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

Sheet 5 / October 18, 2019 **Solutions**

Exercise 21.

At the height of $h = 2000$ m the potential and the kinetic energy are equal:

$$mgh = \frac{mv^2}{2} \qquad \Rightarrow \qquad v = \sqrt{2gh} = 198 \quad \text{m/s}$$

The initial velocity is described by:

$$v = \sqrt{-2gh + v_0^2} \qquad \Rightarrow \qquad v_0 = \sqrt{2}v = 280 \quad \text{m/s}$$

Exercise 22.

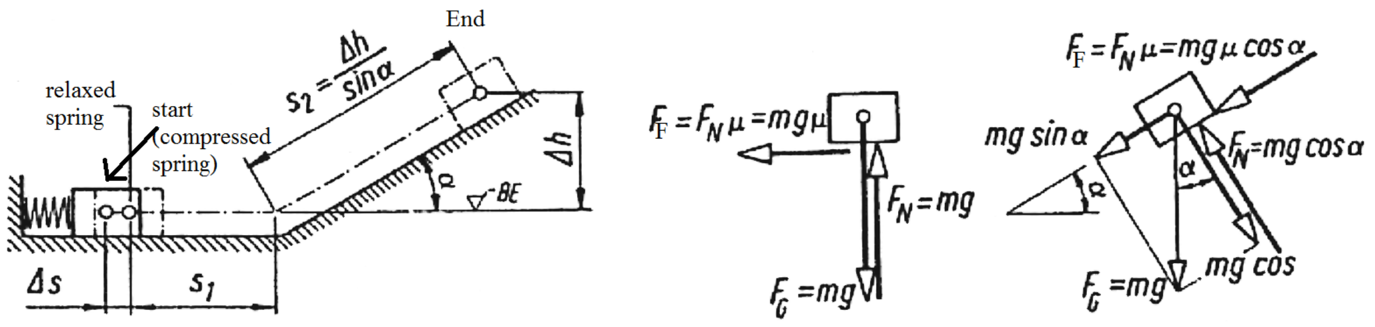
Lifting and friction work have to be performed. The first one is given by mgh, and the second one by $\mu F_N s$, where $F_N = mg\cos\alpha$ is the normal force and $s = h/\sin\alpha$ is the distance of the path on the inclined plane is:

$$\begin{aligned} W &= mgh + \mu mgh\frac{\cos\alpha}{\sin\alpha} = mgh(1 + \mu\cot\alpha) \\ &= mgs(\sin\alpha + \mu\cos\alpha) = 61.85 \quad \text{kJ} \end{aligned}$$

The lifting work depends only on the difference in height h from the starting and the final position of the movement. The frictional work depends on the actual covered distance s. The gravitational force is conservative and the frictional force is non-conservative.

Exercise 23.

a) Sketch:



b) The energy at the end of the movement E_E is equal to the kinetic energy E_A, at the beginning, minus the loss due to the friction:

$$E_E = E_A \pm W_{+,-}$$

$$mg\Delta h = 0 + \frac{k}{2}\Delta s^2 - mg\mu(s_1 + \Delta s) - mg\mu\cos\alpha\frac{\Delta h}{\sin\alpha}$$

$$\Delta h = \frac{\frac{k}{2}\Delta s^2 - mg\mu(s_1 + \Delta s)}{mg(1 + \mu\cot\alpha)} = 1.65 \quad \text{m}$$

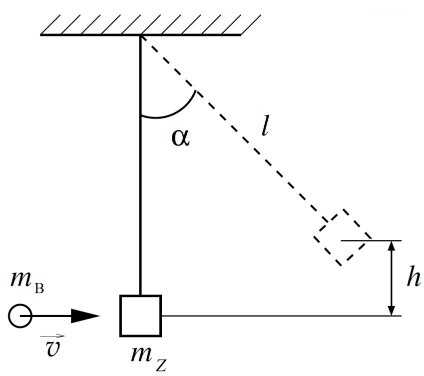
Exercise 24.

For the initial velocity of the object it follows from the law of conservation of momentum:

$$v_0 = \frac{m_B v}{m_Z + m_B}$$

The height (see figure) can be calculated from the law of energy conservation:

$$\frac{(m_Z + m_B)v_0^2}{2} = (m_Z + m_B)gh \qquad \Rightarrow \qquad h = \frac{v_0^2}{2g}$$



In conclusion:

$$\cos\alpha = 1 - \frac{h}{l} = 1 - \frac{m_B^2 v^2}{(m_Z + m_B)^2 2gl} \qquad \Rightarrow \qquad \alpha = 73^\circ$$

Exercise 25.

a) System is in equilibrium, so nothing happens.

b) We zero the total energy in the resting state $= 0$ (any other value or constant is also possible since it gets later canceled out anyway). If the mass m_1 moves downwards by the distance x, then:

$$m_1 g x - m_2 g x + \frac{1}{2} m_1 \dot{x}^2 + \frac{1}{2} m_2 \dot{x}^2 = 0$$

$$2g(m_2 - m_1)x = (m_1 + m_2)\dot{x}^2$$

$$2g \frac{m_2 - m_1}{m_1 + m_2} x = \dot{x}^2$$

The derivative with respect to the time is:

$$2g \frac{m_2 - m_1}{m_1 + m_2} \dot{x} = 2\dot{x}\ddot{x}$$

Divide by $\dot{x}$, $\dot{x} \neq 0$

$$\ddot{x} = a = g \frac{m_2 - m_1}{m_1 + m_2}$$

Alternative solution:

$$\begin{aligned} Z - m_1 g &= m_1 a \\ m_2 g - Z &= m_2 a \end{aligned}$$

with Z as tension force. Since the wheel has no friction, the value of the tension force in the rope is the same. Consequently we obtain the same result:

$$a = g \frac{m_2 - m_1}{m_1 + m_2}$$