Physics 5B

Lecture 13, February 10, 2012

Chapter 16, Doppler Effect, Shock Waves

Chapter 32, Geometric Optics

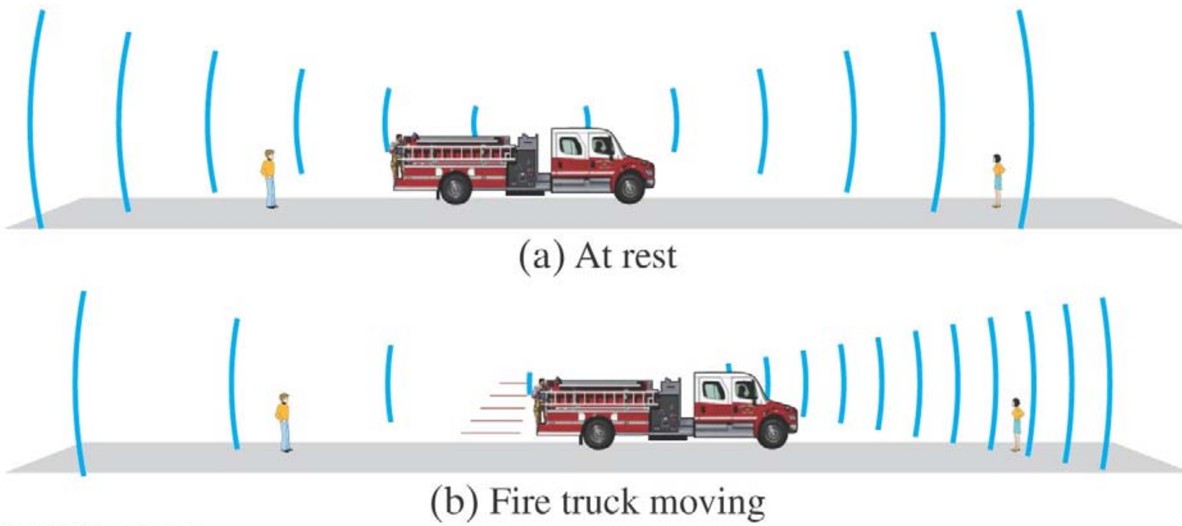
A piano tuner hits the A key on the piano and simultaneously rings a 440 Hz tuning fork. A 2 Hz beat is heard. How should the tension of the string be adjusted?

A. Tighten the string (increase the tension).

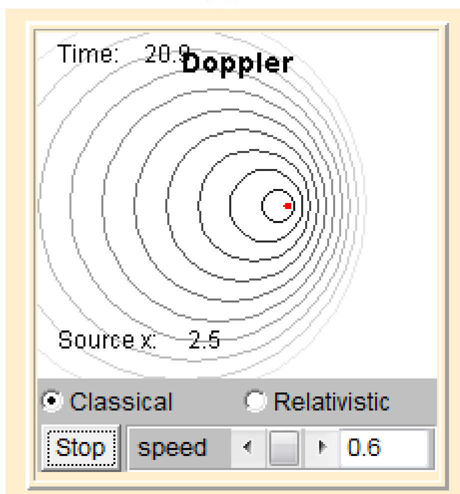
B. Loosen the string (reduce the tension).

