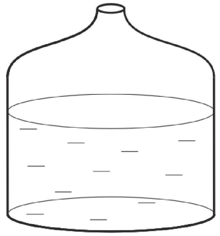
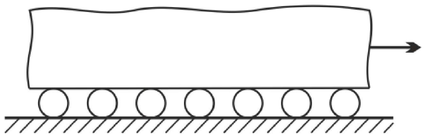
Task 1. (5-7 gr.) 1 litre of water was poured into a bottle with an oval bottom, and the water obviously occupies more than half the bottle's volume. How to measure the volume of the bottle using only a ruler?



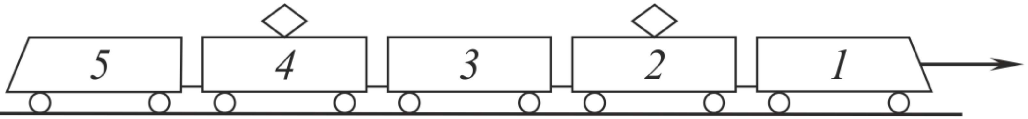
Task 2. (5-7 gr.) Stonehenge, a prehistoric monument in England in built out of blocks of stone, the largest of which are 9 metres tall and weigh approximately 25 tonnes. It is believed that they have been brought from a distance of 30km by placing logs underneath them. If the distance between two consecutive logs was roughly 1 metre, how many times the builders had to bring the log that had rolled out from behind the stone to the front during the stone's travel?



Task 3. (5-8 gr.) If you take a sheet of glass that is frosted on one side only and place it on a book page frosted side down, the text is easy to read. However, if you place it frosted side up, it is impossible to read anything — the letters are completely blurred. Why?

Glass is frosted when its surface is pitted — covered by tiny defects. When light passes through such a surface, it is scattered in all directions.

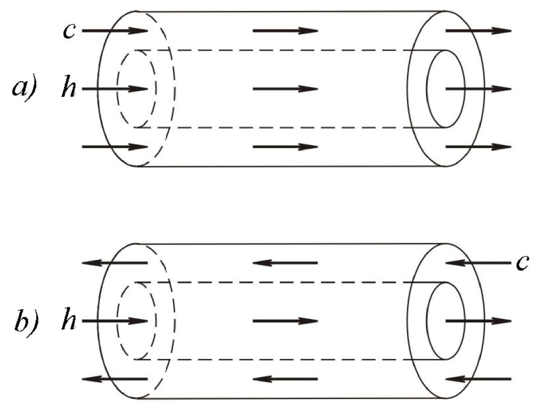
Task 4. (7-9 gr.) A suburban train consists of five carriages (cars). The second and fourth are so called power cars — they carry engines that propel the train and all the other carriages are rolling stock — they do not have engines. The masses of all carriages are equal, as are the propulsion forces of both power cars. During the acceleration of the train the tension in the coupling (the mechanism connecting the cars in a train) between the second and third carriages was 5000N (is was being stretched). Is the coupling between the third and the fourth carriage stretched or compressed? With the force acting within it. Also, find the propulsion force of the power cars.



Task 5. (8-10 gr.) Two identical vessels, both holding a small light ball are balanced on the pans of a scale (the balls are also identical). In the first vessel the ball is simply lying on the bottom and in the second it is tied to it with a short light string. If you fill the vessels with water, the first ball would rise to the surface and the second would not — the string would stretch and hold it in the water. Molly and Max are discussing whether it would change the balance of the scales. Max believes that the first vessel would outweigh the second — the second one has a string pulling its bottom upwards, so it would appear lighter. Molly disagrees — the balls and the vessels are identical, both vessels are filled with the same amount of water, so the scales should stay balanced. Who is right and where is the mistake in the other's argument?

You have to explain the mistake in the argument you believe to be wrong.

Task 6. (8-11 gr.) A **flow heat exchanger** consists of a long double-walled tube. Hot water flows in the inner tube and cold water — in the gap between the walls. As a result of the heat exchange cold water heats up and cold water cools down. Suppose that hot water at a temperature of 80°C is pumped into the heat exchanger at the rate of 1 l/s, while cold water at 20°C is pumped at a rate of 2 l/s. Find the maximum temperature the cold water can reach at the point it exits the heat exchanger if:

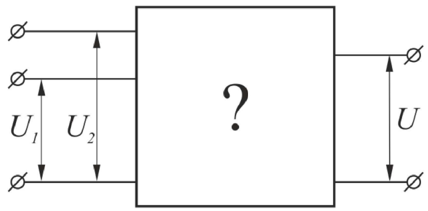


a) hot and cold water are pumped in at the same side of the heat exchanger.

b) hot and cold water are pumped in from the opposite sides of the heat exchanger (counter flow heat exchanger).

Heat loss can be considered negligible.

