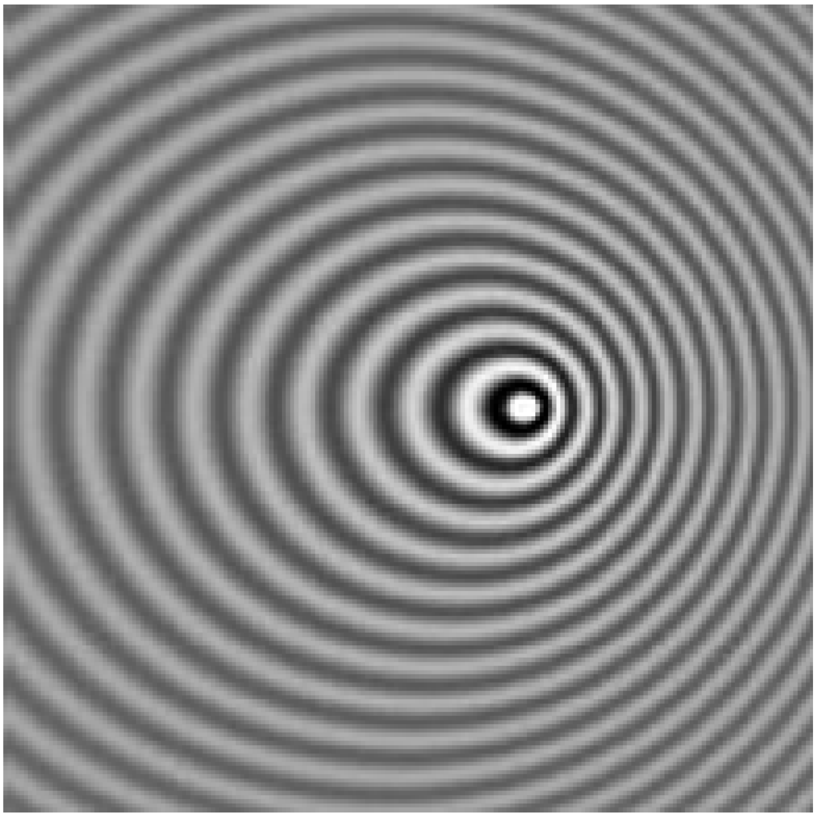


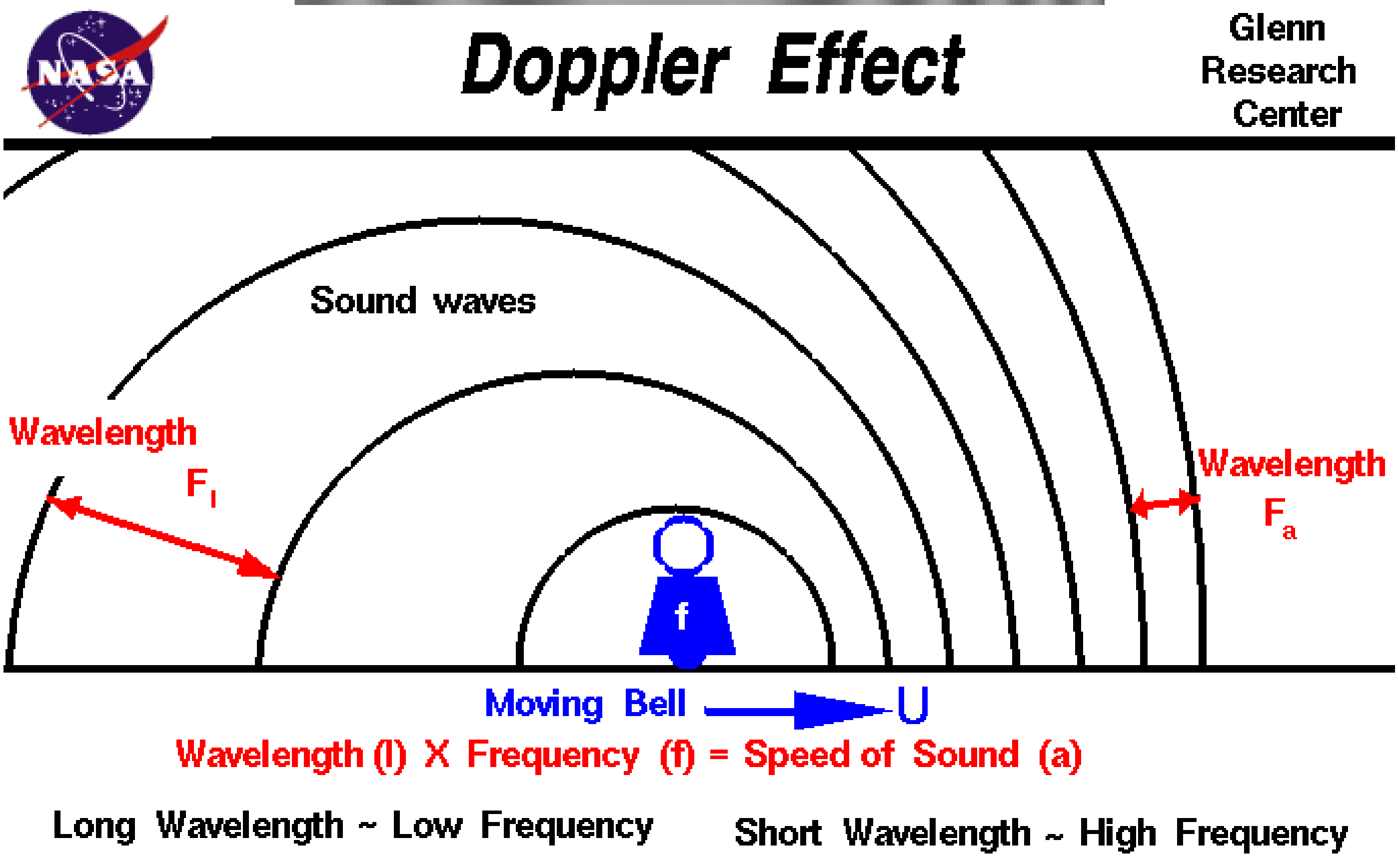
Source traveling right with a speed 4/3 of the speed of wave

[wikipedia.com]

