Two-Dimensional Waves

In our previous lessons, we discussed one-dimensional waves — waves that can only travel in straight lines, such as along the length of a spring. In this next part of the unit, we will examine **two dimensional waves** — waves that are able to move freely in two dimensions, such as along the surface of a liquid.

Water waves are an excellent example of a two-dimensional wave, since waves in water are able to travel in any horizontal direction (north, south, east, or west), but they simply cannot travel vertically (up or down). We will generally treat water waves as two-dimensional, transverse waves. This is not entirely accurate, but will be sufficient for our purposes.

Wavefronts and Wave Rays

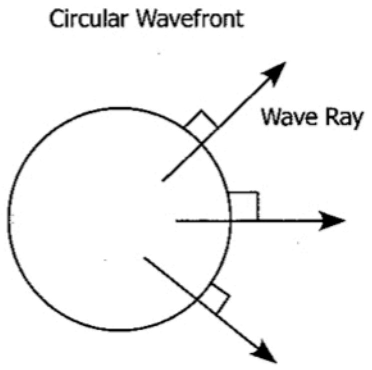
Water waves are generated by an object that is dipped or dropped into the water. Dropping a small object, such as a pebble, into water will generate a **circular wave**. When the object disturbing the surface of the water is quite small, we refer to it as a **point source**.

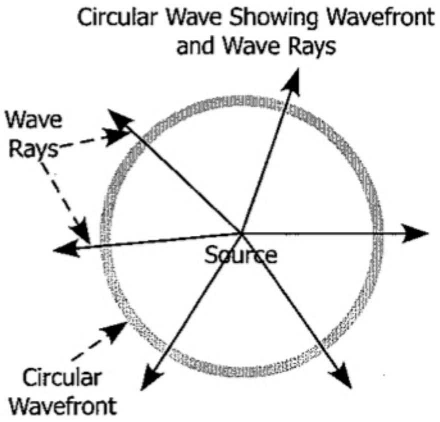
Dropping a long, straight stick into the water will generate a straight, or **plane wave**. A long, straight object that disturbs the surface of the water is referred to as a **linear source**.

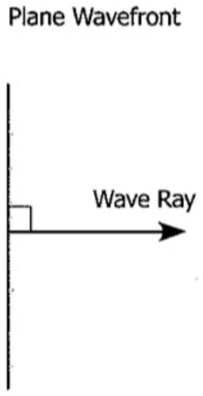
Water waves tend to form long, continuous crests and troughs. In order to accurately represent a two-dimensional wave in a diagram, we typically draw a line that represents each crest. This line is called a **wavefront**.

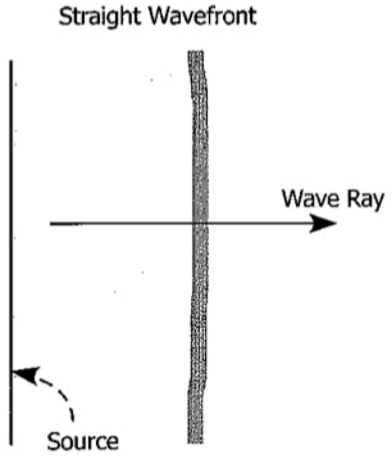
While the wavefront shows us the appearance of the crest of a wave, it does not tell us anything about the direction the wave is moving. To illustrate this, we draw arrows pointing in the direction of wave motion. These arrows, which are always perpendicular to the wavefront, are called **wave rays**.

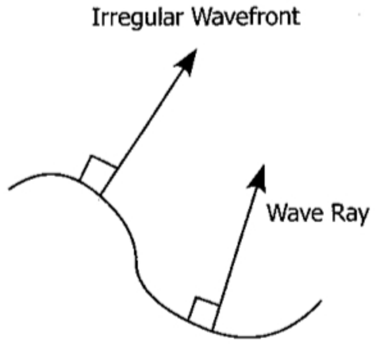
The diagrams below illustrate both circular and plane waves, along with their wavefronts and wave rays.





