Physics 101.

Lecture 25

Monday, March 10, 2003.

Topics Covered.

The Doppler Effect.

standing waves.

Beats.

Ref: 14-6, 7, 8, 9.

- The Doppler effect.

  — The observed frequency is shifted when there is a relative motion between the source and the observer.

① No relative motion, No shift.

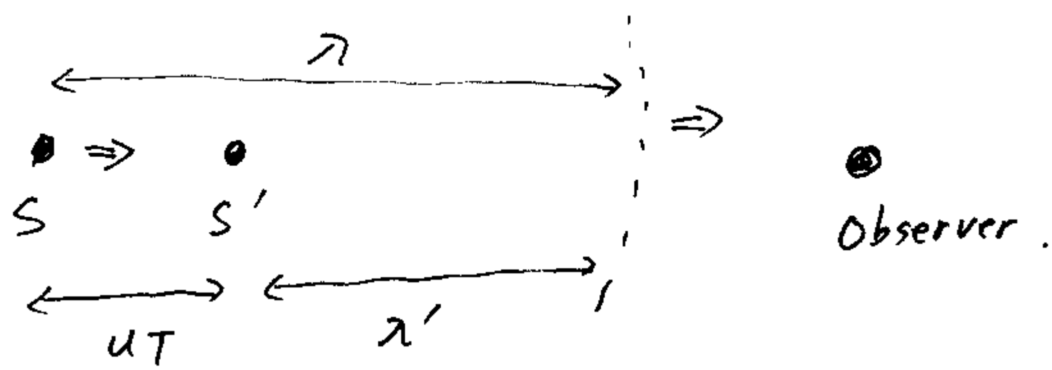
$$f' = f. \qquad \begin{cases} f' - \text{observed freq.} \\ f - \text{original freq. generated by the source.} \end{cases}$$

2. Source approaching.

$$f' = \frac{f}{\left(1-\frac{u}{v}\right)}.$$

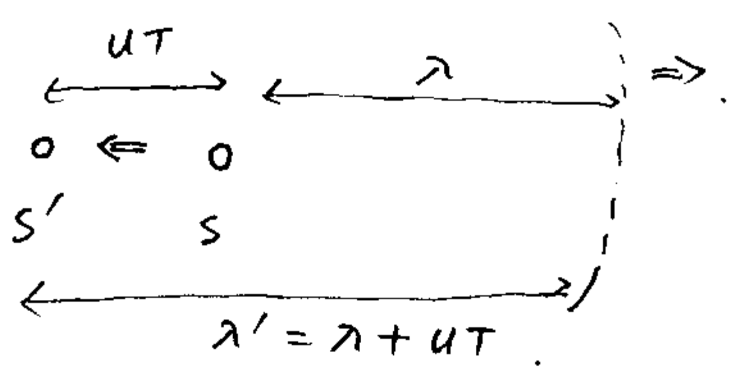
v — speed of wave.
u — speed of source.

Reason: wave length becomes shorter: $\lambda' = \lambda - uT$.



3. Source receding.

— wavelength becomes longer: $\lambda' = \lambda + uT$.

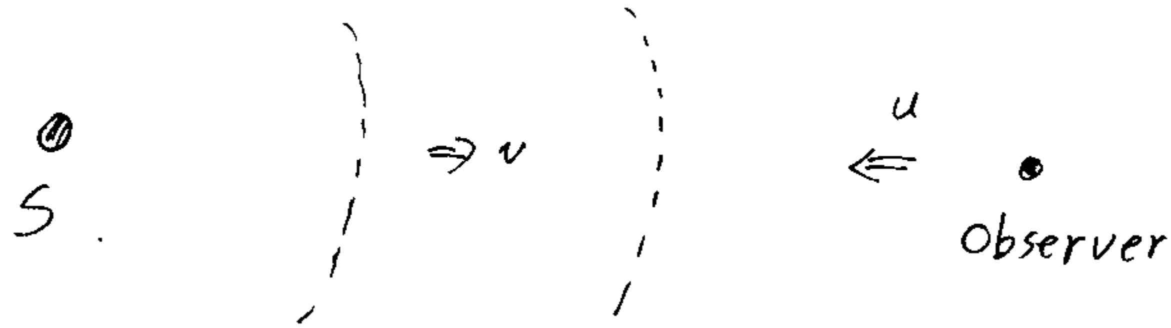


Then: $$f' = \frac{f}{\left(1+\frac{u}{v}\right)}. \qquad f' < f.$$

The observed freq. is lower.

④ Observer approaching.

— The source doesn't move, but the observer moves towards the source.