Task 7. (9-11 gr.) **An analogue computer.** Construct a circuit of resistors which has the following property: if you apply two voltages U_1 and U_2 to its inputs, it has a voltage of U on its output, and



a) $U = 0.001 \cdot U_1 + 0.002 \cdot U_2$

b) $U = 0.1 \cdot U_1 + 0.2 \cdot U_2$.

Calculation error should be no more 1%. You must necessarily specify values of resistors, that included in your circuit. Sources, which supplying voltages to your device U_1 and U_2, possess internal resistances of the order of several Ohms. Flowing out current can considered equal to zero.

Task 8. (10-11 gr.)Incandescent lightbulbs in our homes work from the mains electricity which is AC at 50Hz. The voltage in the mains supply has a time dependence of $U(t) = U_0 cos\omega t$. This means that this lamp should blink very frequently (100 times per second), turning off every time voltage passes though zero. However, in various sources you can find and argument that this blinking does not occur due thermal inertia of the filament. Make the required estimate and answer the question of whether the lightbulb really blinks or the fluctuations of its brightness are negligible.

Consider the power of the bulb the be equal to 100W. The operation temperature of the filament is $2700°C$.The diameter of the filament is 20 microns, its length is 17cm. The density of tungsten is 19.3 g/cm^3, its heat capacity at the operation temperature is 186 J/(kg×K).

Task 9. (11 gr.) What is greater — the number of molecule collision with the floor of the room or the ceiling (per unit area)? Estimate the difference.

The temperature is the same in all parts of the room. The average molar mass of air is $M \approx 29$ g/mol, value of the universal gas constant is $R \approx 8.31$ J/(molK), the atmospheric pressure is $p_0 \approx 10^5$ Pa.

Task 10. (9-11 gr.) Read the "Colour vision" text on the handout. Using the plot in the text answer the questions:

a) Find the ratio of the responses of the "red" and "green" cones to the monochromat yellow light (545nm) for a typical trichromat.

b) Find the ratio of the intensities of monochromatic red and green lights correspon to the sensitivity peaks of red and green cones of a typical trichromat for the combined light to the indistinguishable from yellow (545nm).

c) Would atypical trichromats of the kinds described in the text be able to distinguish between the red-green mix and the pure yellow from point b)? Consider these two light signals to be indistinguishable if the response ratios of "red" and "green" cones differ less than by 5%.

Additional materials for task 10.

COLOUR VISION

In 1881 Lord Rayleigh determined that for the majority of people the mixture of "pure" red and green light in a particular proportion is indistinguishable from "pure" yellow. This means that a combination of two spectrally pure light signals of certain intensities for a typical observer looks the same as a different spectrally pure light signal. Later, other "colour addition" rules were discovered: for example, mixtures of green and red in other proportions can look like orange or lime green, mixtures of green and blue as various hues of turquoise, and mixtures of red and blue as purple-pink colours. On the basis of those laws in the end of the XIXs century a trichromatic (Young-Helmholtz) theory of colour vision was formulated, which was improved over the XXs century and is still being improved today. These days, due to the widespread use of computer graphics, this theory is common knowledge, which doesn't make it less interesting...

