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Exercises and Complements for the Introduction to Physics I for Students of Biology, Pharmacy and Geoscience

Sheet 9 / 16.11.2020 **Solutions**

Exercise 41.

(a) The frequency is calculated by:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} = 0.13\,\mathrm{Hz}$$

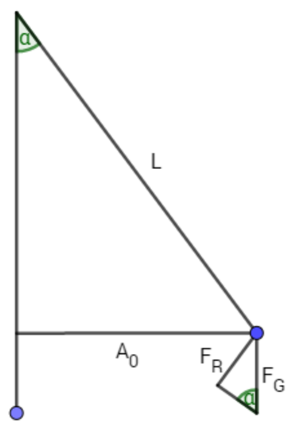
(b) The oscillation period is the reciprocal of the frequency:

$$T = f^{-1} = 7.8\,\mathrm{s}$$

(c) The total distance s_{ges} of a period in x-direction can be divided into four sections. According to the sketch, each section A_0 can be calculated using the sine:

$$A_0 = \sin(5^\circ) \cdot 15\,\mathrm{m}$$

$$s_{\mathrm{ges}} = 4 \cdot A_0 = 5.23\,\mathrm{m}$$



(d) The $x(t)$ equation can be formed as follows from the amplitude A_0 and the angular frequency ω:

$$x(t) = A_0 \cdot \cos(\omega \cdot t)$$

With $A_0 = s_{\frac{1}{4}} = 1.31$ m and $\omega = 0.81$ s^{-1} it follows:

$$x(t) = 1.31\,\mathrm{m} \cdot \cos(0.81\,\mathrm{s}^{-1} \cdot t)$$

(e) The velocity can be formed by the time derivative of the $x(t)$ equation:

$$v(t) = \dot{x}(t) = -A_0 \cdot \omega \cdot \sin(\omega \cdot t)$$

With $A_0 = 1.31$ m and $\omega = 0.81$ s^{-1} it follows:

$$|v(5\,\mathrm{s})| = |-1.31\,\mathrm{m} \cdot 0.81\,\mathrm{s}^{-1} \cdot \sin(0.81\,\mathrm{s}^{-1} \cdot t)| = 0.84 \text{ m/s}$$

(f) The restoring force F_R can be calculated as follows according to the sketch:

$$F_R = F_G \cdot \sin(\alpha) = 8\,\mathrm{kg} \cdot 9.81\mathrm{m/s}^2 \cdot \sin(5°) = 6.84\,\mathrm{N}$$

Exercise 42.

After the clock has run 12 hours, it shows 11.5 h. So, it made just 11.5/12 = 95,8% of the required pendulum motions, respectively the time of oscillation T_0 is too big. To be on time, it must be:

$$T = T_0 \cdot 0.958$$

The equation for a mathematical pendulum (pendulum clock) describing the time of oscillation is:

$$T_0 = 2\pi\sqrt{\frac{l_0}{g}}$$

and from this it follows:

$$\frac{T'}{T_0} = \sqrt{\frac{l'}{l_0}} = 0.958 \qquad \Rightarrow \qquad l' = l_0 \cdot 0.958^2 = 0.459 \text{ m}$$

Exercise 43.

(a) The eigenfrequency of a mathematical pendulum is:

$$\omega_P = 2\pi/T_P = \sqrt{g/l}$$

The eigenfrequency of the combined system of spring and pendulum is:

$$\omega_F = 2\pi/T_F = \sqrt{D/m + g/l}$$

for the time of contact t it must be $t = T_F/2$ (since the spring is considered as massless) and for T_F:

$$T_F = \frac{2\pi}{\sqrt{D/m + g/l}}$$

and consequently t is:

$$t = T_F/2 = \frac{1}{2} \cdot \frac{2\pi}{\sqrt{D/m + g/l}} = 0.32 \text{ s}$$

(b) Since the time of the oscillation of the pendulum (for small deflections) is independent of the angle and $T_P = T_F \cdot \sqrt{2}$, is the time of contact independent of α.

Exercise 44.

(a) The following force is needed to bring the cuboid out of equilibrium by pushing it by the distance Δh into the water:

$$F = m_{water} g = V_{water} \rho_{water} g = A \Delta h \rho_{water} g$$

whereby the force is proportional to the deflection Δh (compare with the behavior of a spring) and the systems is oscillating harmonically.

(b) the constant of proportionality (spring constant):

$$c = \frac{F}{\Delta h} = A \rho_{water} g$$

The following equation describes the harmonic oscillation:

$$T = 2\pi \sqrt{\frac{m_{cuboid}}{c}} = 2\pi \sqrt{\frac{A h \rho_{cuboid}}{A \rho_{water} g}} = 2\pi \sqrt{\frac{h \rho_{cuboid}}{\rho_{water} g}}$$

(c) In the case of a wooden sphere (instead of the cuboid) the cross-sectional area is not constant in height. As a result, the buoyant force is not proportional to the depth of immersion (deflection) and as a consequence the sphere is not oscillating harmonically. Therefore the result obtained in (b) is not valid for a sphere.

Exercise 45.

It is given that (script 108-6):

$$x(t) = c_0 e^{-\delta t} \sin(\omega t - \phi_0)$$

accordingly is:

$$x(t_0) = c_0 e^{-\delta t_0} \sin(\omega t_0)$$

$$x(t_0 + 5T) = c_0 e^{-\delta(t_0+5T)} \sin(\omega(t_0 + 5T)) = c_0 e^{-\delta(t_0+5T)} \sin(\omega t_0)$$

The ratio is:

$$\frac{x(t_0 + 5T)}{x(t_0)} = \frac{1}{2} = e^{-5\delta T}$$

and therefore

$$\delta = \frac{ln 2}{5T} = 0.0462 \text{ s}^{-1}$$