Exercises in Introductory Physics I

Exercise Sheet 6
due to 27.11.23, 11:59 AM

Tension

1. Derive the capstan equation that relates the tensions of a rope that is wound around a cylinder as it is just about to slip (1P):

$$T_{load} = T_{\text{hold}}\, e^{\mu_S \theta}$$

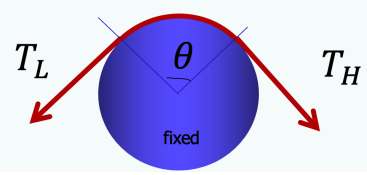

Figure 1: Capstan equation

Some hints may be found in the lecture notes.

Energy and Potential

1. A commonly used potential describing intermolecular interactions in liquids and real gases is the so-called Lennard-Jones potential. In this model the interaction of atoms and molecules with each other is given by $U(r) = 4\epsilon \left[\left(\frac{r_m}{r}\right)^{12} - 2\left(\frac{r_m}{r}\right)^{6} \right]$.

   a) Explain why molecules in this potential have a common average distance r_m to their neighbors. (1P)

   b) Determine the energy that is required to evaporate a molecule from such fluids. (1P)

2. A mass of 275 g falls under the action of gravity onto a vertical coil spring (spring constant $D = 2.7\,\frac{\text{N}}{\text{cm}}$). The spring is compressed by 20 cm until the mass reaches its lowest position.

   a) Draw the sketches for b) and d) side by side and include an appropriate coordinate system. (1P)

   b) What is the velocity of the mass just before touching the spring? (1P)

   c) If the mass is doubled, what is the distance by which the spring would be compressed? (1P)

   d) After a while, due to friction, the system comes to halt and the mass is sitting still on the spring. How much is the spring compressed? (1P)

3. A Foucault pendulum is oscillating around a point of equilibrium. The plane of oscillations changes with $\omega = \sin(\varphi)\ \frac{2\pi}{24\,\mathrm{h}}$, where φ is the latitude of the location. A metal rod is placed $x = 163\,\mathrm{cm}$ from the equilibrium point and $d = 3\,\mathrm{cm}$ from the starting plane of the oscillation. $t = 5.5\,\mathrm{min}$ after starting, the pendulum collides with the metal rod. At which latitude was the experiment performed? (1P)

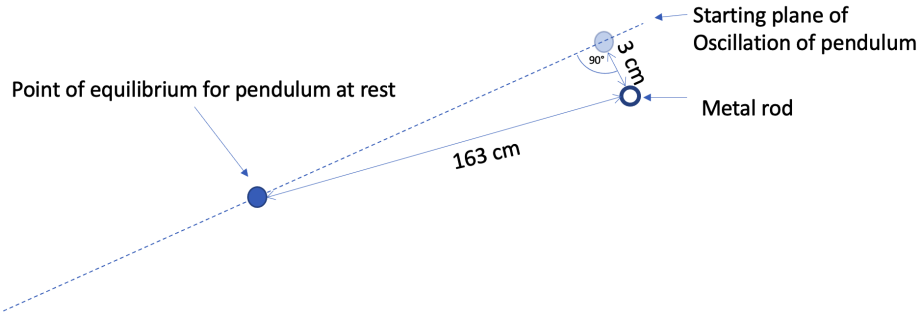

Figure 2: Sketch of the Foucault Pendulum