Senior's Tuition And Mentorship Program (Semester 2, 2014)
Year 3

3.1 Physics: Sound, C.R.O. and Lenses

Topic 4 – Sound and C.R.O

Definition of Sound Waves & Characteristics

Sound waves are:

- **Longitudinal** waves
- Comprise series of **compressions and rarefactions**
- Propagate energy from one point to another **without transporting matter**
- Produced by the **vibration** of some objects

*Note: Sound cannot travel in vacuum.

Speed of sound

Factors affecting speed of sound:

1. Probability of particle collision to propagate energy
    a. Particle arrangement/strength of interatomic forces (medium)
    b. Speed of individual particles (temperature of medium)

*Note: **Wave speeds are dependent only on the medium**. Hence, the speed of the wave will be the fastest in a solid as the particles are very closely packed, which means that there is a greater probability of particles colliding with one another and thus transmitting energy.

Speed of Sound vs. Temperature

When temperature ↑, probability of particle collision ↑.
Hence, wave **speed ↑.**

Speed of Sound vs. Humidity

When humidity ↑, more water molecules in the air ↑.
Hence, **wave speed ↑.**

Speed of Sound vs. Wind Conditions

When wind is in same direction as sound:

$V_{moving\ air} > V_{still\ air}$

When wind is in opposite direction as sound:

$V_{moving\ air} < V_{still\ air}$

Pitch/Loudness of Sound

The **loudness** of sound is dependent on **the amplitude** of the wave. Hence, a sound wave with greater amplitude will be louder in volume.

The **pitch of sound** is dependent on **the frequency** of the wave. Hence, a sound wave with a greater frequency will be higher in pitch.

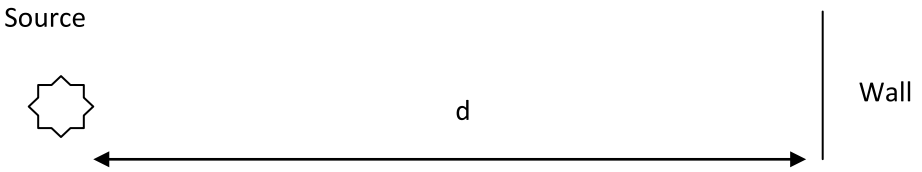
Ultrasound / Infrasound

The **range of audible frequencies** for an average **human** is between **20 Hz and 20 kHz.** The range decreases as we get older and our ears lose their sensitivity to the extreme end of the range.

Ultrasound is sound **> 20 kHz** in frequency, while **infrasound** is sound **< 20 Hz** in frequency.

Echo

An echo is essentially the **reflection of sound.** Sound obeys the **law of reflection**.



In the above case, the time taken for the sound to return to the source after the echo, t is given by:

$$t = 2d / v$$

where d is the distance between the source and wall, and v is the speed of sound.

Reverberation

When multiple reflections of sound occur, reverberation occurs. **Reverberation** is the persistence of sound in a particular space after the original sound is removed. A reverberation occurs when a sound is produced in an enclosed space causing a large number of echoes to build up and then slowly decay as the sound is absorbed by the walls and air.

Cathode Ray Oscilloscope (C.R.O.)

The CRO plots a graph of **voltage (y axis)** against **time (x axis).** The scales on the y and x axes can be adjusted using the time base and voltage gain controls.

**Definitions to note:

Frequency (of a C.R.O. trace): No. of waves / time (across screen)

Time-base frequency = 1 / distance of screen * total time

Topic 6 – Lenses

Definition of an **optical medium**: A material that light can pass through, e.g. water, air, glass. An optical medium is said to be optically dense if it reduces the speed of light.

