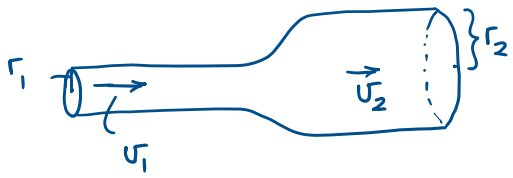
Solutions for PHYS 117 2021 Alternative Midterm Exam

CONCEPT QUESTIONS

2. Water is flowing with a speed of 1.10 m/s in a section of a horizontal pipe. If the pipe then widens from a radius of 0.120 m to 0.240 m, calculate the speed of the water in the larger section of the pipe (in m/s). 0.275 m/s



Continuity Equation for Incompressible Fluid

$$A_1 v_1 = A_2 v_2$$

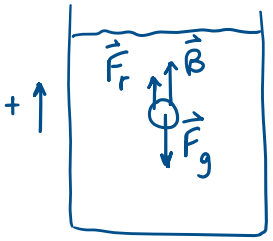
$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$v_2 = \left(\frac{\pi r_1^2}{\pi r_2^2}\right) v_1 = \left(\frac{r_1}{r_2}\right)^2 v_1 = \left(\frac{0.120\,\text{m}}{0.240\,\text{m}}\right)^2 (1.10\,\text{m/s})$$

$$v_2 = \frac{1.10\,\text{m/s}}{4} = 0.275\,\text{m/s}$$

3. Two spheres are released from rest in a viscous fluid and reach their terminal speeds. The spheres are made of the same material but the radius of sphere 1 is 2 times larger than that of sphere 2. The density of the spheres is greater than the density of the fluid. Which one of the following statements is correct?

(A) The magnitude of the buoyant force on sphere 1 is the same as that on sphere 2. x $F_B \propto r^3$
(B) The magnitude of the buoyant force on either sphere equals the magnitude of its weight. x
(C) The magnitude of the resistive drag force on sphere 1 is the same as that on sphere 2. x $F_r \propto r$
(D) The resistive drag forces of the fluid on the marbles decrease as the speeds of the marbles increase. x $F_r \propto v$
(E) The terminal speed of sphere 1 is greater than that of sphere 2. ✓



At terminal speed,

$\Sigma \vec{F} = 0$

$F_r + B - F_g = 0$

fully submerged, so $V_f = V_{obj}$

$6\pi\eta r v_t + \rho_f V_f g - mg = 0$

$m = \rho_{obj} V_{obj}$

$6\pi\eta r v_t + \rho_f V_{obj} g - \rho_{obj} V_{obj} g = 0$

$6\pi\eta r v_t = \rho_{obj} - \rho_f (V_{obj} g)$

$v_t = \dfrac{(\rho_{obj} - \rho_f)(\frac{4}{3}\pi r_{obj}^3 g)}{6\pi\eta r_{obj}} \Rightarrow v_t \propto r_{obj}^2$

∴ terminal speed of larger object is larger

4. A mass m connected to an ideal spring of spring constant k is oscillating with an amplitude A on a horizontal frictionless surface. Which one of the following statements is **FALSE**?

(A) The elastic potential energy stored in the spring changes as the spring stretches and compresses.
(B) The kinetic energy of the mass changes as the mass oscillates.
(C) The kinetic energy of the mass is zero when the spring is at maximum compression.
(D) The elastic potential energy stored in the spring is zero when the mass is at the equilibrium position.
(E) The total energy of the system changes as the mass oscillates.

(A) $PE_s = \frac{1}{2}kx^2 \neq$ constant $\therefore$ TRUE

(B) $KE = \frac{1}{2}mv^2 \neq$ constant $\therefore$ TRUE

(C) $v = 0$ at max. compression $\therefore$ TRUE

(D) $PE_s = 0$ at $x = 0$ $\therefore$ TRUE

(E) $E_{tot} = PE_s + KE = \frac{1}{2}kA^2 =$ Constant $\therefore$ FALSE ✓

5. A silk thread has a cross-sectional area of 7.49×10^{-12} m^2 and an initial length of 45.5 cm. Calculate the amount that the thread stretches when a spider of weight 6.95×10^{-3} N hangs from it. Young's modulus for the thread is 2.95×10^{9} N/m^2.