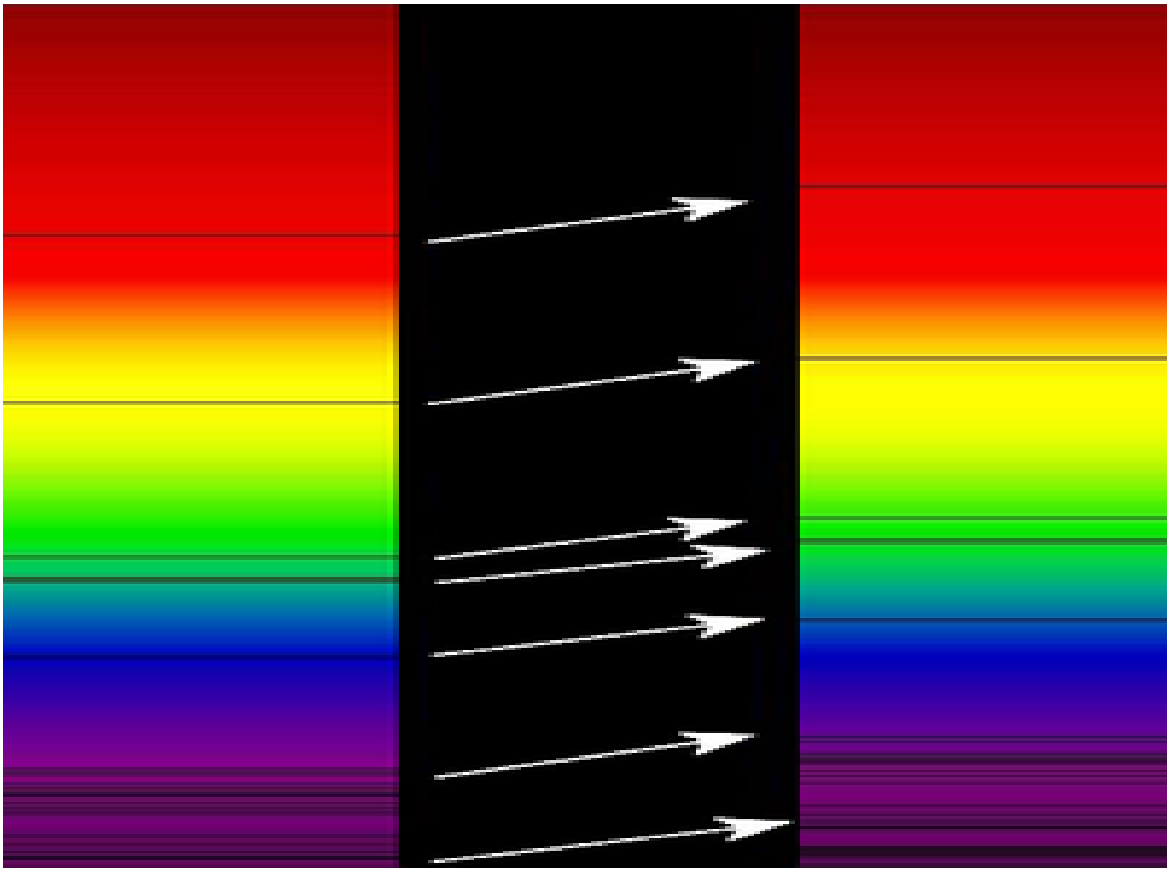


http://www.acs.psu.edu/drussell/Demos/doppler/mach1.html





What about the electromagnetic waves emitted by distant galaxies in space ?

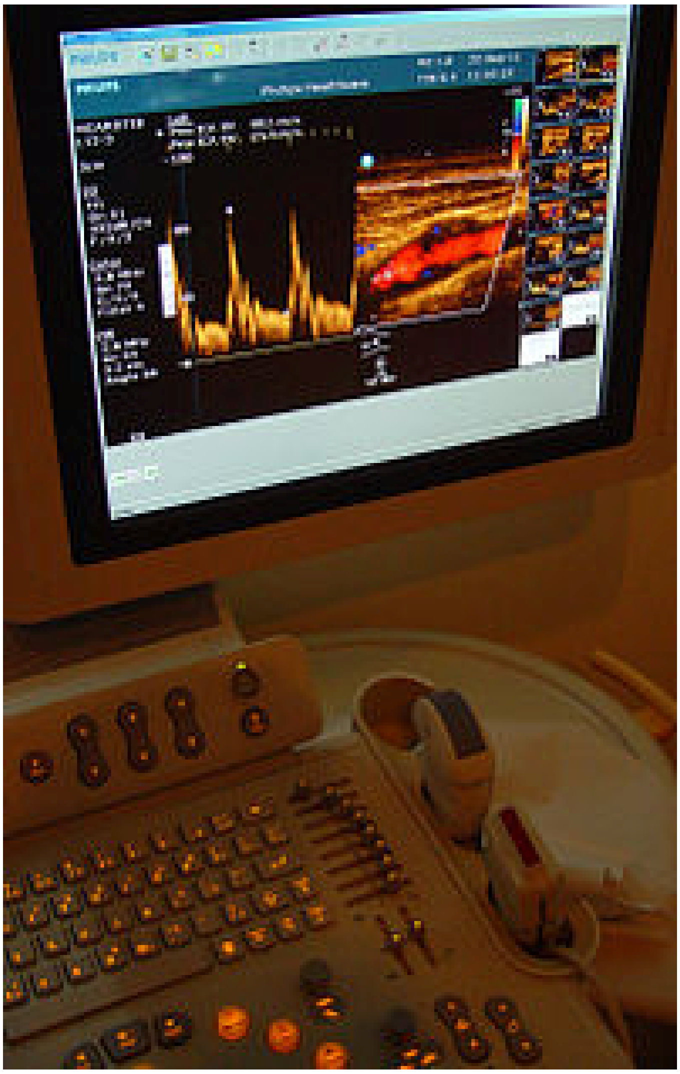


Sun measurements (equivalent to the stationary laboratory measurements.)

