Name____

Physics 110 Quiz #7, May 29, 2020

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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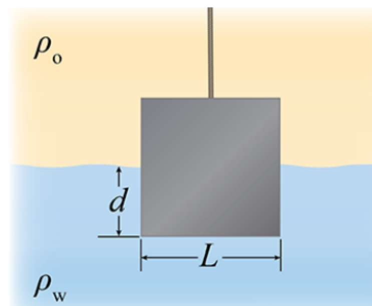
A cube with an edge length of $L = 0.11m$ and density $\rho_C = 2100\frac{kg}{m^3}$ is totally submerged in water ($\rho_W = 1000\frac{kg}{m^3}$) and oil ($\rho_O = 810\frac{kg}{m^3}$) as shown in the figure. The cube is submerged in water to a depth of $d = 0.06m$ while the rest of the cube is in oil. The cube is suspended by a taut string and is at rest in the fluids.



a. What is the bouyant force on the cube due to the water and the oil?

The buoyant force is equal to the weight of the displaced fluid. Here we have two fluids displaced. The total buoyant force is the sum of the buoyant forces from the oil and water.

$F_{B,total} = F_{B,w} + F_{B,o} = m_w g + m_o g = \rho_w V_w g + \rho_o V_o g$

Where,

$F_{Bw} = \left(1000\frac{kg}{m^3} \times (0.11m \times 0.11m \times 0.06m) \times 9.8\frac{m}{s^2}\right) = 7.12N$

$F_{Bo} = \left(810\frac{kg}{m^3} \times \left(0.11m \times 0.11m \times (0.11m - 0.06m)\right) \times 9.8\frac{m}{s^2}\right) = 4.80N$

Thus,

$F_{B,total} = F_{B,w} + F_{B,o} = 7.12N + 4.80N = 11.92N$

b. What is the tension in the string?

Assuming a standard cartesian coordinate system and applying Newton's laws of motion in the vertical direction we have:

$F_T - F_W + F_{B,total} = ma_y = 0$

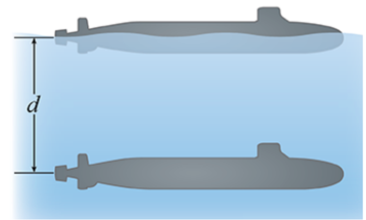
The mass of the block is given by the product of the density and the volume.

$\rho = \frac{M}{V} \to m = \rho V = 2100\frac{kg}{m^3} \times (0.11m)^3 = 2.80kg$

Thus,

$F_T = F_W - F_{B,total} = \left(2.8kg \times 9.8\frac{m}{s^2}\right) - 11.92N = 15.47N$

c. Seawolf class nuclear submarines have a hull crush depth of approximately $d = 705m$. This is the depth at which the outer hull of the submarine will get crushed by the surrounding seawater ($\rho_{sw} = 1025\frac{kg}{m^3}$). What is the magnitude of the inward force on a porthole of radius $r = 0.11m$ at this depth? Hint, air pressure is $P_{air} = 1.01 \times 10^5 \frac{N}{m^2}$.



The pressure varies linearly with depth.

$P_d = P_{air} + \rho_{sw} g d$

$P_d = 1.01 \times 10^5 \frac{N}{m^2} + \left(1025\frac{kg}{m^3} \times 9.8\frac{m}{s^2} \times 705m\right) = 7.18 \times 10^6 \frac{N}{m^2}$

The pressure is the force exerted per unit area, so the inward force is:

$$P_d = \frac{F_{in}}{A_{porthole}} \rightarrow F_{in} = P_d A_{porthole} = 7.18 \times 10^6 \frac{N}{m^2} \times \pi(0.11m)^2 = 2.7 \times 10^5 N$$

d. If the interiour of the sumbarine is kept at atmospheric pressure ($P_{air} = 1.01 \times 10^5 \frac{N}{m^2}$), what will be the net force (magnitude and direcction) on the porthole?

The force exerted on the porthole from the inside (pointing out) is:

$$P_{in\ sub} = \frac{F_{out}}{A_{porthole}} \rightarrow F_{out} = P_{in\ sub} A_{porthole} = 1.01 \times 10^5 \frac{N}{m^2} \times \pi(0.11m)^2 = 3839N$$

The net force is the difference between the forces inside and outside of the sub. Assuming that the positive x-direction is points towards the water from the sub, we have the net force:
$F_{net} = F_{out} - F_{in} = 3839N - 2.7 \times 10^5 N = -2.66 \times 10^5 N$ or $2.66\times 10^5 N$ pointing from the water into the sub.

e. When water flows from your kitchen faucet the radius of the stream of water gets narrower the farther it falls from the faucet. The reason the stream of water changes in radius is most likely due to which of the following?
1. The flow rate of the water changes as the water falls.
2. The energy of the water decreases as the water falls.
3. The surrounding air exerts an upward buoyant force on the water.
4. The flow rate of the water is continuous as the water falls
5. None of the above answers are correct.