C. Not enough information to know whether to tighten it or loosen it.

Doppler Effect



Demo



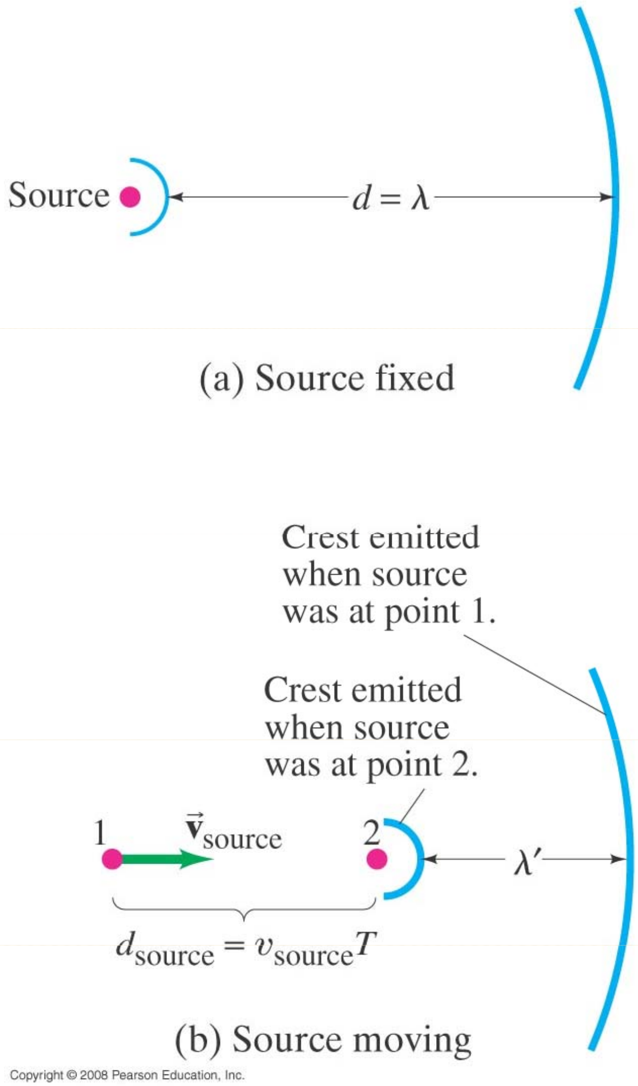
Animation from
Davidson College

http://webphysics.davidson.edu/Applets/Doppler/Doppler.html

Doppler Effect

- The Doppler effect occurs for all types of waves, but there is an important distinction:
- Mechanical waves (sound, water, etc.):
  - The effect depends on whether the ***source or observer*** (or both) ***is moving*** with respect to the medium.
  - Motion is defined with respect to the medium through which the wave propagates (be careful with wind in the case of sound)!
- Electromagnetic waves in vacuum (light, radio, X-ray, etc.)
  - The effect depends only on the ***relative motion*** of the source and observer.
  - There is no medium through which the wave propagates, so it is not possible to have a absolute concept of "being at rest".
  - See Chapter 44.

Moving Source of Sound

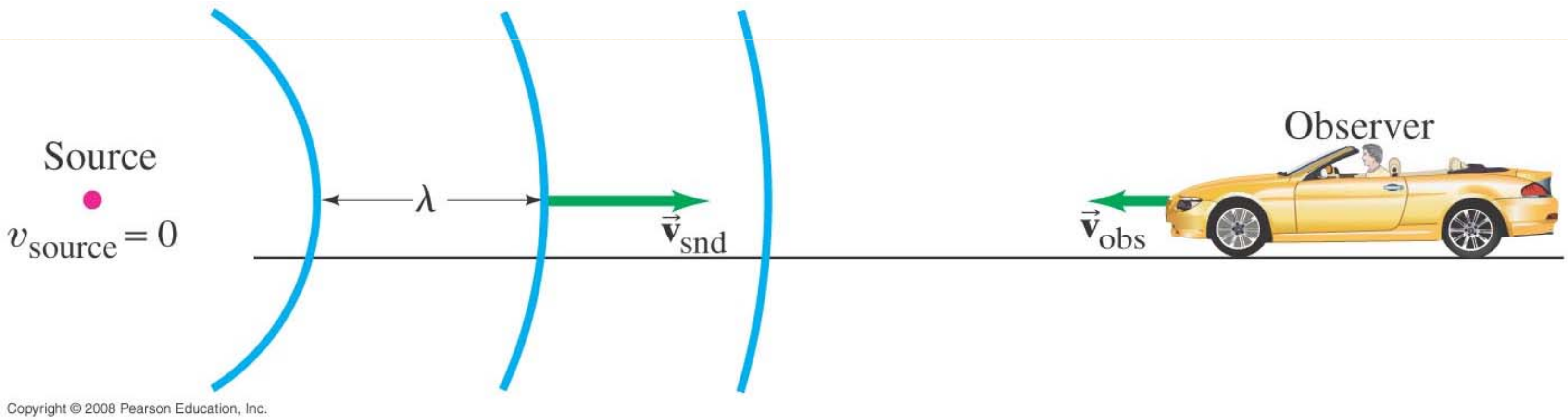


$$f' = \frac{f}{\left(1 \mp \frac{v_{source}}{v_{sound}}\right)}$$

Careful: moving means moving with respect to the air. The presence of wind may complicate this slightly.

Moving Listener; Stationary Source

$$f' = \left(1 \pm \frac{v_{\text{observer}}}{v_{\text{sound}}}\right) \cdot f$$



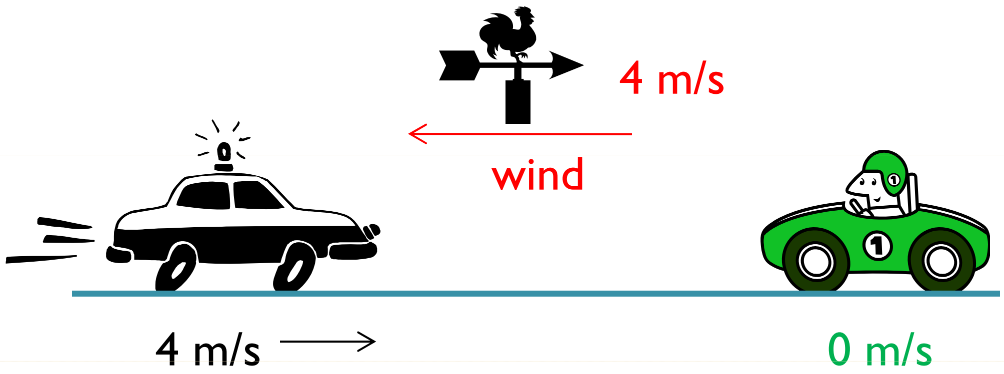
Note: since $\dfrac{1}{1 \mp x} \approx 1 \pm x$ if x is small, then the two formulas are nearly the same if $v << v_{\text{sound}}$.