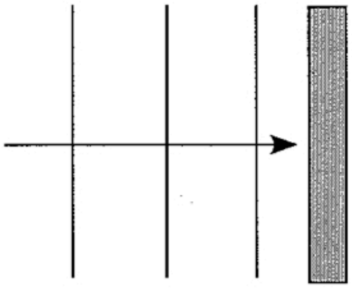




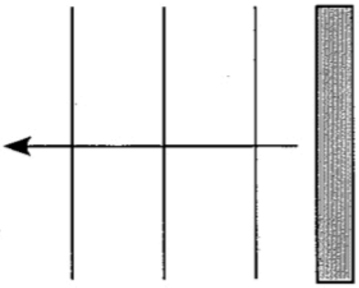


Reflection of Plane Waves from a Straight Barrier — Head On

The diagram below shows what happens when a plane wave approaches a straight barrier head on, and is then reflected. The wave is reflected back along its original path, as shown.



Incident (incoming) waves

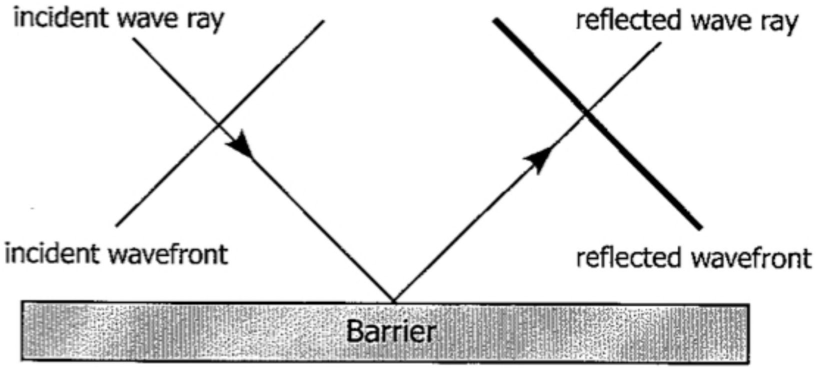


Reflected (outgoing) waves

Notice that the reflected waves are identical to the incident waves. As it turns out, they will have the same frequency, wavelength, speed, and amplitude as the incident waves. The only difference is their direction of travel.

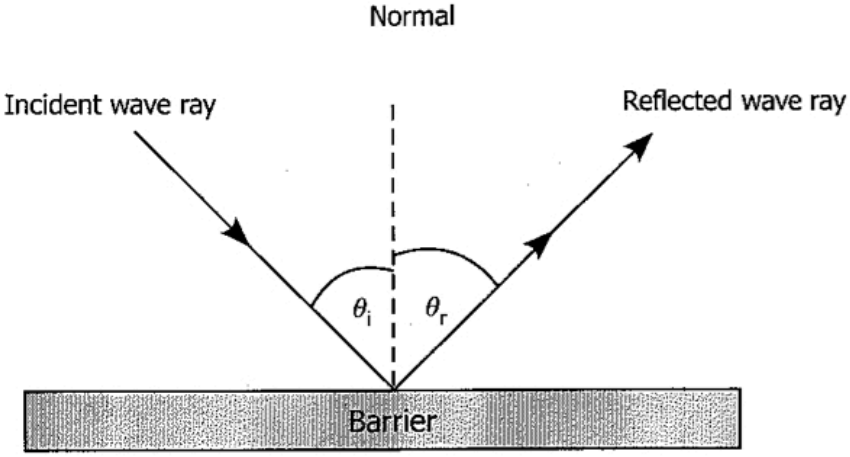
Reflection of Plane Waves from a Straight Barrier — At an Angle

The diagram below shows what happens when a plane wave approaches a straight barrier at an angle, and is then reflected. The wave is reflected at an angle.



In general, when we describe the angles involved in wave reflection, we describe them relative to an imaginary line drawn perpendicular to the reflecting surface. This line is called the **normal**.

The angle between the incident ray and the normal is called the **incident angle**. The angle between the reflected ray and the normal is called the **reflected angle**. The **law of reflection** states that the angle of incidence is always equal to the angle of reflection. This is illustrated in the diagram below.



