Tyngdpunkten

Easier, English

November 2024

Every problem can give at most 10 points. Good luck!

1. (Poor Newton!)

According to legend, Isaac Newton got the inspiration for his famous law of universal gravitation when he was philosophizing under an apple tree and an apple fell on his head. Assume that the tree branch from which the apple fell was located 2.0 m above Newton's head and calculate the speed of the apple when it hit the poor scientist. Neglect air resistance.

2. (Two balls)

Exactly the same amount of thermal energy is added to two identical metal balls. One of the balls has been placed on a table, while the other one hangs from a cord in the ceiling. Assume that no heat is transferred between the balls and their surroundings (nor between the balls and the table or the cord). Which ball will have a higher temperature? Justify your answer.

3. (Falling leaves)

Autumn is soon to be over. All the beautiful autumn leaves have fallen, and Christmas songs will soon be heard wherever you go. Estimate the potential energy that was released this year when all the autumn leaves in Sweden fell from the trees to the ground.

Remark: Points are based on your reasoning rather than your numerical answer.

4. (Diving)

A person jumps into water from a height of $h = 10\,\mathrm{m}$. How deep will the person sink if *all energy loss due to friction (against air and against water) is neglected*? The person has mass $m = 60\,\mathrm{kg}$ and volume $V = 66\,\mathrm{l}$. The density of water is $\rho = 1000\,\mathrm{kg/m^3}$ and you can use $g = 10\,\mathrm{m/s^2}$.

Remark: You do not need to take into account that the person is not entirely submerged for a short amount of time.

5. (Coefficient of friction)

Determine experimentally the coefficient of friction μ between two papers. Describe in detail how you proceed.

Permitted tools: Ruler, paper (for example exam paper), calculator. You are especially *not* permitted to use a dynamometer.

Remark: In this assignment your method of solving the problem is primarily assessed, and not your numerical answer. Although a completed measurement and a numerical value is required for full points!

6. (A growing bubble)

An air bubble is rising from the bottom of a lake. A fish saw that the bubble had the volume $V = 10\,\mathrm{mm^3}$ at the depth $H = 6.0\,\mathrm{m}$. Determine the volume of the bubble when it reaches the surface of the lake. Assume that the water temperature does not depend on the depth. You will perhaps need to look up some information in a table!

7. (An unknown planet)

You are situated at the top of a 1015 m high tower on an unknown planet. Even though there is perfect visibility, you can only see things on the surface located at most 65.61 km away from your position because of the curvature of the surface (where the distance is calculated along a straight line from your position at the top of the tower). When you drop a ball from the top of the tower, it takes 25.42 s for the ball to reach the ground. What is the mass of the planet? Because the atmosphere is very thin, you can neglect air resistance. You can also assume the planet to be a perfect sphere.

Hint: Newton's law of universal gravitation says that the magnitude of the gravitational force between two bodies with masses m_1 and m_2 is given by

$$F = G\frac{m_1 m_2}{r^2},$$

where r is the distance between the centers of mass of the bodies and $G \approx 6.674 \times 10^{-11}\,\mathrm{Nm^2kg^{-2}}$ is a constant. In this case you can let r be the radius of the planet, since the height of the tower is small compared to the radius of the planet.

8. (Light refraction)

You want to measure the refractive index of water. To do this, you fill a large bucket (with flat bottom) with water of depth $d = 20.0\,\mathrm{cm}$. After that you pick a point P at the surface of the water. You point a laser at the point P, so that the laser beam has the angle of incidence α (see Figure 1). Then you check where the laser hits the bottom of the bucket. Finally you measure the distance x between the point where the laser hits the bottom of the bucket and the point on the bottom of the bucket located straight under P (in other words: the point that the laser beam would hit if the angle of incidence were $\alpha = 0$). Your measurements can be found in Table 1.

Task: Using the given data points, determine a value for the refractive index of water. You may assume that air has a refractive index of $n_{air} = 1$.

Table 1: Measured values of the distance x at different angles of incidence α.

α [degrees]	x [cm]
0	0
10	2.4
20	5.0
30	8.7
40	10.6
50	15.0
60	17.5

Remark: For maximal points it is required that *all* of the information in the table is used, preferably in the form of a graph. Only a part of the points can be obtained if only one data point is used. An error estimation is *not* required.

Hint: How light changes direction when it passes from a medium with refractive index n_1 to a medium with refractive index n_2 is described by Snell's law. The law states that $n_1 \sin(\alpha) = n_2 \sin(\beta)$, where α is the angle of incidence and β is the angle of refraction (see Figure 1).

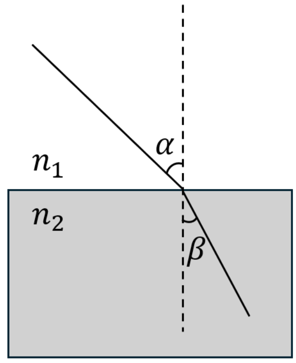

Figure 1: The image shows a beam that refracts when it goes from a medium with refractive index n_1 to a medium with refractive index n_2. The angle of incidence α is related to the angle of refraction β by Snell's law: $n_1 \sin(\alpha) = n_2 \sin(\beta)$.

9. (A charged infinite plane sheet)

You have a uniformly charged infinite plane sheet with thickness h and charge density (charge per unit volume) ρ. The charge of the plane is positive, i.e. $\rho > 0$. A rat has eaten a perfectly spherical part of the plane, forming a hole with diameter h (see Figure 2). Find the electric field at the point A - both its magnitude and its direction!

Hint 1: The electric field outside (and on the surface of) a uniformly charged sphere with total charge $Q > 0$ at a distance r from the center of the sphere has magnitude $E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$, where ϵ_0 is the so-called *electric constant*[1]. The field is pointing out from the center of the sphere. (In other words, the field is identical to the field formed by a point charge with charge Q placed in the center of the sphere).

Hint 2: Use symmetry arguments!

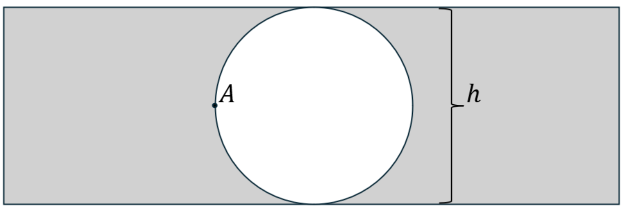

Figure 2: The image shows a cross-section of the plane sheet. Note, however, that the plane sheet is infinitely large - in the figure you can of course only see a small part of it.

10. (Four resistors)

You have four resistors with resistances $10\,\Omega$, $20\,\Omega$, $30\,\Omega$ and $40\,\Omega$. You also have a voltage source with EMF (Electromotive Force) $\mathcal{E} = 20\,\text{V}$ and internal resistance $r = 25\,\Omega$. How should you connect the resistors to the voltage source to maximize the power consumed by *the resistors*. You must use every resistor exactly once. Motivate your answer!

Hint: Use your graphing calculator!

Good luck!

[1]You are perhaps used to the so-called *Coulomb constant* k. It is related to ϵ_0 by the relation $k = \frac{1}{4\pi\epsilon_0}$.