(A) 0.572 m (B) 0.000699 m (C) 0.286 m (D) 0.072 m (E) 0.143 m

$$\frac{F}{A} = Y\frac{\Delta L}{L} \Rightarrow \Delta L = \frac{FL}{AY} = \frac{(6.95\times10^{-3}\,\text{N})(0.455\,\text{m})}{(7.49\times10^{-12}\,\text{m}^2)(2.95\times10^{9}\,\text{N/m}^2)} = 0.143\,\text{m}$$

6. In the process of tuning their instruments, two violinists in an orchestra play their instruments at the same time and a beat frequency of 7 Hz is heard. If one of the violins is playing a frequency of 231 Hz, what are the two possible frequencies of sound produced by the other violin? (Enter your answers from smallest to largest, in Hz, to at least three significant figures.) 224.0 Hz, 238.0 Hz

$$f_{beat} = |f_2 - f_1|$$

$$7 = |f_2 - 231\,Hz| \Rightarrow f_2 = 231\,Hz + 7\,Hz = 238\,Hz$$

$$\text{or } f_2 = 231\,Hz - 7\,Hz = 224\,Hz$$

7. At a certain distance, the typical sound intensity level of a buzzing mosquito is 40 dB. At the same distance, a typical vacuum cleaner produces a sound intensity level of 70 dB. Approximately how many buzzing mosquitoes produce a sound intensity level equal to that of a vacuum cleaner?

   (A) 110 (B) 1600 (C) 1000 (D) 2800 (E) 30

$\beta_m = 40\,dB$; $\beta_V = 70\,dB$

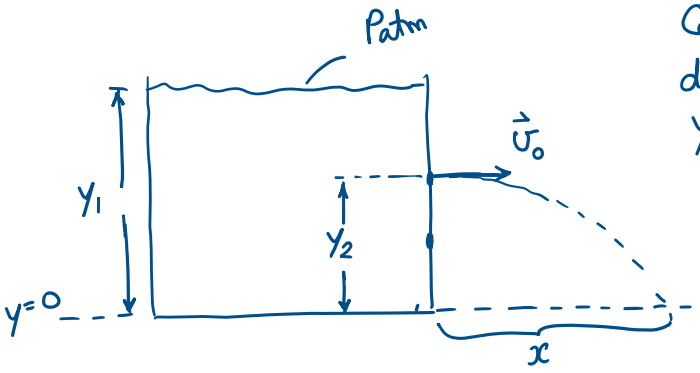
$\Delta\beta = n(10\,dB) \Rightarrow \frac{I_2}{I_1} = 10^n$

$\therefore \Delta\beta = 30\,dB \Rightarrow \frac{I_2}{I_1} = 10^3 \Rightarrow I_V = 1000\, I_m$

$\therefore$ 1,000 mosquitoes are required

WORD PROBLEMS

8. A large container of water open at the top and sitting on the floor has a very small hole punched in its side. The hole is 4.00 cm above the floor. A stream of water leaves the hole horizontally and hits the floor at a distance of 14.1 cm from the container.
   (a) Calculate the speed of the stream of water as it leaves the container. (HINT: The stream of water undergoes projectile motion when it leaves the container.) 15.6 m/s
   (b) Calculate the height of the surface of the water in the tank above the floor. 16.4 cm



Can use Bernoulli's Principle to determine a relationship b/w y_1 and v_0.

Recall that the pressure at an opening is P_{atm}

Also, if the hole is small, the change in height of the water in the tank is negligible and the speed at the top of the tank is negligible.

$$P_{atm} + \rho g y_1 = P_{atm} + \frac{1}{2}\rho v_0^2 + \rho g y_2 \quad (1)$$

$$g y_1 = \frac{1}{2} v_0^2 + g y_2$$

$$y_1 = \frac{v_0^2}{2g} + y_2 \quad (2)$$

(a) Apply kinematics to determine v_0

In vertical direction, $y_2 = v_{0y} t + \frac{1}{2} g t^2$ (down is taken as the +ve direction)

$$y_2 = \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2y_2}{g}}$$

where t is the time for the stream of water to hit the floor.