Definition of **refraction**: Bending of light when it passes from one medium to another, with differing refractive indices

Converging lenses

Definition of terms

- **Principal axis –** the line passing through the centres of curvature of the lens
- **Principal** focus/**focal point** – A point on the principal axis where rays of light parallel to the principal axis converge. There is one on either side, which means that an ideal lens could be flipped and the results would be the same.
- **Focal length** – horizontal distance between focal point and optical centre of lens.
- **Optical centre** – imaginary point inside a lens through which a light ray is able to travel without being deviated

Drawing ray diagrams

A. Centre ray – Ray passing through the optical centre of the lens emerges without being deflected
B. Parallel ray – Ray parallel through the axis on the incident side passes through the focus point on the other side.
C. Focal ray – Ray through the focus point on the incident side emerges parallel on the other.

***Note: Usually A and B are sufficient to find the image location. C can serve as a check.**

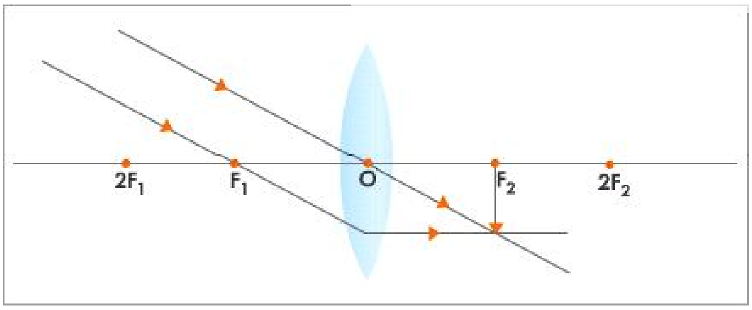
Identifying real and virtual images

Real images – Rays converge on an image point so that they could be **captured on a screen**

Virtual images – Rays do not converge, and so **cannot be captured,** but seem to come from an image point.

The 6 Different Ray Diagrams (arranged with decreasing **u)

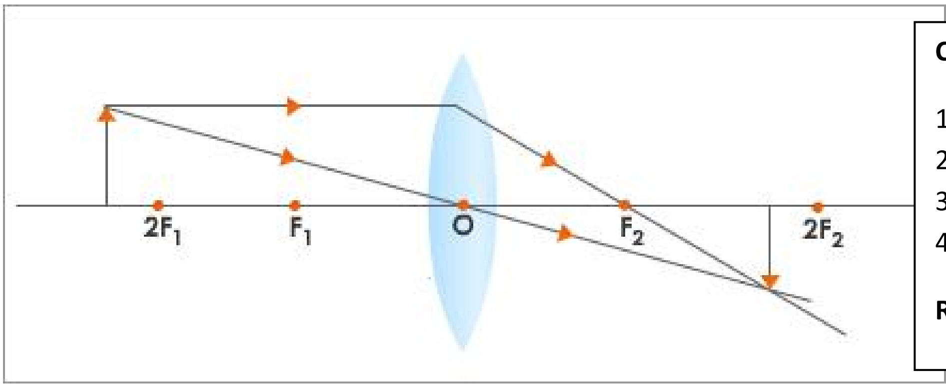
***Note: f is focal length, u is object distance, v is image distance.**



Case #1: When object at infinty:

1. Image location: at F (focal point)
2. Image type: Real
3. Orientation: Inverted
4. Size: Same

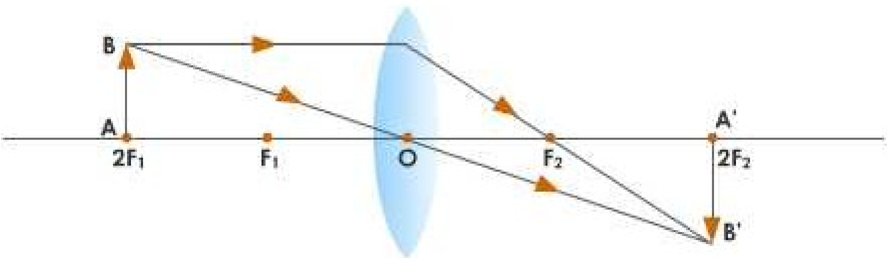
Real, inverted, image formed at F



Case #2: When u > 2f:

