Oberlin College Physics 103, Fall 2023

Model Solutions to Assignment 11: Fluids; Oscillations

Problems from *College Physics* by P.P. Urone and R. Hinrichs.

Chapter 11, problem 40: Bird bones

Our procedure follows U&H example 11.10 on page 455.

(a) apparent mass loss = 45.0 g - 3.60 g = 41.4 g, so mass of displaced water is 41.4 g

(b) density of water is 1.000 g/cm^3, so volume of displaced water = volume of bone = 41.4 cm^3

(c) average density of bone is

$$\frac{\text{mass of bone}}{\text{volume of bone}} = \frac{45.0\text{ g}}{41.4\text{ cm}^3} = 1.09\text{ g/cm}^3$$

⟦*Grading:* 2 points for part **(a)**, 2 points for part **(b)**, 2 points for formula for density of bone, 2 points for number 1.09, 1 point for units "g/cm^3", 1 point for three significant figures in final numerical answer.⟧

Chapter 11, problem 42: Density of a fluid

(a) apparent mass loss = 390.0 g - 350.5 g = 39.5 g, so mass of displaced fluid is 39.5 g

(b) density of iron is 7.8 g/cm^3, so

$$\text{volume of iron} = \frac{\text{mass of iron}}{\text{density of iron}} = \frac{390.0\text{ g}}{7.8\text{ gm/cm}^3} = 50\text{ cm}^3$$

and the volume of iron is the same as the volume of displaced fluid **(c)** density of fluid is

$$\frac{\text{mass of displaced fluid}}{\text{volume of displaced fluid}} = \frac{39.5\text{ g}}{50\text{ cm}^3} = 0.79\text{ gm/cm}^3$$

Table 11.1 on page 434 suggests that the fluid is ethyl alcohol. ⟦*Grading:* 2 points for part **(a)**, 2 points for formula for volume of iron in part **(b)**, 2 points for number 50, 1 point for two significant figures "50", 2 points for density of fluid, 1 point for identification as ethyl alcohol (or as some other fluid).⟧

Chapter 16, problem 18: Bouncing on a diving board

For simple harmonic oscillation,

$$\omega = \sqrt{\frac{k}{m}} \qquad \text{so} \qquad \text{period} = T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}.$$

The female and male divers have different masses and hence different periods, but they're on the same diving board so they have the same k. Solve for k:

$$\begin{aligned} T &= 2\pi\sqrt{\frac{m}{k}} \\ T^2 &= 4\pi^2\frac{m}{k} \\ k &= 4\pi^2\frac{m}{T^2}. \end{aligned}$$

The female (subscript f) and male (subscript m) divers have the same k so

$$\begin{aligned} 4\pi^2\frac{m_f}{T_f^2} &= 4\pi^2\frac{m_m}{T_m^2} \\ \frac{m_f}{T_f^2} &= \frac{m_m}{T_m^2} \\ m_f\left(\frac{T_m}{T_f}\right)^2 &= m_m. \end{aligned}$$

We don't need to actually find the value of k, we don't need to multiply by $4\pi^2$, we need to take a square only once, not twice. The numerical result is

$$m_m = (55.0\text{ kg})\left(\frac{1.05\text{ s}}{0.800\text{ s}}\right)^2 = 94.7\text{ kg}.$$

(I've emphasized that you don't *need* to find a value for k. But if you do, it's 3.39 kN/m.)
⟦*Grading:* 2 points for writing down a formula for ω or for period T, 2 points for noticing that k will be the same for both divers, 4 points for getting the number 94.7, 1 point for three significant figures, 1 point for units.⟧

Chapter 16, problem 20: Baby bouncer
(Side note: As a parent, I recommend this toy for giving babies both entertainment and exercise. Both of our kids loved it.)
(a)

$$k = \frac{\text{force}}{\text{extension}} = \frac{(8.0\text{ kg})(9.81\text{ m/s}^2)}{0.250\text{ m}} = 0.31\text{ kN/m}.$$

(b)

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m}{mg/(\text{extension})}} = 2\pi\sqrt{\frac{\text{extension}}{g}} = 2\pi\sqrt{\frac{0.250\text{ m}}{9.81\text{ m/s}^2}} = 1.00\text{ s}.$$

(c) From the textbook's equation 16.21,

$$v_{\max} = \frac{2\pi(\text{amplitude})}{T} = \frac{2\pi(0.200\text{ m})}{1.00\text{ s}} = 1.26\text{ m/s}.$$

⟦*Grading:* There are several ways to do this problem. If you use the numerical value of k found in part **(a)**, then the results for parts **(b)** and **(c)** will have two significant figures, not three. Consequently, I won't give detailed grading tips on number of significant figures. Generally, be on the lookout for missing units and absurd significant figures. As a guideline, part **(a)** earns 3 points, part **(b)** earns 4 points, part **(c)** earns 3 points.⟧