A police car is traveling eastward at 4 m/s into a 4 m/s headwind, with its siren on, emitting a f=1.0 KHz tone. To find *exactly* what frequency is heard by an observer in a car at rest on the road in front of the police car, which formula do we use?

A) $f' = \dfrac{f}{\left(1 - \dfrac{v_{\text{source}}}{v_{\text{sound}}}\right)}$

B) $f' = \left(1 + \dfrac{v_{\text{obs}}}{v_{\text{sound}}}\right) \cdot f$

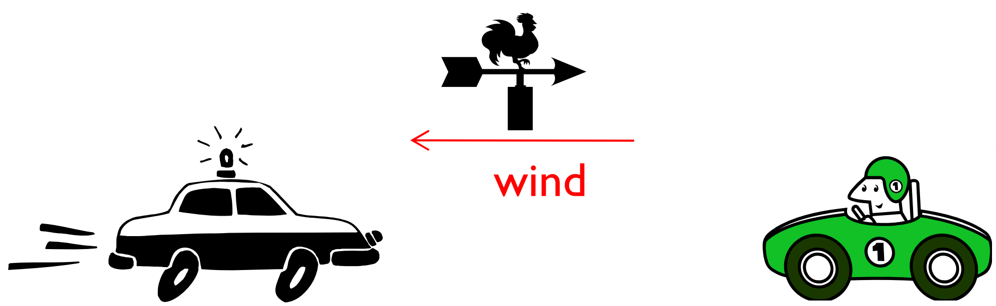
C) $f' = \left(1 - \dfrac{v_{\text{obs}}}{v_{\text{sound}}}\right) \cdot f$



D) Both formulas from (A) and (B) above.

E) Both formulas from (A) and (C) above.

A police car is traveling eastward at 4 m/s into a 4 m/s headwind, with its siren on, emitting a f=1.0 KHz tone. What frequency is heard by an observer in a car at rest on the road in front of the police car?



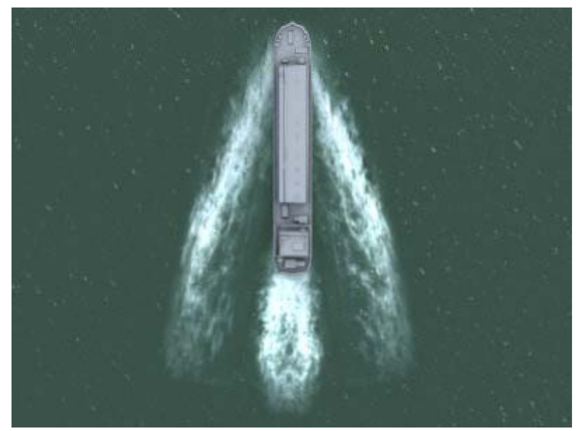
Source moving eastward with respect to the air at a speed of 8 m/s.

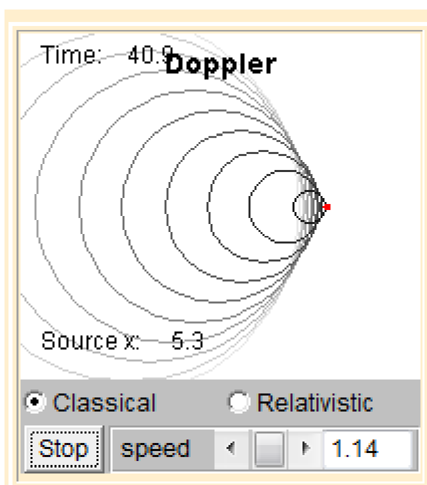
Observer moving eastward with respect to the air at a speed of 4 m/s

Shock Waves

Occurs whenever the wave source is moving faster than the waves themselves:

- Water waves: bow wave of a boat
- Sound waves: sonic boom
- Light waves: Cherenkov light