1. Image location: v > f, v <2f
2. Image type: Real
3. Orientation: Inverted
4. Size: Diminished

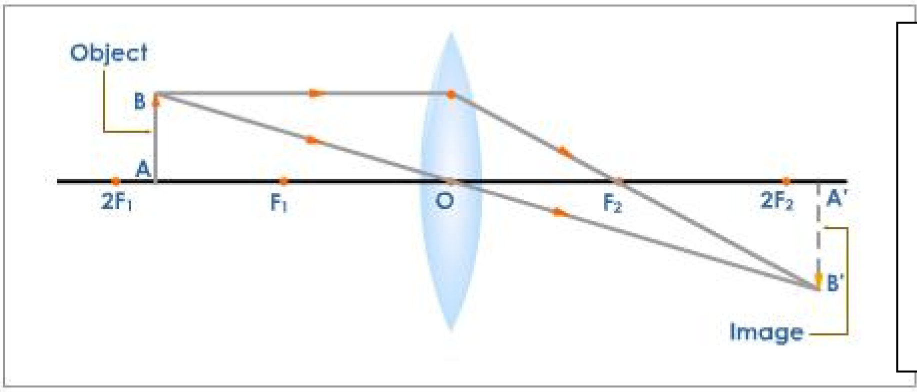
Real, inverted, diminished image



Case #3: When u = 2f:

Image location: v =2f
Image type: Real
Orientation: Inverted
Size: Same

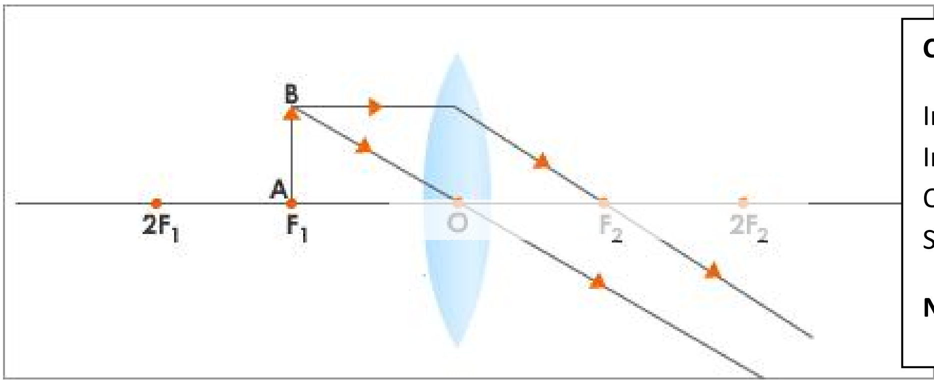
Real, inverted image of the same size



Case #4: When u < 2f and u > f:

Image location: v > 2f
Image type: Real
Orientation: Inverted
Size: Magnified

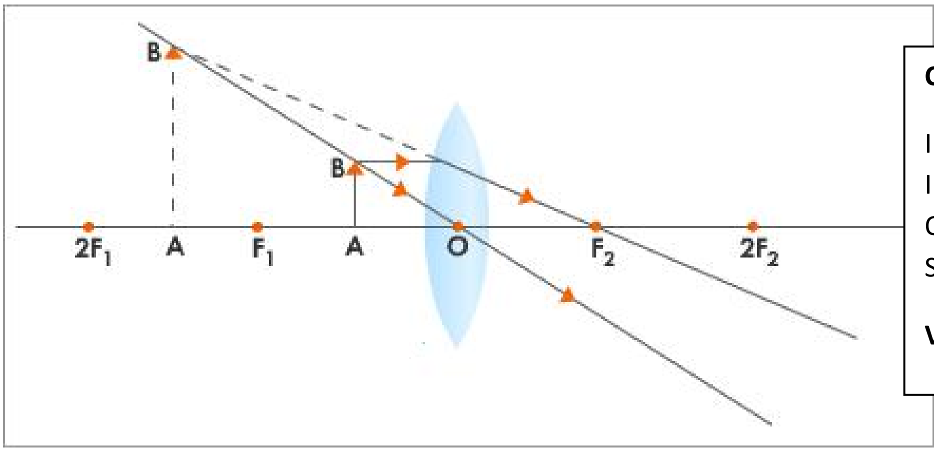
Real, inverted, magnified image



Case #5: When u = f:

Image location: At infinity
Image type: Doesn't form
Orientation: Doesn't form
Size: None

No Image



Case #6: When 0 < u < f:

Image location: v < 0, 0 < |v| < f
Image type: Virtual
Orientation: Upright
Size: Magnified

Virtual, upright, magnified image

2 Formulae to remember

1. $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ where f is focal length, u is object distance and v is image distance.

