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

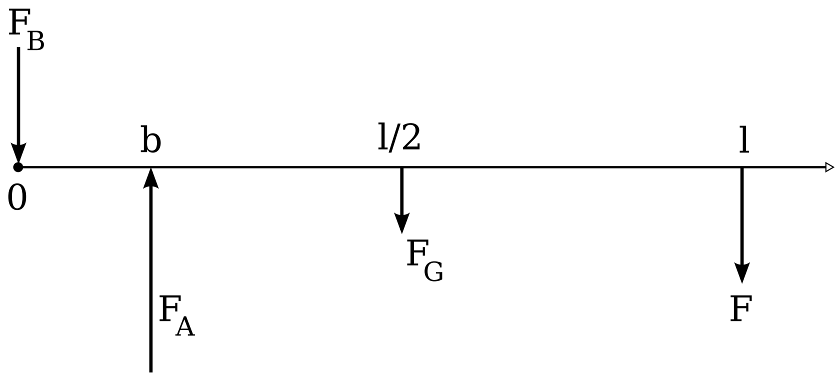
Sheet 4 / September 26, 2017 **Solutions**

Exercise 14.

1) No equilibrium ($M_{tot} \neq 0$); 2) equilibrium ($M_{tot} = 0$); 3) no equilibrium ($F_{tot} \neq 0$); 4) no equilibrium ($M_{tot} \neq 0$).

Exercise 15.

a)



b) The condition for a force equilibrium is :

$$F_A - F_B - Mg - mg = 0$$

The condition for a torque equilibrium acting on position B is:

$$F_A b - \frac{l}{2} Mg - mgl = 0$$

and from this F_A and F_B it can be calculated:

$$F_A = \frac{l}{b}\left(mg + \frac{1}{2}Mg\right) = 415.9\ N$$

$$F_B = F_A - (mg + Mg) = 286.4\ N$$

Exercise 16.

On the object with the weight mg acting in the direction of the motion, the down-hill slope force $F_H = mg\sin\alpha$ and in the opposite direction the friction force $F_R = \mu F_N$ with the normal force $F_N = mg\cos\alpha$. If F_H is greater than F_R , then the object will slide downwards. The accelerating force is then:

$$F_H - F_R = mg(\sin\alpha - \mu\cos\alpha) = ma$$

resulting in the coefficient of sliding friction:

$$\mu = \frac{\sin\alpha - (a/g)}{\cos\alpha} = 0.20$$

In the limiting case where $F_H = F_R$ (stiction), at $\alpha = \beta_0$ (friction angle), is $\mu_0 = \tan\beta_0 = 0.36$.

Exercise 17.

a) The kinetic friction on a horizontal plane is:

$$F = ma \qquad \text{and} \qquad F_R = \mu_g F_N = \mu_g mg$$

In the case where the system is in motion, the mass M which needs to be moved is composed of the two individual masses m_1 and m_2:

$$M = m_1 + m_2$$

The effective acceleration is:

$$a = \frac{F - F_R}{M} = \frac{F}{M} - \mu_g g$$

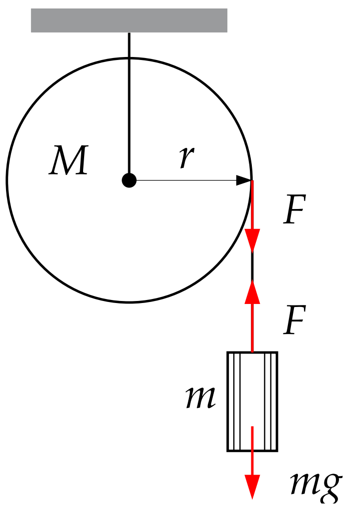
b) F_1: only mass m_1

$$F_1 = m_1 a + \mu_g m_1 g$$

$$F_1 = m_1(\frac{F}{M} - \mu_g g) + \mu_g m_1 g$$

$$F_1 = \frac{m_1 F}{M}$$

Additional Exercise



The only force which induces a torque on the cylinder is the tensile force in the string which is acting via the lever r at the cylinder and induces a rotation.

$$M = F \cdot r = J \cdot \alpha$$

with α the angular acceleration. Two forces are acting on the cylinder: F and F_G, therefor:

$$F_G - F = mg - F = ma$$

Since the string is not sliding on the cylinder, the velocity of the string is equal to any point at the edge of the cylinder. Hence, the acceleration is equal to the tangential acceleration of a point of the cylinder.

$$a = r\alpha$$

Resulting in:

$$F = \frac{J\alpha}{r}$$

by using this in the equation of forces we obtain the following relation:

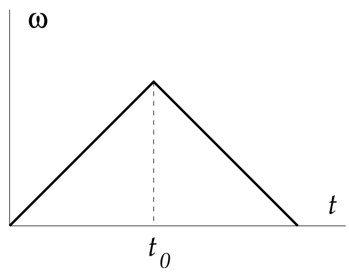
$$mg - \frac{J\alpha}{r} = m \cdot \alpha r$$

and by using the equation for the moment of inertia for a cylinder $J = \frac{M \cdot r^2}{2}$ it follows:

$$\alpha = \frac{mg}{r\left(m + \frac{M}{2}\right)}$$

Since $\omega = \alpha \cdot t$:

$$\omega = \underbrace{\frac{mg}{r\left(m + \frac{M}{2}\right)}}_{constant} \cdot t$$



From this equation follows that the velocity is increasing proportionally to the time. At it time t_0, see sketch, the string is completely rolled off from the cylinder. Afterwards the string gets coiled up in the contrary direction, which corresponds to a decease of the angular frequency.