Drawing the Reflection of a Plane Wave from a Straight Barrier

If you're given a plane wave incident on a straight barrier, you can use the following procedure to draw in the reflected wavefront.

Step 1: Draw in the incident wave ray.
Draw an arrow that is perpendicular to the incident wavefront and extend it until it touches the barrier. This point will be referred to as the point of reflection.

Step 2: Draw in the angle of incidence.
Draw a normal line at the point of reflection. Measure the angle of incidence and label it.

Step 3: Draw in the reflected wave ray.
From the normal, measure and draw in the reflected ray. The reflected ray should begin at the point of reflection and extend away from the barrier on the opposite side of the normal from the incident ray. Label the reflected angle and reflected ray.

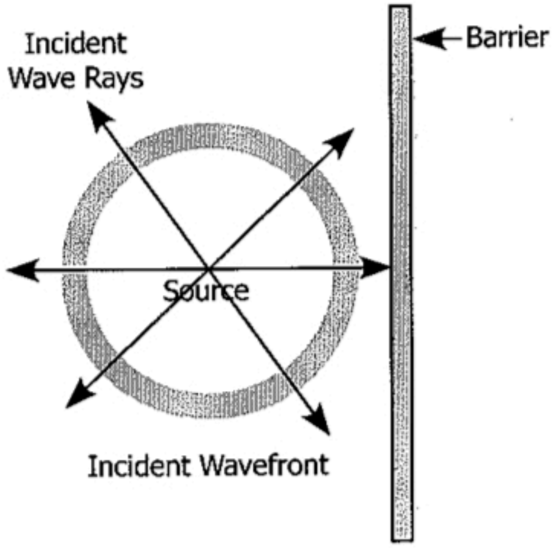
Step 4: Draw in the reflected wavefront.
Draw a line that is perpendicular to the reflected ray and label it as the reflected wavefront.

Special Cases for Reflection of Waves

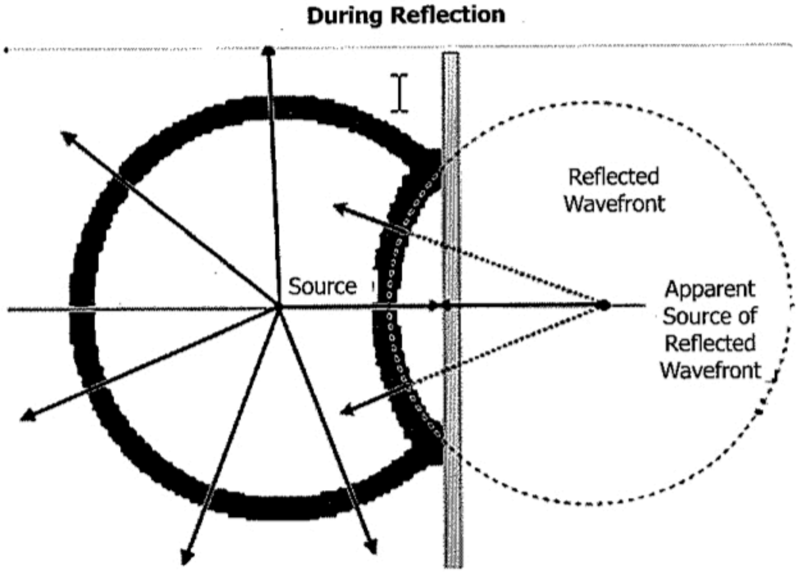
Reflection of Circular Waves from a Straight Barrier

The following diagram shows a circular wave that is incident upon a straight barrier.

