

Thermodynamics and energetics I: Exercise 1, solution

Units

Mass: kg

Velocity: m/s

Acceleration: m/s^2

Force: N ($\equiv \text{kg}\cdot\text{m/s}^2$)

Energy: J

Power: W ($\equiv \text{J/s}$: energy per unit time)

Pressure: Pa ($\equiv \text{N/m}^2$: force per unit area, or: J/m^3 : energy per unit volume)

Temperature: K ($^{\circ}\text{C}$)

1. Open or closed systems

- Tea pot on the stove **Open**
- Thermos flask **Closed**
- Turbine in an electrical power plant **Open**
- Combustion chamber in automotive engine **Open**
- Family house with PV panels and heat pump for warm water **Closed** (ventilation is not considered)

2. Cylinder suspended from a spring scale

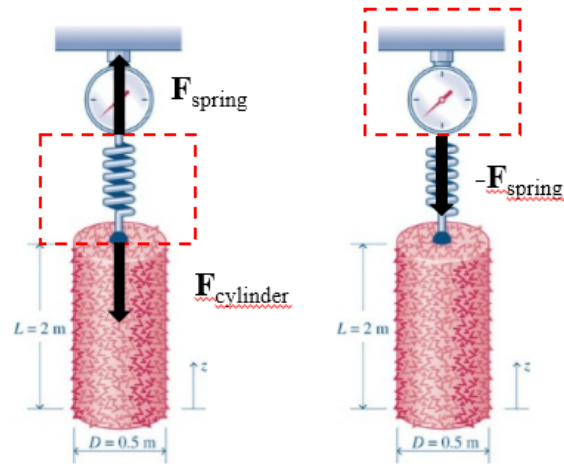


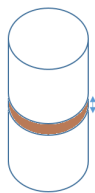
Figure 1: Weight hanging on a spring.

Force balance in z -direction:

$$F_{\text{spring}} - F_{g,\text{cylinder}} = 0 \quad (1)$$

$$F_{g,\text{cylinder}} = m_{\text{cylinder}} \cdot g \quad (2)$$

Calculation of cylinder mass - integration of cylinders mass along z -axis:



$$\begin{aligned} m_{\text{cylinder}} &= \int_m dm = \int_V \rho(z) dV = R^2 \pi \int_z \rho(z) dz \\ &= R^2 \pi \int_{z=0}^L \left(7800 - 360 \left(\frac{z}{L} \right)^2 \right) dz = 0.25^2 \cdot 3.14 \cdot \left[7800z - 120L \left(\frac{z}{L} \right)^3 \right]_0^L \\ &= 3014.4 \text{ kg} \end{aligned}$$

Scale reading:

$$|F_{\text{spring}}| = m_{\text{cylinder}} \cdot g = 2.96 \cdot 10^4 \text{ N} \quad (3)$$

3. Fill in the tables.

- Pressure:

| bar | kPa | atm | N/m ² |
|--------|------|----------------------|-------------------|
| 1 | 100 | 0.987 | $1.00 \cdot 10^5$ |
| 10.0 | 1000 | 9.87 | $1.00 \cdot 10^6$ |
| 1.01 | 101 | 1 | $1.01 \cdot 10^5$ |
| 0.0100 | 1.00 | $9.87 \cdot 10^{-3}$ | 1000 |

- Temperature:

| K | °C |
|--------|--------|
| 250 | -23.15 |
| 293.15 | 20 |

- Mass flow:

| kg/s | kg/min | kg/h | t/h |
|----------------------|--------|-------------------|-------|
| 0.1 | 6.00 | 360 | 0.360 |
| 0.333 | 20 | $1.20 \cdot 10^3$ | 1.20 |
| $2.78 \cdot 10^{-3}$ | 0.167 | 10 | 0.010 |
| 2.78 | 167 | $1.00 \cdot 10^4$ | 10 |