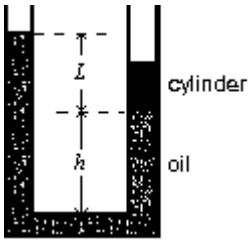
1. The diagram shows a U-tube having cross-sectional area A and partially filled with oil of density ρ. A solid cylinder, which fits the tube tightly but can slide without friction, is placed in the right arm. The system reaches equilibrium. If the height of the cylinder is H (not shown), what is its density?



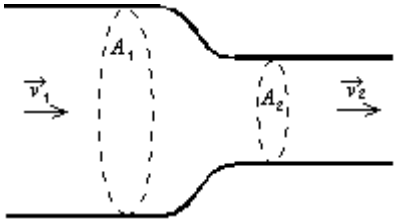
A) ALρg
B) L^3ρg
C) Aρ(L + h)g
D) ρL/H
E) none of these

2. A swimmer in a pool of water is initially floating, but then dives to the bottom of the pool. The water level
   A) rises
   B) falls
   C) remains the same
   D) depends on the density of the swimmer
   E) none of these

3. An object hangs from a string in air; the tension in the string is 60 N. When the object is lowered under water, the tension in the string is 52 N. What does would be the tension in the string if the object were submerged in liquid with a density that is twice that of water?:
   A) 56 N
   B) 52 N
   C) 48 N
   D) 44 N
   E) none of these

4. A flat roof in the shape of a rectangle 12 m wide and 9 m long covers the sealed attic of a house. The air pressure inside the attic is standard atmospheric pressure, 101,000 Pa, the same as the pressure outside. If the outside air pressure later decreases by 0.5 percent, while the attic pressure remains the same, what would be the net air pressure force on the roof, in kilo-newtons (kN)?
   A) 14.55
   B) 54.54
   C) 22.62
   D) 28.80
   E) none of these

5. An incompressible liquid flows along the pipe as shown. In which portion of the pipe is the pressure greater?



   A) The wider part.
   B) The narrower part.
   C) Cannot determine without more information.
   D) In whichever part the speed is greater
   E) None of these

6. A narrow water pipe enters a house 2.0 m above ground. The pipe widens and becomes a larger diameter pipe that carries water to a basement faucet 1.3 m below ground. Water flows at 3.0 m/s in the above-ground pipe and at 1.1 m/s in the narrowed portion of the pipe in the basement. Take the density of water to be 1000 kg/m^3. The difference in pressure between the basement line and the main line (in kPa, kilo-pascal) is approximately:
   A) 36
   B) 22
   C) 59
   D) 83
   E) none of these

7. The displacement of a mass oscillating on a spring is given by $x(t) = A \sin(\omega t + \phi)$. If the initial displacement (at t = 0) is negative and the initial velocity is in the positive x direction, then the phase constant ϕ is in which range of angles, in radians?
   A) 0 to π/2
   B) π/2 to π
   C) π to 3π/2
   D) 3π/2 to 2π
   E) Not enough information is provided to answer

8. An object is oscillating horizontally on the end of a spring at an angular frequency ω and with amplitude *A*. Its speed when its position is x = A/3 is:
   A) Aω/3
   B) $2^{1/2}$ Aω/9
   C) 3Aω
   D) $2^{3/2}$Aω/3
   E) None of these

9. A wave on a string is described by $y(x,t) = 3.3 \sin(4x - \pi t/8)$, where *x* is in meters, *y* is in centimeters and *t* is in seconds. The period of motion (in seconds) of any one of the points along the string is:
   A) 2
   B) 4
   C) 12
   D) 16
   E) none of these

10. An object of mass m = 6 kg is oscillating horizontally on a frictionless surface at the end of a spring whose spring constant is 900 N/m. Its equation of motion is given by x = A sin (ωt + ϕ). At time t = 0 seconds, the object is observed to have a speed of 1.7 m/s, and is moving to the left; at that same instant, it is 0.16 m to the right of the object's equilibrium position (at x = 0). What is the phase constant, ϕ, in radians?
    A) -0.34
    B) -0.86
    C) 0.25
    D) 0.48
    E) none of these

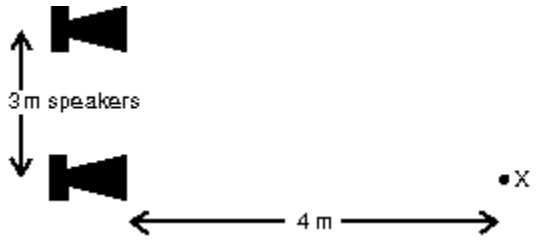
11. A string, clamped at its ends, vibrates with four antinodes. The string is 100 cm long. The tension in the string is 100 N, and the mass per length is 0.25 kg/m. The string is vibrating at what frequency (in hertz)?
    A) 10
    B) 20
    C) 30
    D) 40
    E) none of these

12. A 40-cm long string is clamped at both ends. The speed of waves on this string is 8 m/s. What is the *second*-lowest frequency of vibration of standing waves on this string, in hertz?
    A) 32
    B) 16
    C) 8
    D) 20
    E) none of these

13. The speed of sound in air is 340 m/s. The shortest air column, closed at one end, which will respond to a 512 Hz tuning fork is approximately:
    A) 4.2 cm
    B) 9.4 cm
    C) 17 cm
    D) 33 cm
    E) 66 cm

14. An organ pipe with both ends open is 0.85 m long. Assuming that the speed of sound is 340 m/s, the frequency (in hertz) of the harmonic mode of vibration that has three nodes is:
    A) 200 Hz
    B) 300 Hz
    C) 400 Hz
    D) 600 Hz
    E) none of these

15. Two small identical speakers are connected (in phase) to the same source. The speakers are 3 m apart and at ear level. An observer stands at X, 4 m in front of one speaker as shown. For which wavelength (in meters) will the observer hear the *no* sound?



A) 2/5
B) 5
C) 3/2
D) 1/2
E) 1

16. A source emits sound with a frequency of 800 Hz. It is moving at 20 m/s toward an observer moving toward the sound source at a certain speed. If the speed of sound is 340 m/s, and the observer hears a frequency 975 Hz, what is the speed of the observer, in m/s?
A) 50
B) 70
C) 90
D) 110
E) none of these

17. A non-viscous incompressible fluid is pumped steadily into the narrow end of a long tapered pipe and emerges from the wide end. The pressure at the input is greater than at the output. A possible explanation is:
A) the fluid speed increases from input to output
B) the fluid speed is the same at the two ends
C) the fluid is flowing uphill
D) the fluid is flowing downhill
E) the fluid is flowing horizontally

18. About how much force (in N) would be required to push a 30-N ball of radius 12 cm completely under water?
A) 22
B) 28
C) 41
D) 56
E) none of these

19. A non-viscous incompressible fluid is pumped steadily at speed 20 m/s into the wide end of a long tapered pipe and emerges from the narrow end. The radius of the wide end is 4.30 cm, and the radius of the narrow end is 1.44 cm. What is the speed of the fluid that emerges from the narrow end, in m/s?
    A) 74
    B) 89
    C) 123
    D) 178
    E) none of these

20. Two speakers are emitting (in phase) sound at a frequency of 400 Hz. The speakers are at an observer's ear level. What is the least distance (in m) *from the midpoint* on the line connecting the two speakers the observer may stand in order to hear *no* sound? Assume the speed of sound is 340 m/s.
    A) 0.56
    B) 0.21
    C) 1.22
    D) 1.67
    E) none of these