Animation from Davidson College

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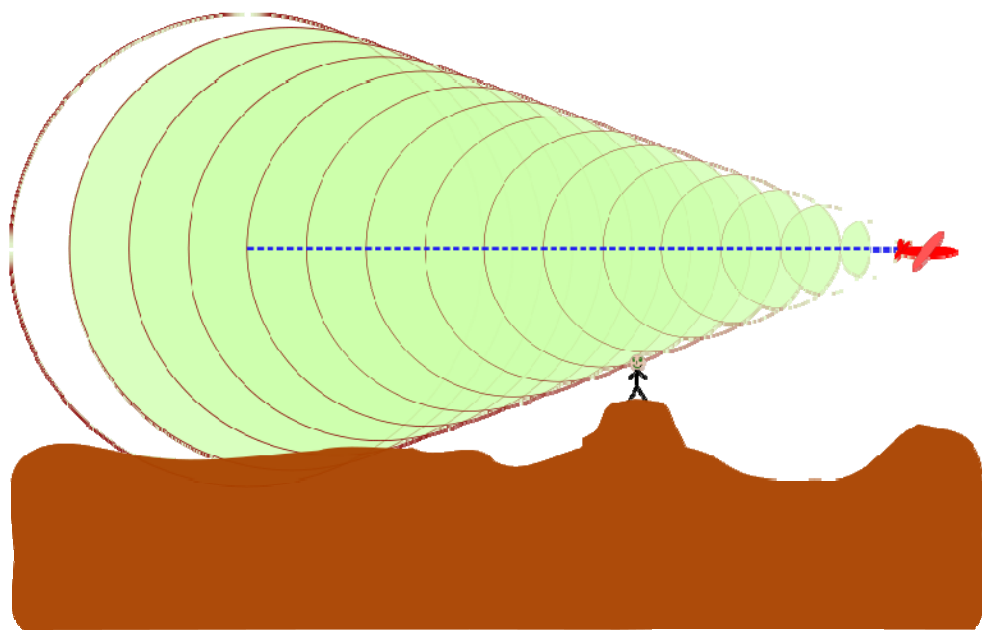

Water condensing in a shock wave

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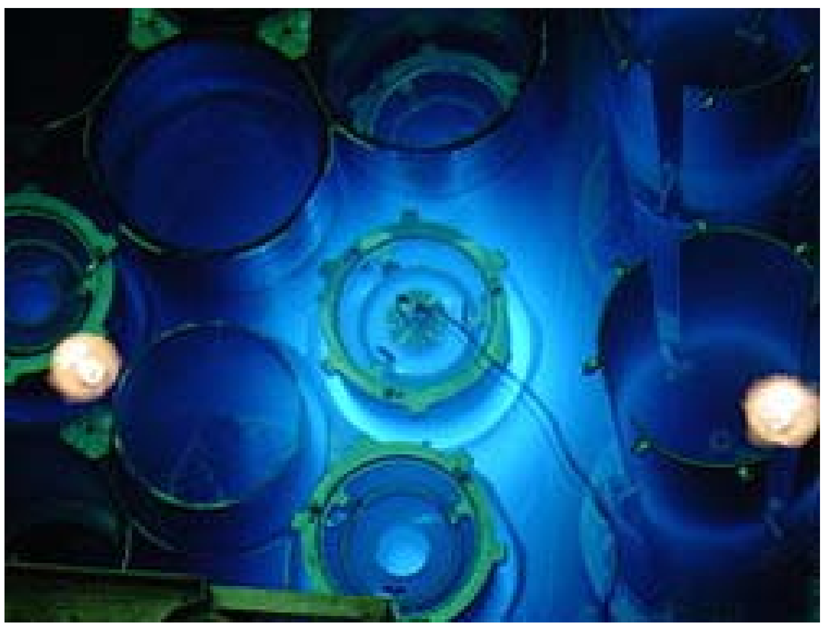
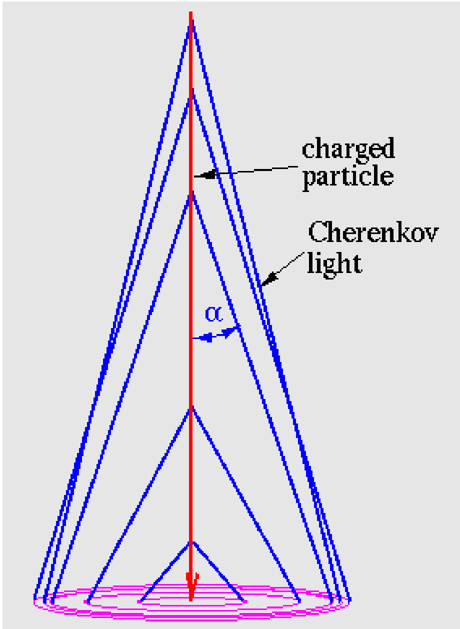
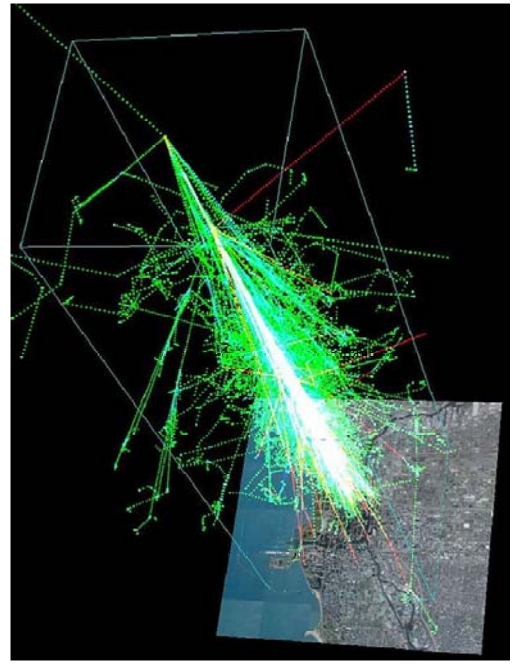