Then, to the observer, the speed of the wave is

$$v' = v + u.$$

the observed frequency:

$$f' = \frac{v'}{\lambda} = \frac{u+v}{\lambda} = f\left(1+\frac{u}{v}\right).$$

$f' > f$. The observed freq. is higher

⑤. observer receding at a speed of u.

The speed of wave to the observer becomes:

$$v' = v - u.$$

Then: $f' = f\left(1-\frac{u}{v}\right) < f$. (freq. becomes lower).

⑥ General case

— when both the source and the observer are moving.

$$f' = f\left(\frac{1 \pm u_o/v}{1 \mp u_s/v}\right) \begin{array}{l} \leftarrow \text{observer.} \\ \leftarrow \text{source} \end{array}$$

approaching : $f' > f$. (shift to higher freq)

receding: $f' < f$. (shift to lower freq.).

e.g. CAPA set 6 # 11

Double Doppler effect.

① The van is a moving observer when it receives the wave from the radar. $f' = f(1 - \frac{u}{v})$

②. Then the van becomes a moving source when it reflects the wave to the police. $f'' = f' / (1 + \frac{u}{v})$

$$\therefore \quad f'' = f\left(\frac{1 - \frac{u}{v}}{1 + \frac{u}{v}}\right)$$

If $u \ll v$, f'' is slightly lower than f.

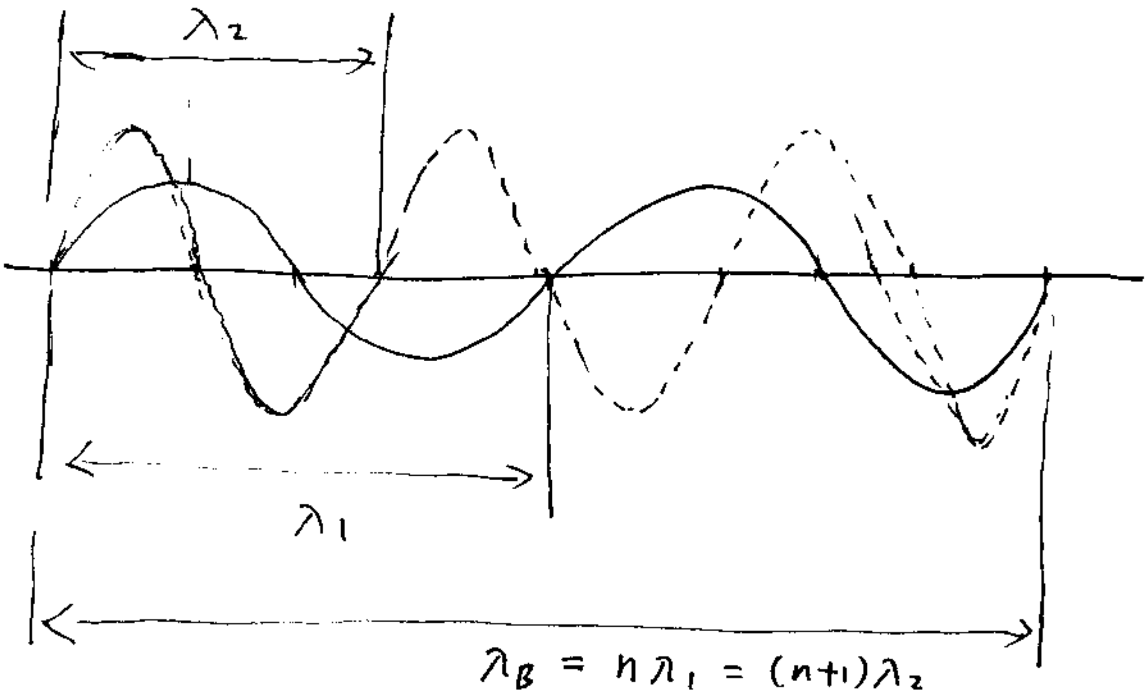
- Beats.

Two waves with nearly the same frequency have a low "Beat frequency".

For sound waves, the beat can be audible. i.e, the intensity varies at a low "beat frequency".

25-5.

Demo : Tuning Forks.



Wavelength of the beat :

$$n\lambda_1 = \lambda_B$$
$$(n+1)\lambda_2 = \lambda_B .$$

eliminate n : $$\frac{\lambda_B}{\lambda_1} = \frac{\lambda_B}{\lambda_2} - 1$$

$$\frac{1}{\lambda_B} = \frac{1}{\lambda_2} - \frac{1}{\lambda_1} .$$

$$f_B = f_2 - f_1 \qquad (\because f = \frac{v}{\lambda})$$

$\therefore$ frequency of the beat : $f_B = \left| f_2 - f_1 \right| .$

~~Math derivation~~

- Math derivation for the frequency of the beat.
  (p.449)

Idea: at a given location (fixed x).

wave 1: $y_1 = A_1 \cos(\omega_1 t)$

wave 2: $y_2 = A_2 \cos(\omega_2 t)$.