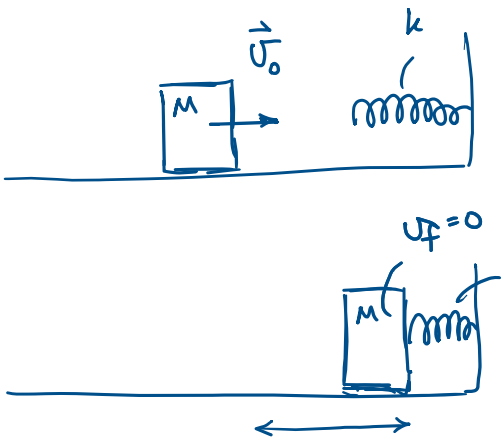
In horizontal direction, $x = v_0 t \Rightarrow v_0 = \frac{x}{t} = x\sqrt{\frac{g}{2y_2}}$

$$v_0 = (0.141\text{m})\sqrt{\frac{(9.80\text{m/s}^2)}{2(0.0400\text{m})}} = \boxed{1.56\text{ m/s}}$$

(b) Substitute for v_0 in equation (2): $y_1 = \frac{v_0^2}{2g} + y_2$

$$y_1 = \frac{(1.56\text{ m/s})^2}{2(9.80\text{m/s}^2)} + 0.0400\text{m} = 0.164\text{m} = \boxed{16.4\text{ cm}}$$

9. A horizontal spring of constant 1,730 N/m is attached to a wall. An object with a mass of 3.96 kg is sliding toward the spring on a horizontal frictionless surface at a speed of 6.86 m/s.
   (a) Calculate the kinetic energy of the object. 93.2 J
   (b) Calculate the maximum compression of the spring due to the collision with the object. 0.328 m
   (c) When the object collides with the spring it attaches to the spring and undergoes simple harmonic motion. Calculate the frequency of the motion. 3.33 Hz



(a) $KE_i = \frac{1}{2}mv_0^2 = \frac{1}{2}(4.39\text{ kg})(6.84\text{ m/s})^2$

$KE_i = 102.7\text{ J}$

(b) Energy is conserved.

$KE_i = PE_{s_{max}} = \frac{1}{2}kx_{max}^2$

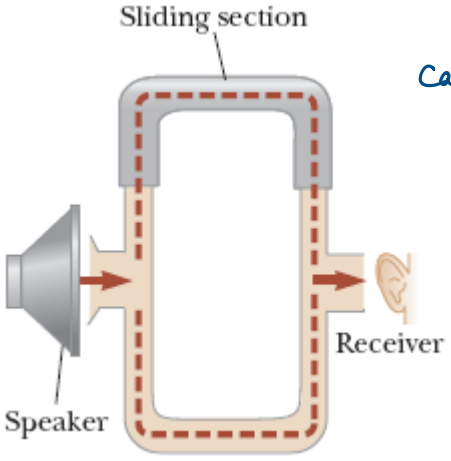
$x_{max} = \sqrt{\frac{2KE_i}{k}} = \sqrt{\frac{2(102.7\text{ J})}{1840\text{ N/m}}}$

$x_{max} = 0.334\text{ m}$

(c) $\omega = 2\pi f = \sqrt{\frac{k}{m}}$

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{1730\text{ N/m}}{3.96\text{ kg}}} = 3.33\text{ Hz}$

10. Sound can travel from a speaker to a listener along two different paths, as shown in the diagram below. The speaker is emitting sound of frequency 718 Hz. Use a value of 343 m/s for the speed of sound.



Calculate wavelength:

$v = f\lambda = \lambda = \frac{v}{f} = \frac{343\,m/s}{718\,Hz} = 0.4777\,m$

(a) Suppose constructive interference occurs at a particular position of the upper U-shaped tube. By what minimum amount should the path length in the upper U-shaped tube be increased so that destructive interference occurs instead? 0.239 m

(b) What minimum increase in the **original** length of the upper tube will again result in constructive interference? 0.478 m

(a) Destructive interference will occur when the difference in path length has been increased by an amount equal to $\frac{1}{2}\lambda$.

$\Delta l_d = \frac{1}{2}\lambda = \frac{1}{2}(0.4777\,m) = \boxed{0.239\,m}$

(b) Constructive interference will occur again when the difference in path length has been increased by λ.

$\boxed{\Delta l_c = \lambda = 0.478\,m}$