Bluish Cherenkov light produced in a used-fuel storage facility for a nuclear reactor. It is produced by charged particles moving through the water faster than the speed of light in the water.



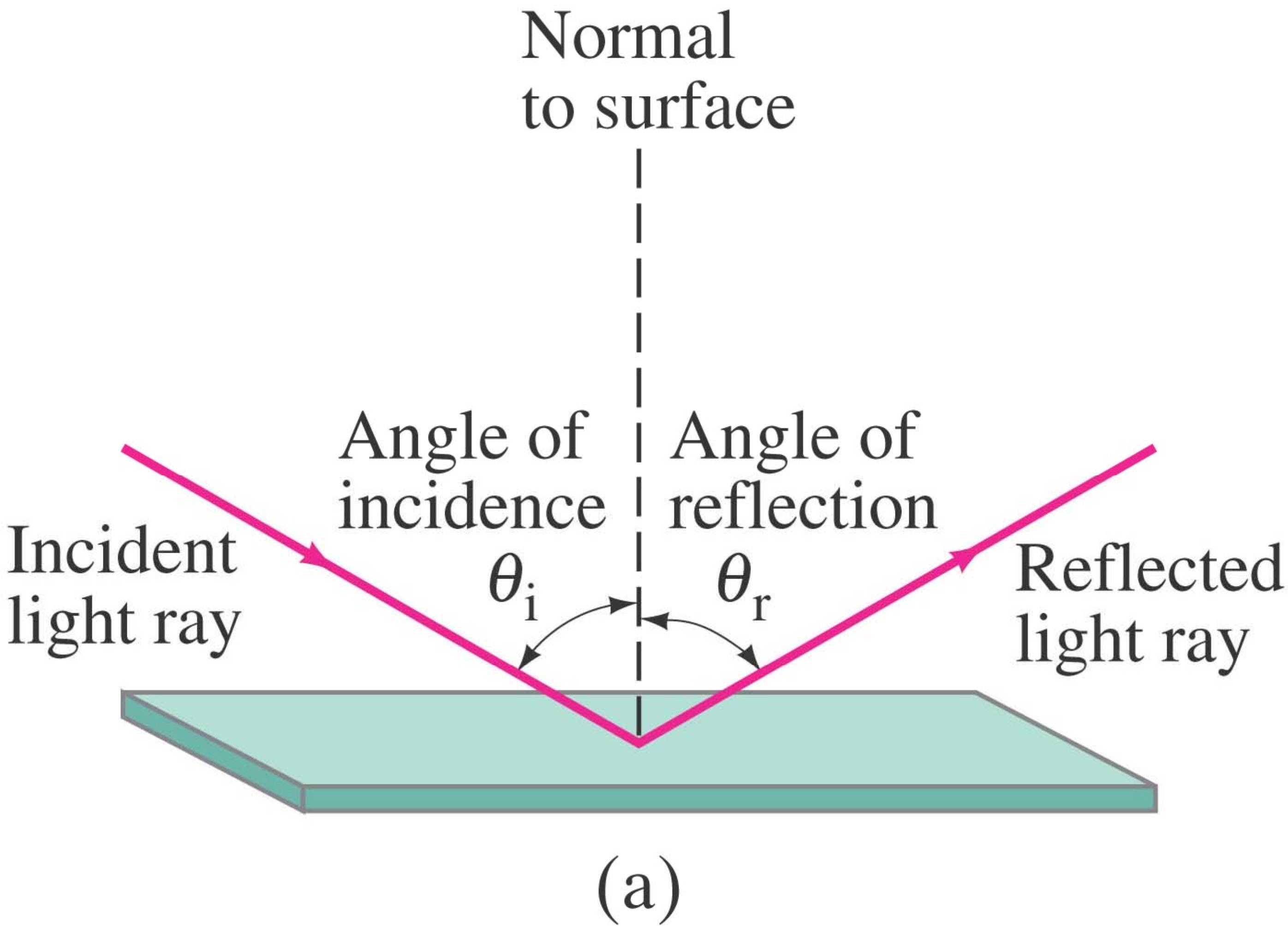
VERITAS project (Prof. David Williams). High energy cosmic rays hitting the upper atmosphere are seen on the ground via Cherenkov light emitted at high altitude.



