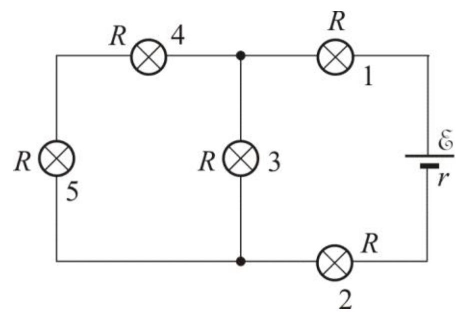
Solutions to the Physics Competition questions

1. 1-C, 2-E **2 points**: 1 point for each correct answer
2. B **2 points**: 1 point for correct rate of temperature increase, 1 pont for correct mean temperature
3. A **2 points**
4. D **2 points**: $20\cdot(35\text{-}20)=V\cdot(60-35)$; $V=300/25=12$
5. C **2 points**: elctric current through bulbs 1 and 2 is:

$$I=\frac{\varepsilon}{r+2R+\frac{2R}{3}}=\frac{3\varepsilon}{3r+8R}=1\,\mathrm{A}\,;$$

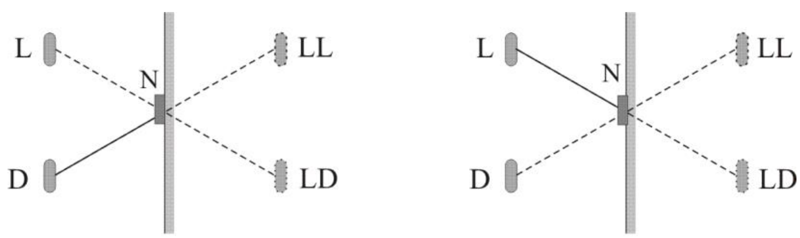


Current through light bulb 3 is 2/3 A, and through light bulbs 4 and 5 1/3 A.
Thus, light bulbs 1, 2 and 3 are on.

6. D **1 point**

7. E **1 point**

Points L and D in the picture are left and right eye and LL and LD are their images. When left eye is closed, the image LL seen with the right eye will be on the D-LL direction so the coin will be placed at a point N as is shown in the picture (a). When the right eye is closed, the coin seen with the left eye now will be on L-N direction (picture b), that is it will cover the right eye image.



(a) (b)

8.

a) <u>doesn't change</u> **1 point**

Let V_V be the volume of the water, m_1 mass of ice, V volume of the submerged part of ice, S crosssection area of the glass, h watre height in the glass, ρ_0 density of water.

$$m_1 g=\rho_0 Vg \quad \text{and} \quad Sh=V_V+V\,, \quad \text{so} \quad Sh=V_V+\frac{m_1}{\rho_0}\,.$$

When the ice melts, there's additional water of mass m_1, so that: $Sh'=V_V+\frac{m_1}{\rho_0}$.

It follows: $h'=h$, that is the height of water in the glass doesn't change.

b) <u>decreases</u> **1 point**

Let ρ be the density of iron and m_2 its mass.

In the beginning: $(m_1+m_2)g=\rho_0 Vg$, ie. $m_1+m_2=\rho_0 V$; $Sh=V_V+V$, ie. $Sh=V_V+\dfrac{m_1+m_2}{\rho_0}$ ...(*)

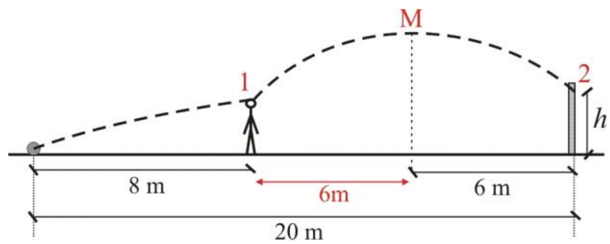
When the iron melts, the piece of iron is at the bottom of the glass. Then: $Sh'=V_V+\dfrac{m_1}{\rho_0}+\dfrac{m_2}{\rho}$ ... (*)

From (*) and (**): $h'<h$ (because $\rho>\rho_0$) , тhat is it decreases.

9. <u>decreases</u> **1 point**

10. a) $A<B$ **2 points**:

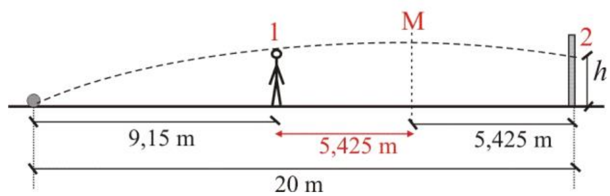
In the first case the highest point of the trajectory is 6m away both from the defensive wall and from the goal, which means that the part of the trajectory between points 1 and 2 is symmetric. It follows that the height h is equal to the height of the point in the defensive wall where the ball bounced off. So the height h is slightly less than 2m.



