#### Lecture Outline

Chapter 19: Vibrations And Waves

# Part 3 Doppler Effect Shock Waves





#### Doppler Effect: Intro

Bug jumps up and down on a pond



Wavefronts move out in concentric circles that are centered on the bug A and B observe waves at the same frequency Bug jumps up and down while moving to the right



Circles are centered on previous position of bug. B observes waves at a higher frequency than A The **Doppler Effect** is a change in the observed frequency of a wave caused by relative motion between the source and an observer.



Ambulance driver hears a constant frequency.

Wave *speed* is the same for A and B (same medium). Same effect if source is at rest and observers move.

20. In the Doppler effect, does frequency change? Does wave speed change?

# The speed of the source affects the observed frequency:



The greater the source speed...

... the more the frequency shifts.

Result: Measure frequency shift to find speed

- The Doppler effect also applies to *light*: Increase in light frequency when light source approaches you → blue shift
  - Decrease in light frequency when light source moves away from you n  $\rightarrow$  red shift



Which observer measure a light wave that is faster?

21. Can the Doppler effect be observed with longitudinal waves, with transverse waves, or with both?

22. What is meant by a blue shift and a red shift for light?

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#### Most galaxies have a red shift

Pass starlight through a prism. Its spectrum has dark lines.

If a galaxy (with its stars) are moving, the dark lines are shifted: blue shift: galaxy moving towards us red shift: galaxy moving away



Most galaxies moving away Universe must be expanding



#### Star light, star .....

A star's speed can tell us if there is a planet orbiting it A star's spin speed can be determined by measurement of frequency shift





# **Doppler radar: Weather prediction** Radar: echo to tell how far away storm is Doppler radar: tells how fast storm is moving



#### **Doppler radar with tornadoes**

Tornado winds are moving towards Nexrad from A, and away from Nexrad at B.

Wave from A: blue shifted Wave from B: red shifted.



More shift  $\rightarrow$  faster speed

#### You can tell is a tornado is forming:



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#### **Traffic enforcement and radar**

Radar gun sends out wave. Frequency of returning wave (echo) is shifted.





#### More shift $\rightarrow$ faster speed

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# The Doppler Effect CHECK YOUR NEIGHBOR

The Doppler effect occurs for

- A. sound.
- B. light.
- C. Both A and B.
- D. Neither A nor B.

# The Doppler Effect CHECK YOUR ANSWER

The Doppler effect occurs for

#### C. Both A and B.

#### **Explanation:**

The Doppler effect occurs for both sound and light. Astronomers measure the spin rates of stars by the Doppler effect.

#### **Bow Waves**

- Wave barrier
  - Waves superimpose (overlap) directly on top of one another producing a "wall".

bug swimming as fast as the wave it makes bug swimming faster than the wave it makes



- Bow wave
  - V-shape form of overlapping waves when object travels faster than wave speed.
  - An increase in speed will produce a narrower
    V-shape of overlapping waves.

bow waves



narrower= faster

23. How fast must a bug swim to keep up with the waves it produces? How fast must it move to produce a bow wave?

#### Skip 24 for now.

25. How does the V shape of a bow wave depend on the speed of the source?

#### Wake up!

A *wake* is the wave pattern produced as a boat moves through water:





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A *bow wave* is produced when many waves overlap. Because it is on the water surface, it is (mostly) 2-dimensional.

#### **Bow Waves, Continued**

- Supersonic
  - Aircraft flying faster than the speed of sound (Mach 1).
  - Difficult to control plane as it passes sound barrier
  - Easier afterwards because air is smoother



24. How fast does a supersonic aircraft fly compared with the speed of sound?

## **Shock Waves**

- Shock wave
  - Pattern of overlapping spheres that form a cone from objects traveling faster than the speed of sound.





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26. A bow wave on the surface of water is two-dimensional. How about a shock wave in air?

- Shock wave (continued)
  - Consists of two cones:
    - a high-pressure cone generated at the bow of the supersonic aircraft
    - a low-pressure cone that follows toward (or at) the tail of the aircraft

The air pressure changes are similar to the expansion of air during an explosion



A *sonic boom* is the sharp cracking sound heard by observes on the ground as a supersonic aircraft flies past.

The shock wave cone is continuously dragged behind the plane.

Which person has already heard it?

Which hasn't?



27. True or false: A sonic boom occurs only when an aircraft is breaking through the sound barrier. Defend your answer.

## Sonic boom

- It is not required that a moving source be noisy.
- Example:
- Crack of circus whip





The whip is not the source of the noise. It produces the sound by generating shock waves. A supersonic bullet is traveling faster than Mach 1 (the speed of sound).

 $\rightarrow$  It drags shock wave cone behind it, creating a noise.



#### 7.5mm Swiss Rifle Bullet at Four (4) Velocities





28. True or false: In order for an object to produce a sonic boom, it must be "noisy." Give two examples to support your answer.