Geometric Optics

CHAPTER 32

Reflection from a Smooth Plane



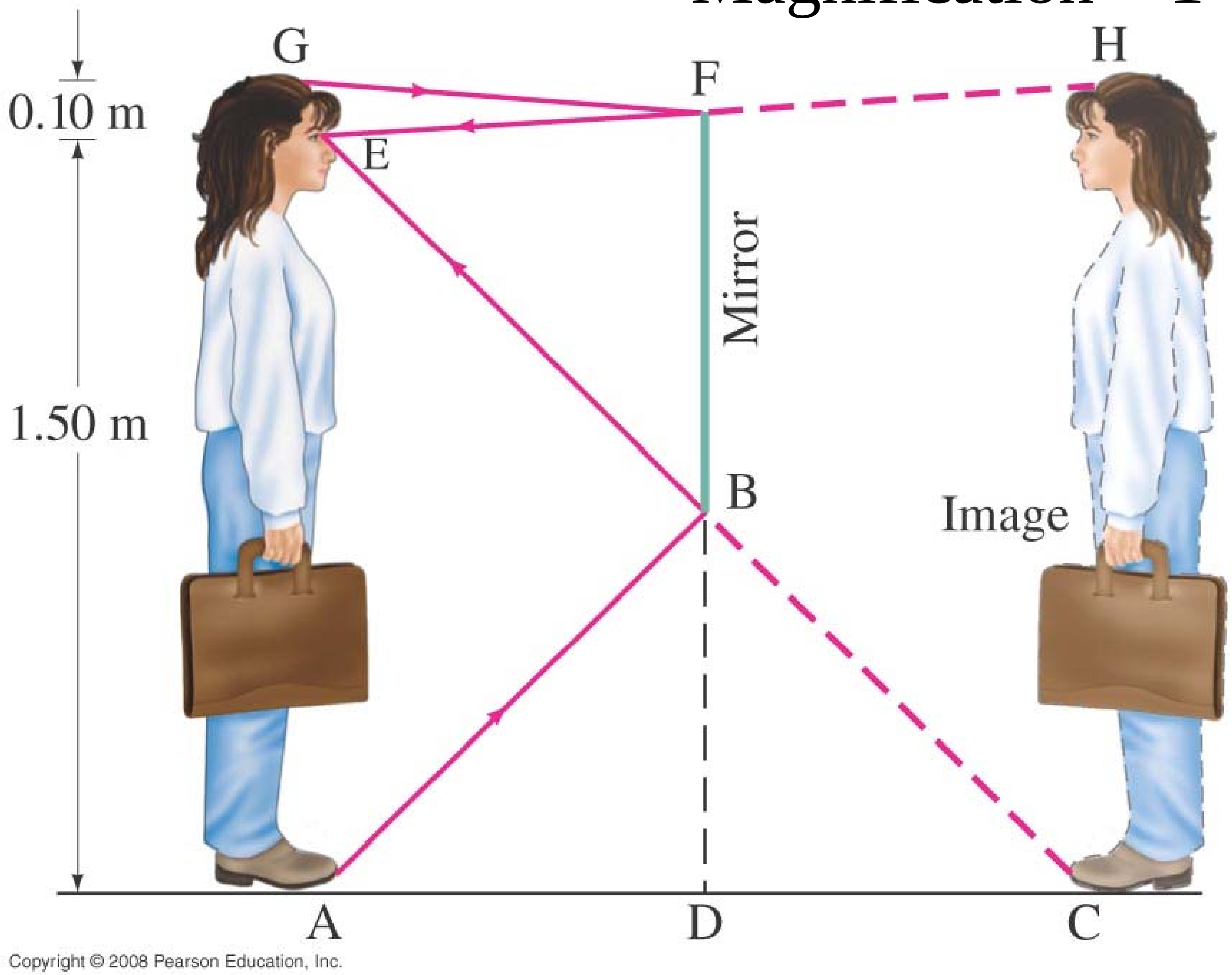
Mirror Concept Test

You stand in front of a plane mirror. How tall does the mirror have to be so that you can see yourself entirely all at once?