Circular Wave Reflecting from a Straight Barrier
Before Reflection



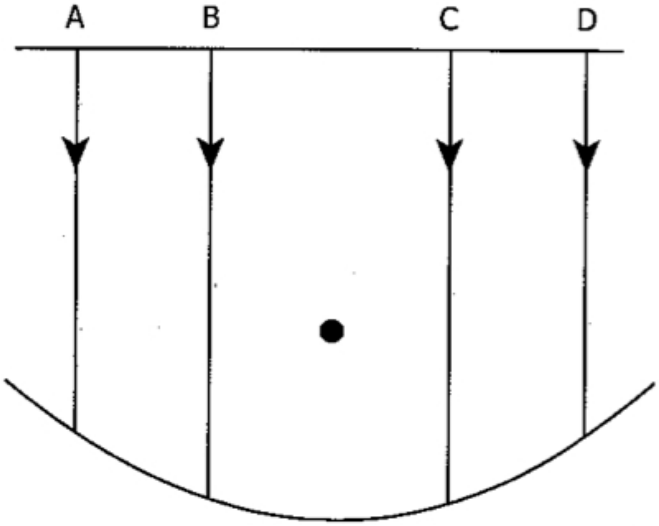
This next diagram shows the wave as it reflects from the barrier.



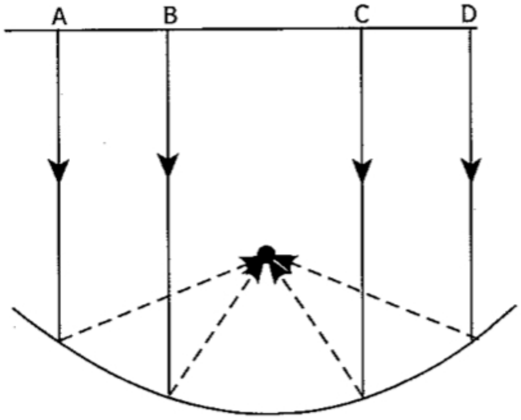
In general, when a circular wavefront strikes a straight barrier, the reflected wavefront will still be circular, and will be centered on a point on the other side of the barrier. The centers of the incident and reflected waves will be the same distance from the barrier.

Reflection of Plane Waves from a Parabolic Reflector

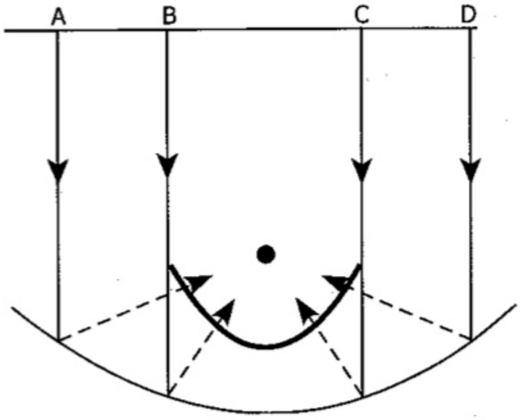
The following diagram shows a plane wave incident upon a parabolic barrier. The dark dot in the center is known as the focal point of the reflector.

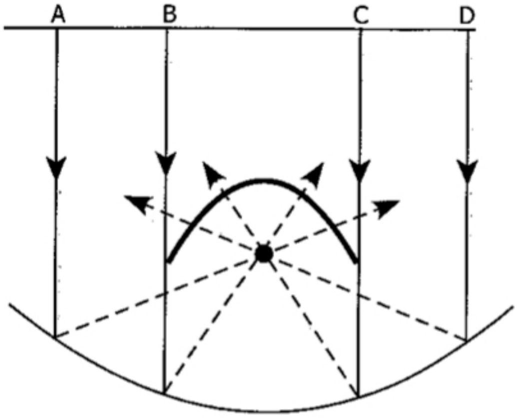


The next diagram shows how the wave rays reflect from the barrier. Notice that all of the wave rays reflect through the focal point.



The next two diagrams show the shape of the reflected wavefronts as they move towards and then beyond the focal point of the reflector.



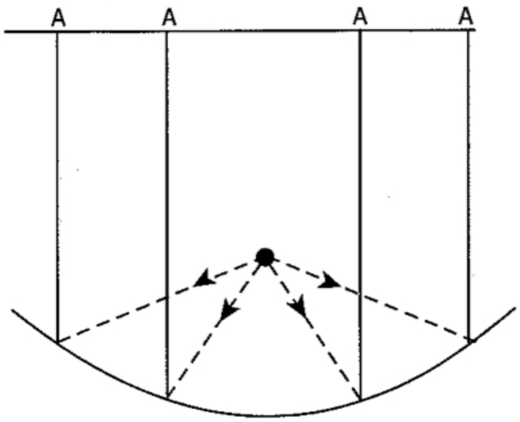


In general, when plane waves reflect from the inside curve of a parabolic barrier, the wave rays reflect through the focal point. The wavefronts converge on the focal point.