Note: **When 0 < u < f, or Case #6, since the image is formed on the same side as the object, **v is negative** when calculating using the thin lens equation.

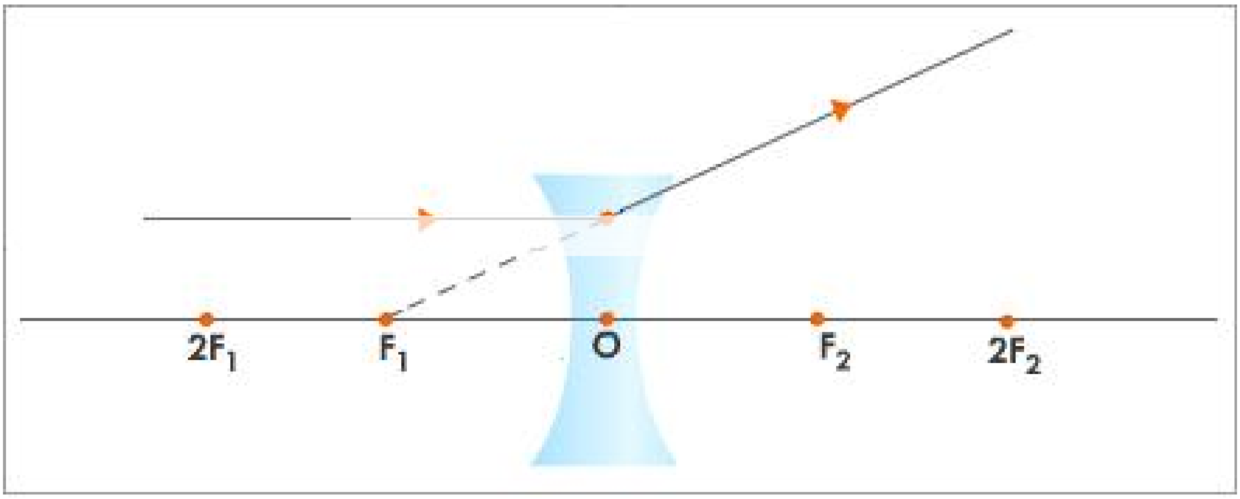
2. Magnification = $\frac{Image\ Height}{Object\ Height} = \frac{Image\ Distance\ (v)}{Object\ Distance\ (u)}$

Diverging Lenses

Drawing diverging lenses diagrams

A. Centre ray is **not deflected**
B. Ray parallel to principal axis of the incident side **refracts through the lens** and **appears to have come from the principal focus.**
C. Ray heading towards the focal point **emerges parallel to the principal axis.**