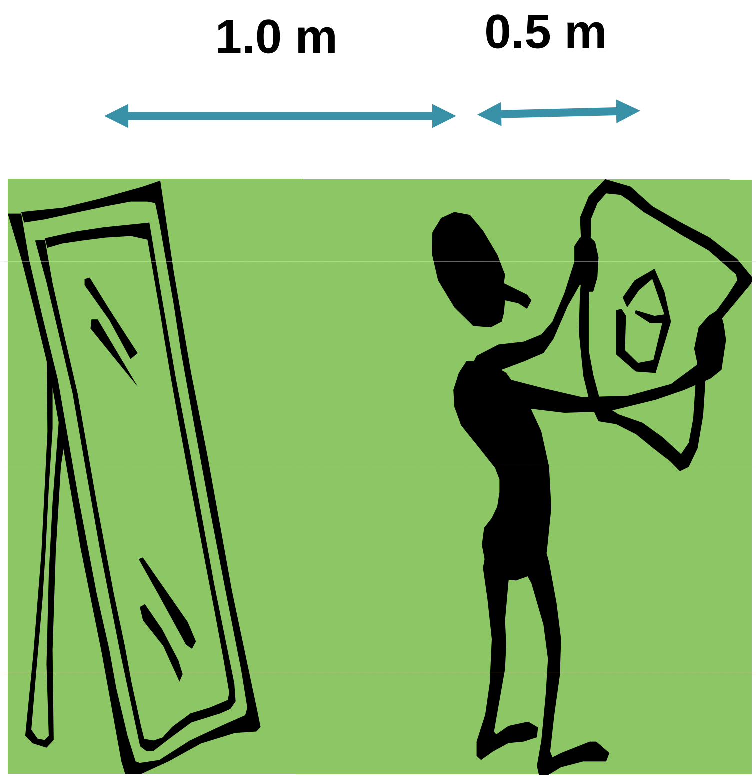
A. Any size will do
B. Less than half your height
C. Half your height
D. More than half your height but less than your full height
E. Your full height

Virtual Image Formation

Magnification = 1



You hold a hand mirror 0.5 m in front of you and look at your reflection in a full-length mirror 1 m behind you. How far in back of the big mirror do you see the image of your head?