Physics 110 Formulas

Motion

$\Delta x = x_f - x_i \qquad v_{avg} = \frac{\Delta x}{\Delta t} \qquad a_{avg} = \frac{\Delta v}{\Delta t}$

Equations of Motion

displacement: $\begin{cases} x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2 \\ y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2 \end{cases}$

velocity: $\begin{cases} v_{fx} = v_{ix} + a_x t \\ v_{fy} = v_{iy} + a_y t \end{cases}$

time-independent: $\begin{cases} v_{fx}^2 = v_{ix}^2 + 2a_x \Delta x \\ v_{fy}^2 = v_{iy}^2 + 2a_y \Delta y \end{cases}$

Uniform Circular Motion

$F_r = ma_r = m\frac{v^2}{r}; \quad a_r = \frac{v^2}{r}$

$v = \frac{2\pi r}{T}$

$F_G = G\frac{m_1 m_2}{r^2}$

Geometry /Algebra

Circles — $C = 2\pi r$, $A = \pi r^2$

Triangles — $A = \frac{1}{2}bh$

Spheres — $A = 4\pi r^2$, $V = \frac{4}{3}\pi r^3$

Quadratic equation : $ax^2 + bx + c = 0$,

whose solutions are given by : $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Vectors

magnitude of a vector: $v = |\vec{v}| = \sqrt{v_x{}^2 + v^2{}_y}$

direction of a vector: $\phi = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

Useful Constants

$g = 9.8\, m/s^2 \qquad G = 6.67\times10^{-11}\, Nm^2/kg^2$

$N_A = 6.02\times10^{23}\, atoms/mole \qquad k_B = 1.38\times10^{-23}\, J/K$

$\sigma = 5.67\times10^{-8}\, W/m^2K^4 \qquad v_{sound} = 343\, m/s$

Linear Momentum/Forces

$\vec{p} = m\vec{v}$

$\vec{p}_f = \vec{p}_i + \vec{F}\Delta t$

$\vec{F} = m\vec{a}$

$\vec{F}_s = -k\vec{x}$

$F_f = \mu F_N$

Work/Energy

$K_t = \frac{1}{2}mv^2$

$K_r = \frac{1}{2}I\omega^2$

$U_g = mgh$

$U_S = \frac{1}{2}kx^2$

$W_T = FdCos\theta = \Delta E_T$

$W_R = \tau\theta = \Delta E_R$

$W_{net} = W_R + W_T = \Delta E_R + \Delta E_T$

$\Delta E_R + \Delta E_T + \Delta U_g + \Delta U_S = 0$

$\Delta E_R + \Delta E_T + \Delta U_g + \Delta U_S = -\Delta E_{diss}$

Heat

$T_C = \frac{5}{9}[T_F - 32]$

$T_F = \frac{9}{5}T_C + 32$

$L_{new} = L_{old}(1 + \alpha\Delta T)$

$A_{new} = A_{old}(1 + 2\alpha\Delta T)$

$V_{new} = V_{old}(1 + \beta\Delta T): \ \beta = 3\alpha$

$PV = Nk_B T$

$\frac{3}{2}k_B T = \frac{1}{2}mv^2$

$\Delta Q = mc\Delta T$

$P_C = \frac{\Delta Q}{\Delta t} = \frac{kA}{L}\Delta T$

$P_R = \frac{\Delta Q}{\Delta T} = \varepsilon\sigma A\Delta T^4$

$\Delta U = \Delta Q - \Delta W$

Rotational Motion

$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$

$\omega_f = \omega_i + \alpha t$

$\omega^2{}_f = \omega^2{}_i + 2\alpha\Delta\theta$

$\tau = I\alpha = rF$

$L = I\omega$

$L_f = L_i + \tau\Delta t$

$\Delta s = r\Delta\theta: \ v = r\omega: \ a_t = r\alpha$

$a_r = r\omega^2$

Sound

$v = f\lambda = (331 + 0.6T)\,\frac{m}{s}$

$\beta = 10\log\frac{I}{I_0}; \quad I_o = 1\times10^{-12}\,\frac{W}{m^2}$

$f_n = nf_1 = n\frac{v}{2L}; \ f_n = nf_1 = n\frac{v}{4L}$

Fluids

$\rho = \frac{M}{V}$

$P = \frac{F}{A}$

$P_d = P_0 + \rho gd$

$F_B = \rho gV$

$A_1v_1 = A_2v_2$

$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

$P_1 + \frac{1}{2}\rho v^2{}_1 + \rho gh_1 = P_2 + \frac{1}{2}\rho v^2{}_2 + \rho gh_2$

Simple Harmonic Motion/Waves

$\omega = 2\pi f = \frac{2\pi}{T}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{l}{g}}$

$v = \pm\sqrt{\frac{k}{m}}A\left(1 - \frac{x^2}{A^2}\right)^{\frac{1}{2}}$

$x(t) = A\sin(\frac{2\pi t}{T})$

$v(t) = A\sqrt{\frac{k}{m}}\cos(\frac{2\pi t}{T})$

$a(t) = -A\frac{k}{m}\sin(\frac{2\pi t}{T})$

$v = f\lambda = \sqrt{\frac{F_T}{\mu}}$

$f_n = nf_1 = n\frac{v}{2L}$

$I = 2\pi^2 f^2 \rho v A^2$