Total wave: $\underline{\underline{y = y_1 + y_2}}$

$\Uparrow$

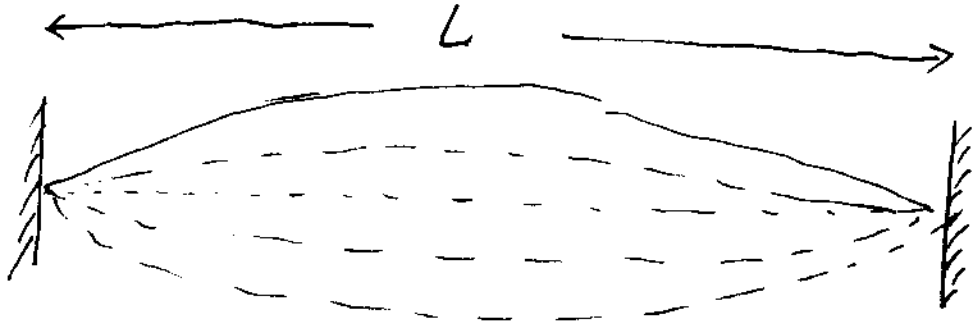
Superposition Principle of waves.

- standing waves.
  — NOT Travelling

If the two ends of a string is fixed, Then there is no motion at the end points. The wave is called a standing wave.

e.g:

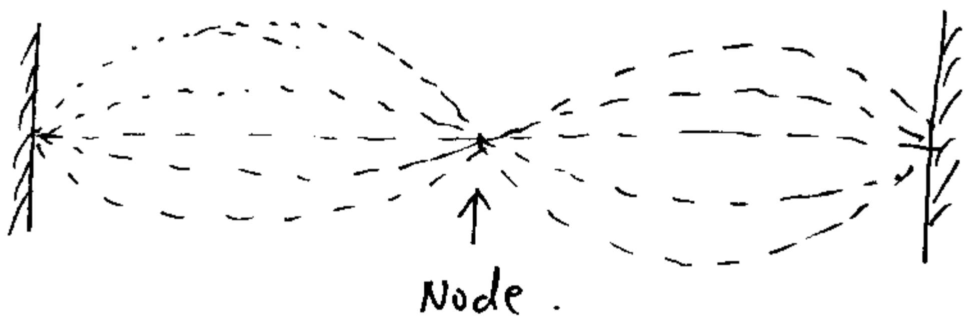
$L = \frac{\lambda}{2}$.



OR.

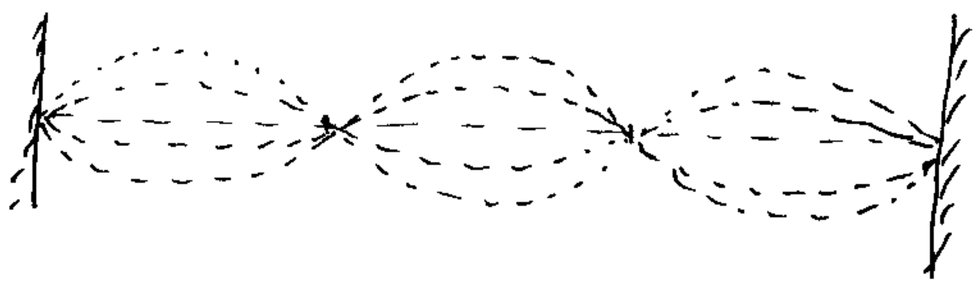
$L = \lambda$.

$= \frac{\lambda}{2} \cdot (2)$



OR

$L = \frac{\lambda}{2}(3)$



... ...

In general: $L = \frac{\lambda}{2}(n)$, $\lambda = \frac{2L}{n}$, $f = \frac{nv}{2L} = n \cdot \frac{v}{2L}$.

$n=1$. 1st Harmonic (fundamental): $f_1 = \frac{v}{2L}$.

$n=2$. 2nd Harmonic. $f_2 = \frac{v}{2L}(2)$

... ...

$n=k$. kth Harmonic. $f_k = \frac{v}{2L}(k)$.

- Math description of a standing wave.

— The combination of an on-going wave to the right and a reflected wave to the left.