Student No. ______________ **PRS Clicker No.** ______________

Last Name____________ **First Name** ______________

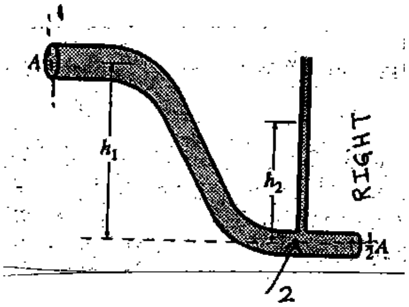
The University of British Columbia — Midterm 1
Physics 101, Section 102 - Oct 15, 2004 — Javed Iqbal

No books or notes permitted. Graphical calculators are allowed, but **formulae may not be stored . Do all four questions.**

Formulae and data:, $Av = \text{const}$, $P + 1/2\rho v^2 + \rho gh = \text{const.}$ $F = -kx$,
$x(t) = A\cos(\omega t + \phi)$, $v(t) = -\omega A\sin(\omega t + \phi)$, $a(t) = -\omega^2 x(t)$
mass-spring system: $\omega = (k/m)^{1/2}$, pendulum: $\omega = (g/L)^{1/2}$, $T = 2\pi/\omega$, $K = 1/2mv^2$, $U = 1/2\,kx^2$,
$Q = (P_1-P_2)\pi r^4/8\eta L$, $1\text{ atm} = 1.01\text{x}10^5\text{ N/m}^2$, water density = 1000 kg/m^3, $g = 9.81\text{m/s}^2$

Problem 1

A pipe of cross-sectional area A is joined to a lower pipe of cross-sectional area A/2. The entire pipe is full of liquid with density ρ, and the left end of the pipe is at an atmospheric pressure P_o. A small open tube extends upwards from the lower pipe. Find the height h_2 of the liquid in the small tube when:



(a) the right end of the lower pipe is closed, so that the liquid is in a hydrostatic equilibrium. (2 points)

Apply Bernoulli's Equation at ① + ②

$$P_o + 0 + \rho g h_1 = P_2 + 0 + 0$$
$$= P_o + \rho g h_2$$
$$\boxed{h_2 = h_1}$$

(b) when the right end is open and the liquid flows with speed v in the upper pipe. (4 points)

Now the fluid velocity through the pipe is non-zero

Applying continuity Equation at ① + ②

$$A \times V = \left(\frac{A}{2}\right) \times V_2 \Rightarrow \boxed{V_2 = 2V}$$

Applying Bernoulli's equation at ① + ②

$$P_o + \frac{1}{2}\rho V^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho(2V)^2 + 0$$
$$\therefore P_2 = P_o - \frac{3}{2}\rho V^2 + \rho g h_1 \quad - Ⓐ$$

But $P_2 = P_o + \rho g h_2 -$ Ⓑ, thus comparing Ⓐ + Ⓑ

$$P_o + \rho g h_2 = P_o - \frac{3}{2}\rho V^2 + \rho g h_1 \Rightarrow \boxed{h_2 = h_1 - \frac{3V^2}{2g}}$$

Problem 2

Consider an object floating in a container of water. If the container is placed in an elevator that accelerates upward

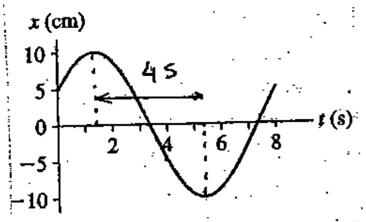
1. more of the object is below water.
2. less of the object is below water.
3. [✓ there is no difference.]
4. There is not sufficient information to answer this question.

Change in effective g, effects both the object + the water.

(Circle only one answer, multiply selected answers will not be given any marks)

Problem 3

The position vs. time graph of a particle is shown in the figure. Determine



(a) the angular frequency of the motion. (1 point)

$$\frac{1}{2}T = 4s \qquad T = 8s$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{8} = \boxed{\frac{\pi}{4}\ \frac{rad}{s}}$$

(b) the phase constant ϕ of the motion. (2 points)

$$x(t) = 0.10\,m \cos\left(\frac{\pi}{4}t + \phi\right)$$

$$x(0) = 0.05\ m = 0.10\,m\cos(\phi)$$

$$\cos(\phi) = \frac{0.05}{0.10} = \frac{1}{2} \qquad \phi = \cos^{-1}\left(\frac{1}{2}\right) = \boxed{\frac{-\pi}{3}\ rad} \leftarrow \text{Correct sign}$$

(c) the velocity of the particle at t = 1.0 s (3 points)

$$x(t) = 0.1 \times \cos\left(\frac{\pi}{4}t - \frac{\pi}{3}\right)$$

$$v(t) = -\left(0.1 \times \frac{\pi}{4}\right) \times \sin\left(\frac{\pi}{4}t - \frac{\pi}{3}\right).$$

$$v(1) = -\frac{\pi}{40} \times \sin\left(\frac{\pi}{4} - \frac{\pi}{3}\right) \quad m/s$$

$$\fallingdotseq \boxed{+0.02\quad m/s}$$

Problem 4

A 0.10 kg ball, attached to a spring with spring constant 2.5 N/m, oscillates horizontally on a frictionless surface. When the ball is 0.05m from the equilibrium position its velocity is 0.2 m/s

(a) What is the total energy of the ball-spring system? (2 points)

$$E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 2.5 \times (0.05)^2 + \frac{1}{2} \times 0.1 \times (0.2)^2 = \boxed{0.0051\ J}$$

(b) What is the amplitude of oscillations? (2 points)

$$E = \frac{1}{2}kA^2$$

$$A = \sqrt{\frac{2E}{k}} = \boxed{0.064\ m}$$

(c) What is the speed of the ball when it is at x = 0.06 m from the equilibrium point? (2 points)

$$E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E}{m} - \frac{k}{m}x^2}$$

$$= \sqrt{\frac{2 \times 0.0051}{0.1} - \frac{2.5}{0.1} \times (0.06)^2} \fallingdotseq \boxed{0.11\ \frac{m}{s}}$$