Note: This is how a satellite dish works.

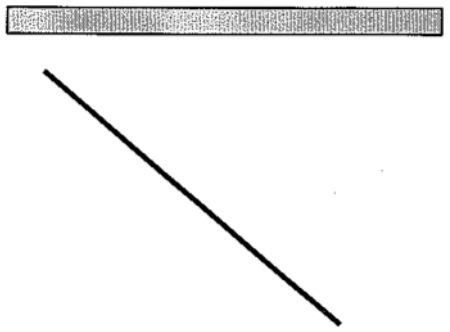
Reflection of Circular Waves from a Parabolic Reflector

Circular waves that originate at the focal point of a parabolic reflector reflect from it as plane waves — moving away from the reflecting parabola.

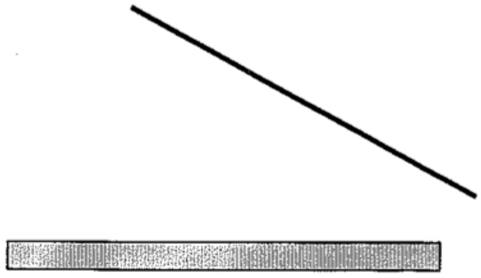


Waves Worksheet # 5

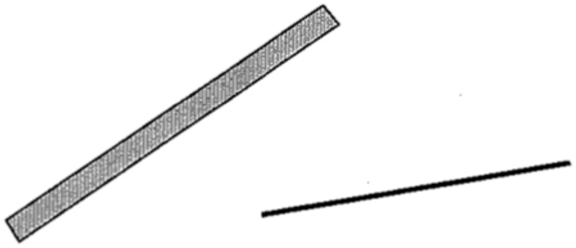
1. The diagram below shows a wavefront moving upwards to the right approaching a barrier. For this wavefront, draw in the incident wave ray. Draw in the normal. What is the angle of incidence?



2. The diagram below shows a wavefront traveling away from a barrier (upwards to the right). For this wavefront, draw in the reflected wave ray. Extend the ray back to the barrier and draw in the normal. What is the angle of reflection?

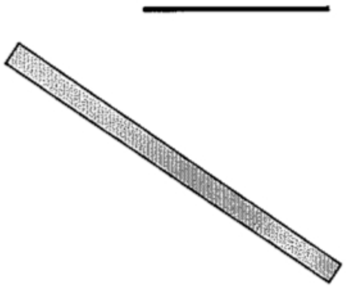


3. The diagram below shows one wavefront approaching (moving upwards to the left) a straight barrier. Draw in the reflected wavefront.

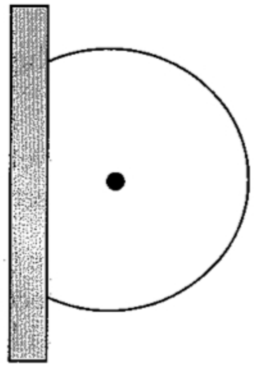


4. The diagram below shows one wavefront moving downward approaching a straight barrier. Add to this diagram the following.

   a) Draw the incident wave rays from the left edge and the right edge of the wavefront.
   b) Using a dashed line, draw a normal from the point where each incident ray makes contact with the barrier.
   c) What is the angle of incidence?
   d) Draw in the angle of incidence and the angle of reflection.
   e) Draw in the two reflected wave rays.
   f) Draw the reflected wavefront at some point on the wave rays.



5. The diagram below shows a circular wave approaching a barrier. The center of the wave is shown. Draw that part of the wave that has been reflected. Also draw a wave ray for the reflected wave from the place where the reflected wavefront seems to originate.



6. The diagram below shows a parabolic reflector. The focal point of the reflector is shown. Circular pulses are generated from the focal point. Draw two incident wavefronts and two reflected wavefronts. Add to the diagram an incident ray and a reflected ray.