A. 0.5 m

B. 1.0 m

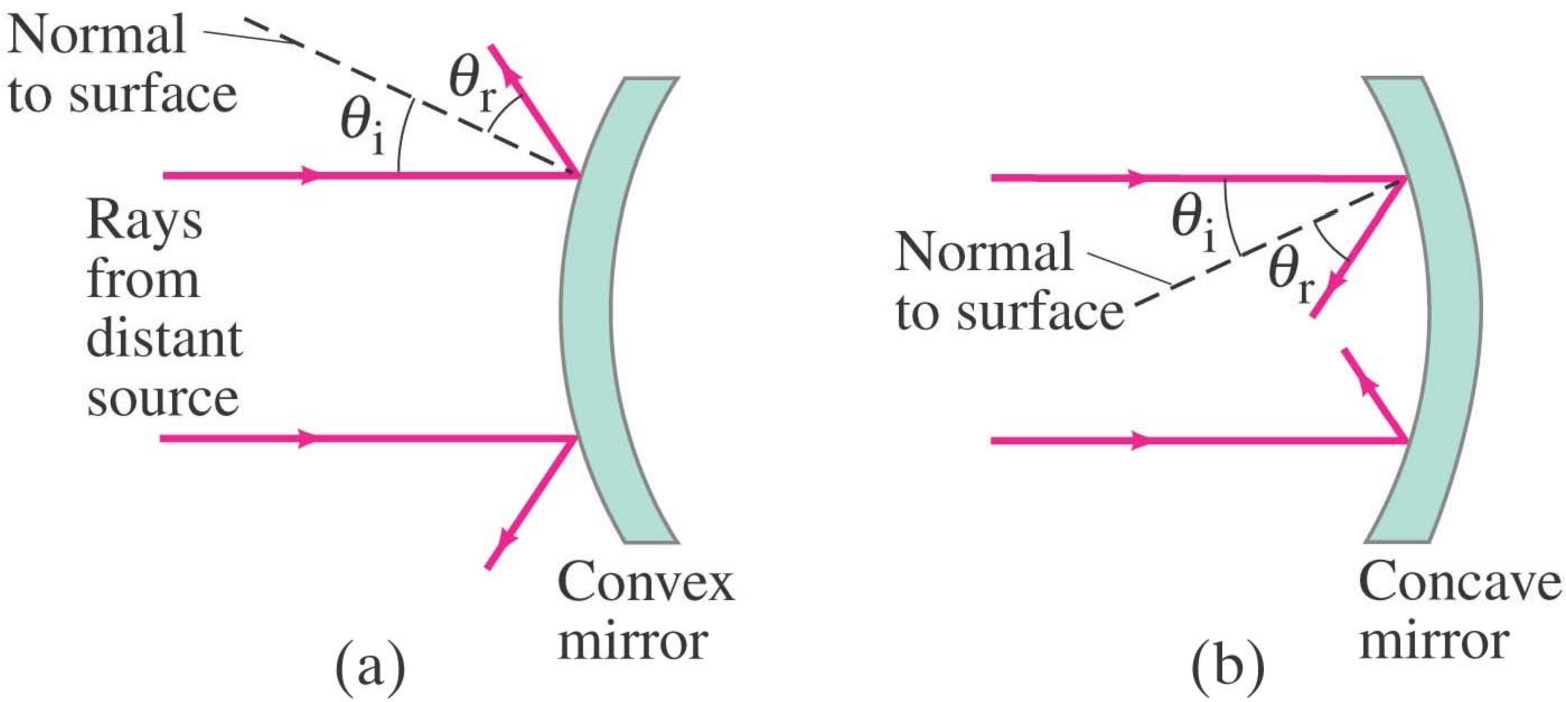
C. 1.5 m

D. 2.0 m

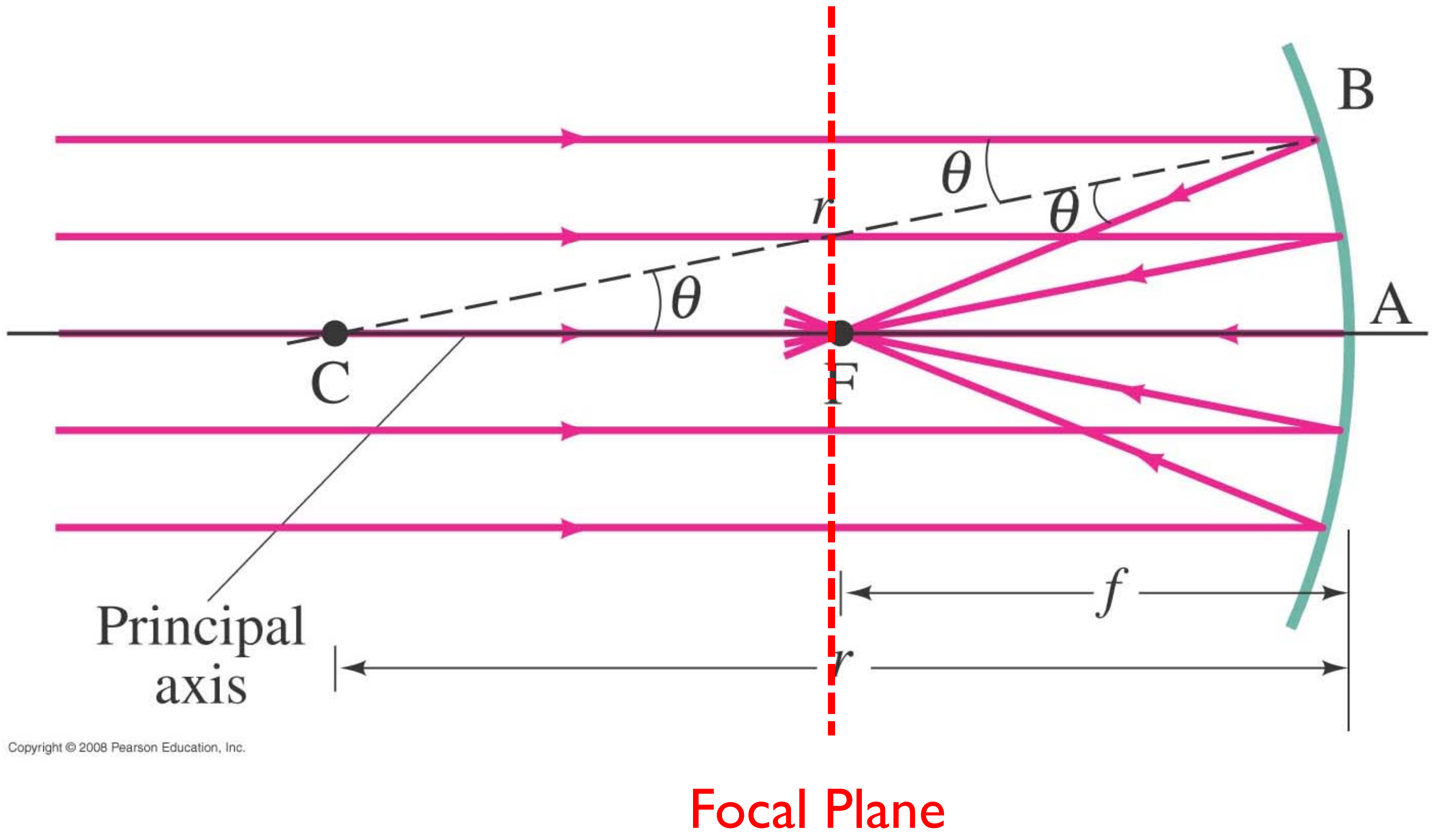
E. 2.5 m

One virtual image can become the object of a second virtual image.

Spherical Mirrors



Spherical Mirror Focus



Spherical Aberration