In the second case the trajectory between the defensive wall and the goal is also symmetric but this time it is exactly equal to the height of the defensive goal $h=2\,\text{m}$.

Answer $A=B$ is also acceptable.

b) $A<B$ **1 point**

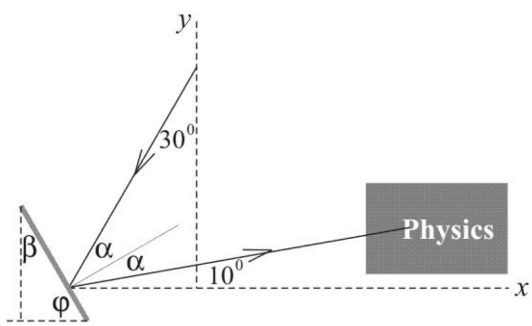


Follows from the conservation of energy (in the first case the ball looses some of its energy in the collision).

11. $A=B$ **1 point**: Tension forces the pull the boats are equal as are their masses, so $A=B$)

12. a) $A=B$ **1 point** б) $A<B$ **1 point**

Since the kettles are identical and the water in them is heated up from the same initial to the same final temperature, the heat transferred to the environment depends only on the time the whole process lasted. More heat is lost in Branko's kettle, so it uses more energy.



13. $2\alpha+10^0=60^0$, $\alpha=25^0$ **(1 point)**;

$\beta=\alpha+10^0=35^0$ (angles with perpendicular arms) **(1 point)**;

$\varphi=90^0-\beta=55^0$ **(1 point)**

14. Velocity of the cat jumping off: $\upsilon_0=5\,\text{m/s}$.

It's landing velocity can be acquired from the law of conservation of energy:

$$mgH+\frac{m\upsilon_0^2}{2}=\frac{m\upsilon_1^2}{2}, \text{ so } \upsilon_1=\sqrt{\upsilon_0^2+2gH}=15\,\text{m/s}.$$ **(2,5 points)**

Velocity of the cat while running towards the mouse: $\upsilon=\dfrac{\upsilon_1}{1{,}5}=10\,\text{m/s}$. **(0,5 points)**

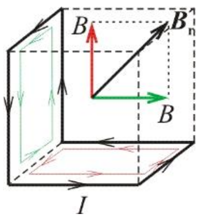
Catmakes to the wall in time: $t=\dfrac{l}{\upsilon}=3\,\text{s}$. **(1 point)**

In that time (or less) the mouse needs to cover a distance *d*. It follows: $u=\dfrac{d}{t}=4\,\text{m/s}$. **(1 point)**

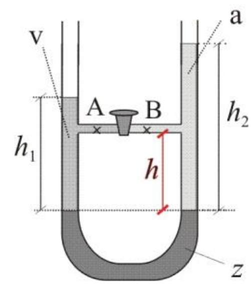
15. In the first circuit: $U_1 = I_1 r_V$, so $r_V = \dfrac{U_1}{I_1}$ **(1 point)**

In the second circuit: $I_2 = \dfrac{U_2}{R} + \dfrac{U_2}{r_V}$, so $R = \dfrac{U_2}{I_2 - \dfrac{U_2}{r_V}} = \dfrac{U_2}{I_2 - \dfrac{U_2 I_1}{U_1}} = \dfrac{U_2 U_1}{I_2 U_1 - I_1 U_2}$ **(1 point)**

In the third circuit: $I_3 = \dfrac{U_3}{R + r_A}$, so $r_A = \dfrac{U_3}{I_3} - R = \dfrac{U_3}{I_3} - \dfrac{U_1 U_2}{I_2 U_1 - I_1 U_2}$ **(1 point)**



16. The contour in the picture (b) is equivalent to the superposition of the green and red square contour, thus $B_r = B\sqrt{2}$ (**4 points)**
Similarly in countour (c) : $B_r = B\sqrt{3}$ (**4 points)**



17. Bottom surfaces of water (v) and alchohol (a) are at the same level, on the surface of mercury. Let p be the pressure of the liquid at that level. Then the pressure on the left and right side of the facuet is:
$p_A = p - \rho_v g h$ and $p_B = p - \rho_a g h$. Since $\rho_v > \rho_a$, so $p_A < p_B$. **(3 points)**
After opening the faucet, alchohol will move towards the left part of the U-tube that is towards the water. (**1 point**)

18. The flame is heating up the water, warmer water moves upward while the colder parts stay in the bottom half of the tube. The air surrounding the tube is also being heated up so the warm air is going up while the colder air is descending to the lower parts of the tube. Thus, there is no way to bring heat to ice by thermal convection. The heat can reach ice only trough thermal conduction but really slowly since both water and glass are poor thermal conductors. (**6 поена)**