Observation by the telescopes

Redshift of spectral lines in the optical spectrum of a supercluster of distant galaxies (right), as compared to that of the Sun (left)

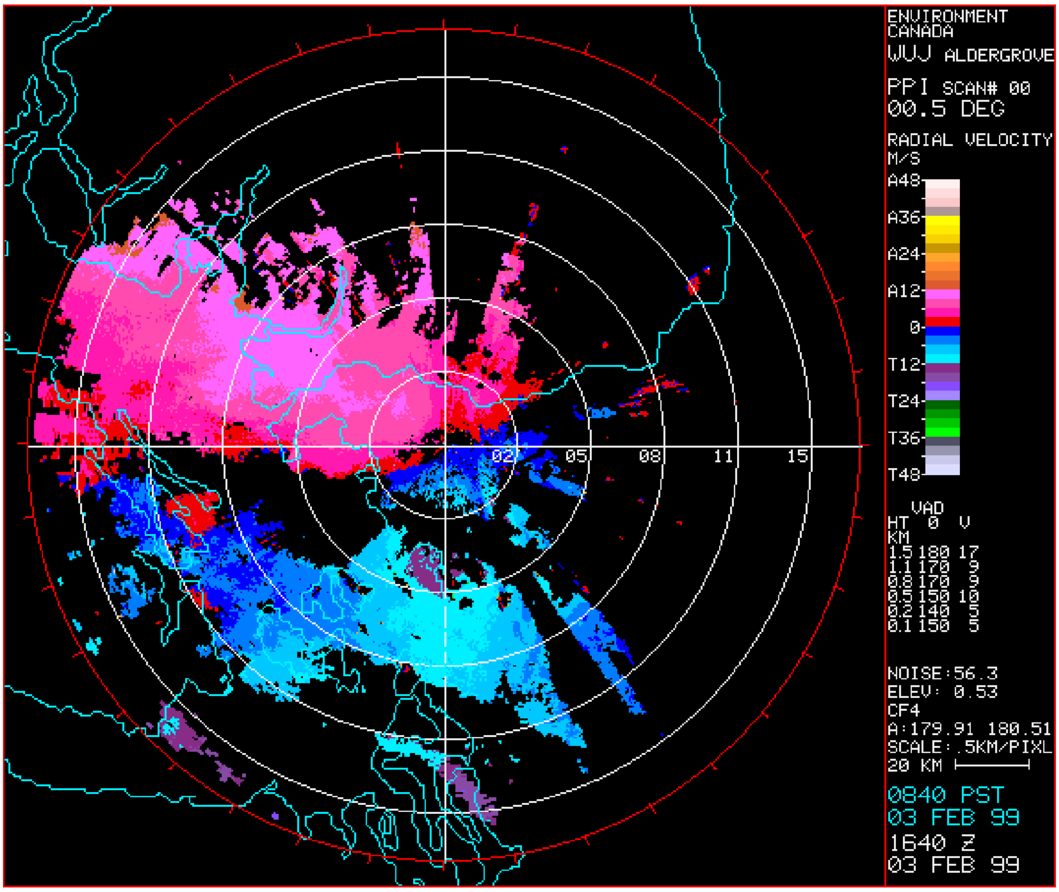
How about ultrasonic sound waves, do you think Doppler effect works on them too?



