Form 11–12

## 1 Snow on benches (3 points)

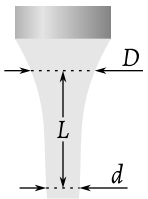
This winter inhabitants of Alūksne noticed regularly distributed heaps of snow on the benches around the local open-air stage (see the photo). Local authorities also shared photos showing how these heaps were changing in time. Propose and justify a mechanism that would describe formation of such heaps of snow.

## 2 Helicopter (3 points)

Estimate the power of the engine that is required to hover a helicopter of mass $m$ = 500 kg if the length of its propeller blades is $L$ = 3 m. Assume that below the blades, air is moving down in a uniform flow.

## 3 Tap water (4 points)

A vertical water stream is flowing from the tap. The diameter of the stream decreases from $D$ = 3 mm to $d$ = 2 mm when flowing through $L$ = 3 cm height difference. Determine the volume of water that flows out of the tap per second.




## 4 Achromatic lens (5 points)

Refractive index of glass, and thus also the optical power of lenses, depends on the wavelength of light. Due to that *chromatic aberration* can be observed. This phenomenon makes it hard to obtain sharp images of coloured objects in optical systems. In order to partly compensate for this drawback, lenses can be made up of two tightly sealed glasses of different types.

Calculate optical powers $D_K$ and $D_F$ of lenses made of two types of glass – crown glass BK7 and flint glass F2 – if, when combined, they should make up a lens of the optical power $D_{KF}$ = 10 m$^{-1}$ for both red and blue light. Calculate the optical powers $D_K$ and $D_F$ of both lens components for green light ($\lambda$ = 550 nm). Optical power of a lens of the given shape in air is proportional to $(n - 1)$, where $n$ is the refractive index of the glass.

| λ, nm | $n_K$ | $n_F$ |
|---|---|---|
| 480 | 1.5228 | 1.6331 |
| 550 | 1.5185 | 1.6237 |
| 700 | 1.5130 | 1.6126 |

## 5 Two coils (4 points)

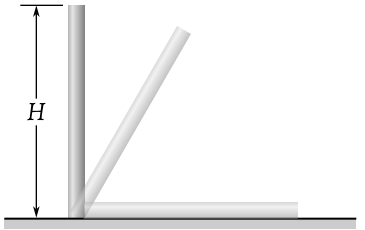
Two identical wire coils are located close to each other. One of them is attached to the sine-wave AC voltage source in series with an ammeter. The leads of the other coil are connected to another ammeter. Readings of ammeters are 1,0 A and 0,2 A. When the circuit of the second coil is broken, what will the reading of the remaining ammeter be? Neglect the active resistance of coils. Assume wires, ammeters and the source to be ideal.

## 6 Falling pole (4 points)

A vertical telegraph pole of height $H$ = 6 m starts falling on a level surface without slipping.

(a) Determine the speed of the free end of the pole when it touches the surface.

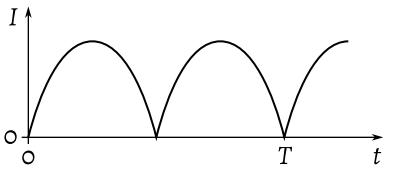
(b) Which of the points of the pole will at all times have the same speed as an object freely falling from the same initial height?




## 7 Charging the battery (4 points)

A rechargeable battery of 40 A·h capacity is charged with rectified AC current (see fig.). An ammeter in the circuit shows the current of 3 A. What time will it take for initially empty battery to fully charge up? Assume that all the current is used for charging.

Capacity of a battery is the charge that this battery can release during discharge. An ammeter measures the RMS value of current.

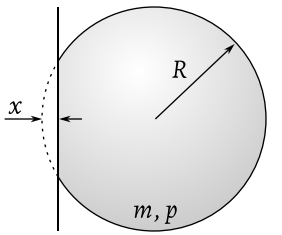



## 8 Holding the atmosphere (3 points)

Estimate the minimal radius of a planet that would suffice to hold carbon dioxide atmosphere for a long period of time. Justify your solution. Average density of the planet (not including the atmosphere) is 3.5 g/cm$^3$, its surface temperature is 250 K.

## 9 Rebound in detail (4 points)

During a weak collision of a basketball with a wall, it deforms as shown in the figure, the deformation $x$ of the ball is much less than its radius $R$ and it can be assumed that air pressure $p$ inside the ball remains constant all the time. Estimate the duration of collision between the ball and the wall neglecting the elasticity of the shell of the ball. Also, give a numerical estimate if the mass of the ball $m$ = 0.5 kg, its radius $R$ = 15 cm, air pressure inside of it $p$ = 200 kPa.




## 0 Snow sparkles (4 points)

Fresh snow sparkles in the light of winter sun. Estimate the average distance between neighbouring sparkles assuming that snow surface is covered by randomly oriented flat crystals 1 mm in size. Angular diameter of the Sun is 0.5°.