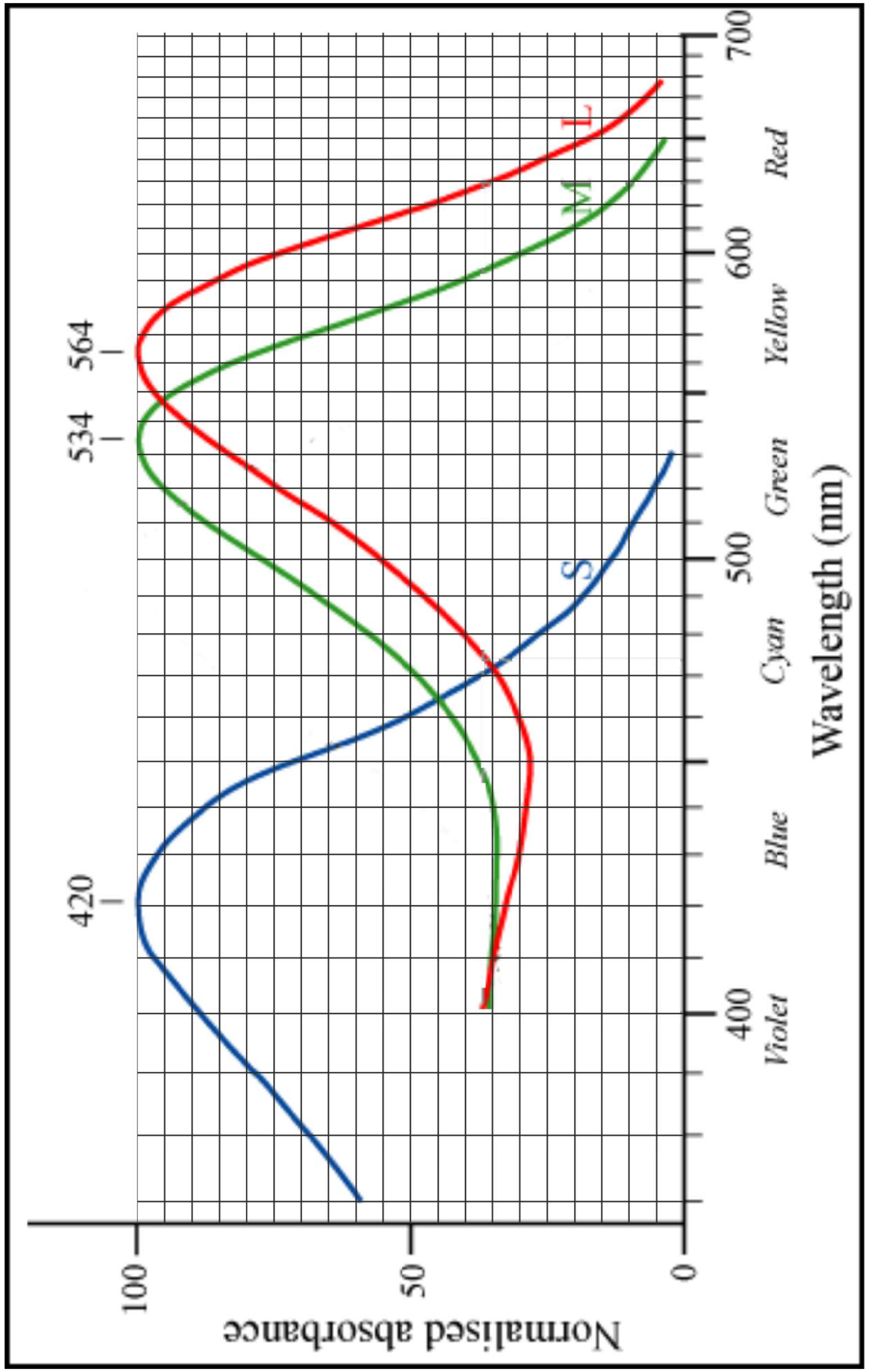
It is often said that any spectrally pure light, and therefore any light signal X is indistinguishable for our vision from a mixture of three signals with given wavelengths — red (R), green (G) and blue (B) — which are called the basis colours of the RGB model (the name trichromatic comes from the number of the basis colours). It can be written as a following formula: $X = c_r R + c_g G + c_b B$, where c_r , c_g and c_b — are the intensities of the three basis signals. However, in this form this thesis is not strictly true. Some spectrally pure colours (from turquoise to violet) cannot be achieved by any choice of coefficients c. For these colours the following is true: a particular mixture of pure X and R is indistinguishable by the eye from a mixture of G and B. Formally it can be written as $X + (-c_r)R = c_b G + c_g G$ or $X = c_r R + c_b G + c_g G$, where $c_r < 0$. As the basis signals any three pure (or even combined) signals which are *linearly independent* for our vision — which means that we see each of them as different for any mixture of the other two and no mixture of all three looks neutrally-grey (a "zero-colour" in this model).

But why is our colour vision three-dimensional and how does it project an infinitely dimensional space of light signals of a three-dimensional space? According to the current understanding, the retina of our eye has three types of photoreceptors — cones. Each type of cone has a maximum close to one of the basis colours: R, G and B. If two light signals excite all three types of cones identically, we see them as identical colours even if their spectral composition can be very different. A further complication is that the peaks of the response characteristics of the cone types are wide and the characteristics themselves overlap significantly. The likely shapes of these characteristic are depicted on the plot. While using this plot it is important to remember that the characteristics had been *normalised* — each of the characteristics had been multiplied by some number so that the heights of the peaks are all equal.

In reality the peak values of the “red”, “green” and “blue” characteristics are in the ratio of 0.65 : 0.3 : 0.05

As it turns out, the colour perception of some people differs significantly from the rules described about. Once it was believed that such colour perception impairments are always to the absence of one type of cones, so that the colour space of the person become effectively two-dimensional. However, according to recent research, these are cases of perception disturbances in which all three types of cones are present in the eye, but the response characteristic of one of them is modified. For these observers (they are called *atypical trichromats*) the colour space remains three-dimensional, but the colour addition laws are different from those of most people (*typical trichromats*).For instance, in some experiments atypical trichromats could distinguish between pairs of light signals, which seemed identical for typical trichromats. In the simplest case of atypical trichromatism one of the spectral response characteristics is shifted along the spectrum “as a whole” — “red” towards “green” (*protanomaly*), or “green” towards “red” (*deuteranomaly*). The magnitude of the shift in these cases is approximately 10nm.

Don’t forget to **sign** your work (please, write the card number, your last name, school and grade) before **submitting** the work. You do not have to submit the sheet with the tasks. The tasks, their solutions and the results of the competition will be published at *http://turlom.olimpiada.ru* after November 20. **Attention!** Results will only be available by your card’s number.



The normalised response characteristics of “red” (L), “green” (M) and “blue” (S) cones — the dependence of absorbance on the wavelength of the exciting light.