Color flow ultrasonography (Doppler) of
a carotid artery - scanner and screen

http://hyperphysics.phy-astr.gsu.edu/hbase/sound/dopp.html
http://www.qrg.northwestern.edu/projects/vss/docs/communications/3-what-is-the-doppler-effect.html

Doppler radar weather report:



http://mail.colonial.net/~hkaiter/Doppler_Effect_Shift.html

Police radar:

Watch The Big Bang Theory – The Doppler Effect !

http://www.youtube.com/watch?v=Y5KaeCZ_AaY

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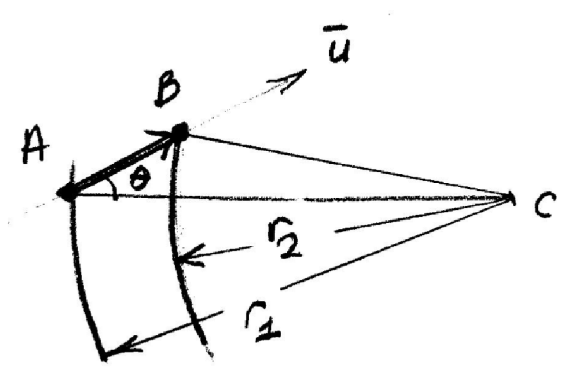

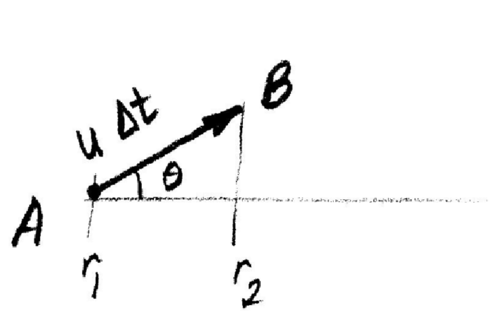

Observer is stationary at point C.

Source is traveling thru points A to B with velocity $\bar{u}$.

Source is at A at $t=0$ and distance r_1.

B at $t=\Delta t$ and " r_2.

Sound will travel from A to C in t_1 secs.

B to C in t_2 secs.

$$t_1 = r_1/c$$

$$t_2 = r_2/c \quad \text{or} \quad \Delta t + r_2/c$$

$$(r_1 - r_2)/c$$

$$r_1 - r_2 = \left[r_1^2 - \underbrace{2 r_1 (u \Delta t)}_{\text{small}} \cos\theta + \underbrace{(u \Delta t)^2}_{\text{very small (negligible)}} \right]^{1/2}$$

If $r_1^2 \gg u \Delta t \rightarrow$ small $\longrightarrow$ very small (negligible)

2

Assume Δt to be the period of the ②
original source, then $f_s = 1/T$ (Hertz).

Let us calculate the time difference $\Delta t'$
observed at the observation point C.

$$\Delta t' = \frac{r_1 - r_2}{c}$$

S.G.Tanyer

$$\cong \frac{1}{c}\left(r_1^2 - 2r_1(u\Delta t)\cos\theta\right)^{1/2}$$

$$\cong \frac{1}{c}\, r_1\left(1 - \frac{2}{r_1}(u\Delta t)\cos\theta\right)^{1/2}$$

Taylor's series

$$\cong \frac{r_1}{c}\left(1 - \frac{(u\Delta t)}{r_1}\cos\theta\right)$$

$$\Delta t' \cong \underbrace{\frac{r_1}{c}}_{\Delta t} - \frac{(u\Delta t)\cos\theta}{c}$$

$$\boxed{\Delta t' = \Delta t - \frac{1}{c}(u\Delta t)\cos\theta} \neq \Delta t\,!$$

Observed period is less than the period of the source. What is the observed f'?

3

$$f_s = 1/\Delta t$$

$$f_{ob} = f' = \overbrace{\frac{1}{\Delta t}}^{f_s} \frac{1}{\left(1 - \frac{u}{c}\cos\theta\right)}$$

observed

Taylor

$$f' \cong f_s \left(1 + \frac{u}{c}\cos\theta\right)$$

valid if $\left(\frac{u}{c}\right)^2 \ll 1$

Doppler shift of frequency

$$\boxed{f^{+}_{doppler} \cong f\left(\frac{u}{c}\right)\cos\theta \quad (\text{Hertz})}$$

If the source is moving away from the observer, then we observe frequency decrease

$$\boxed{f^{-}_{doppler} \cong -f\left(\frac{u}{c}\right)\cos\theta \quad (\text{Hertz})}$$

HW Solve Exercise 7.2.