Diverging lenses diagram



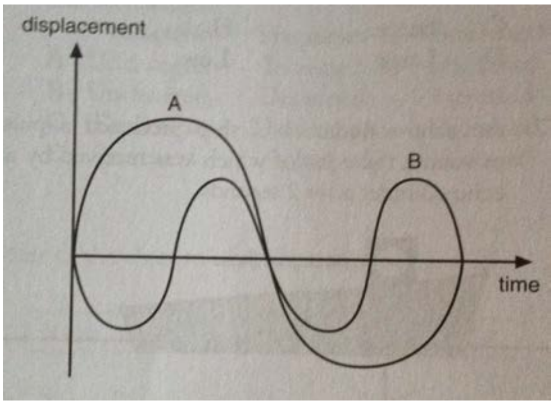
Practice Questions

MCQ

1. What is the distance between two successive rarefactions in sound waves of velocity 330ms^{-1} and frequency 540 Hz?

A. 0.23 m **B.** 0.61m **C.** 1.63m **D.** 2.24m

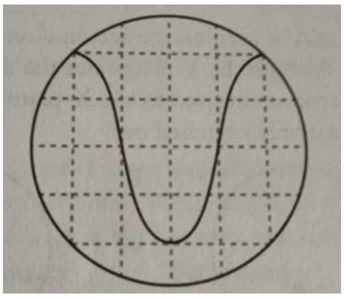
2. The diagram on the right shows the displacement-time graphs of two notes produced by an electronic synthesizer, A and B. Which of following statements about A and B is/are false?



1. A is louder than B
2. Pitch of A is higher than pitch of B
3. Frequency of B is lower than A
4. A and B have the same speed.

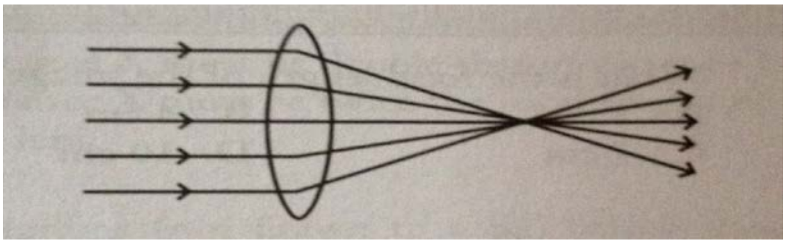
A. 1 and 3 **B.** 2 and 3 **C.** 3 only **D.** 2 and 4

3. The diagram on the right illustrates the trace obtained on the screen of an oscilloscope when a given signal is applied to the input terminals. The time base is set at 3.0 ms/div, and the voltage sensitivity is set at 2.0 V/div. Which of the following correctly represents the peak voltage frequency of the signal?

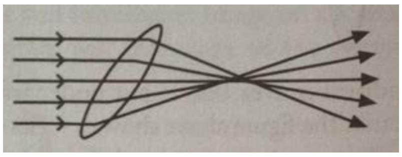


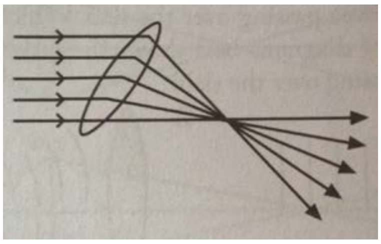
A. 4 V, 83.3 Hz **B.** 8 V, 83.3 Hz **C.** 4 V, 167 Hz **D.** 8 V, 167 Hz

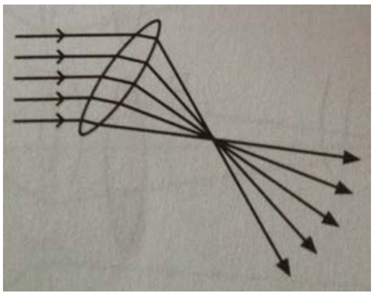
4. A converging lens focuses a parallel set of rays as indicated in the figure below.

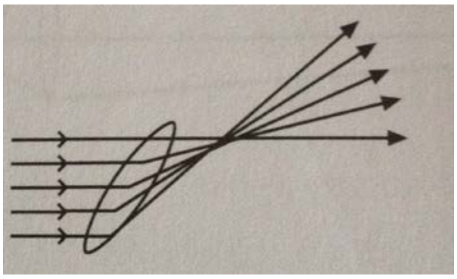


If the lens is tilted to one side as shown, which is the most likely way in which the rays will behave?

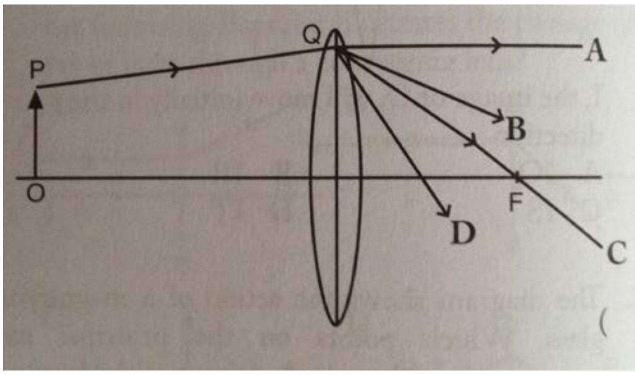
A. 

B. 

C. 

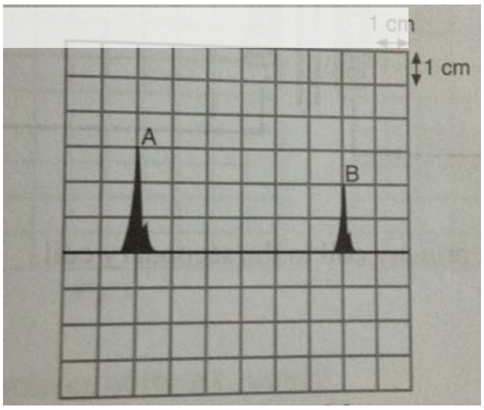
D. 

5. An object OP is placed near a converging lens. F is one of the focal points of the lens. Which one of the rays (**A – D**) best represents the path of the incident ray PQ after it passes through the lens?



Open-ended questions

6. A sonar sends a small pulse of ultrasound from the bottom of a ship. The reflected pulse is detected by a receiver onboard the ship. The display of the oscilloscope screen is shown below.



Given that the time base is set at 0.25 ms per division,

(a) Find the time taken between sending and receiving the pulse. [1]

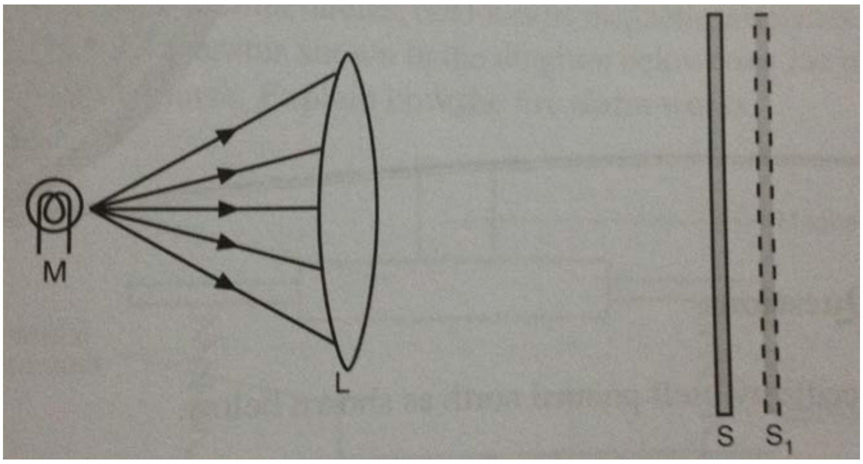
(b) Given that the refractive index of water is 1.33 and that the frequency of ultrasound used is 44 kHz, calculate the depth of the water below the ship. [3]

(c) If the frequency of the ultrasound used is doubled, what effect, if any, will it have on

(i) the speed? (ii) the time between sending and receiving the pulse? [2]

(d) A large submarine passes directly below the ship. If the submarine is one-quarter the depth of the water under the ship, find the new distance between the pulses on the screen. [2]

7. In the diagram shown below, M is a lamp which emits light in all directions. Five light rays are shown in the diagram. L is a converging lens. A screen is move to and fro in front of the lens until a sharp image is obtained when the screen is at position S.



(a) What is meant by the focal length of a converging lens? [1]

(b) Complete the ray diagram when the five light rays reach the screen. [2]

(i) State 2 characteristics of the image formed on the screen. [2]

(ii) If the lens and the screen are 10 cm and 25 cm away from the lamp respectively, calculate the focal length of the lens. [2]

(c) What happens to the image when the screen is now moved to the new position S_1? Explain. [2]

(d) Use a properly labelled ray diagram to explain why no image is formed on the screen when the lamp is moved much closer to the lens. You may draw the lamp as a point source of light. [3]