Mathematical Grammar School Cup

Physics Competition

Circle the correct answer

1. (2 points)

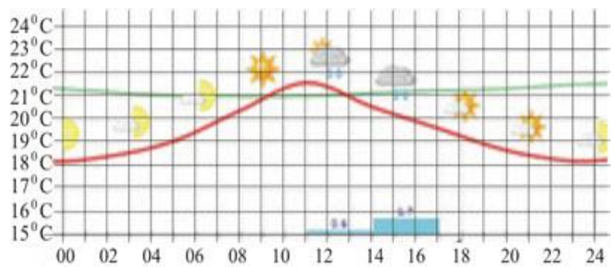
1) Scientist after whom the unit for energy was named was

A) Isaac Newton B) Alessandro Volta C) James Joule D) William Thomson Kelvin E) James Watt

2) How can this unit be expressed in terms of basic units of SI (International System of Units)?

A) $1\,\mathrm{N\cdot s}$ B) $1\frac{\mathrm{kg\cdot m}}{\mathrm{s}}$ C) $1\frac{\mathrm{kg\cdot m}}{\mathrm{s^2}}$ D) $1\frac{\mathrm{kg\cdot m^2}}{\mathrm{s}}$ E) $1\frac{\mathrm{kg\cdot m^2}}{\mathrm{s^2}}$

2. (2 points) The picture shows a graph of temperature change during one day in a certain city.



1) What is the average rate of increase in temperature, expressed in K/h , from midnight till 9h (9 a.m.)?

2) What was the temperature mean value (arithmetic mean of the highest and the lowest temperature) in the given time interval? Express the mean temperature (T_{sr}) in Kelvins and in degrees Celsius.

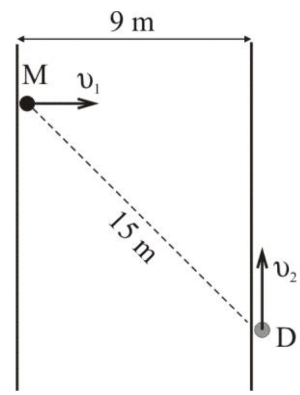
A) $\frac{\Delta T}{\Delta t}=0{,}3\frac{\mathrm{K}}{\mathrm{h}}$; $T_{sr}=19{,}5\,\mathrm{K}$; $T_{sr}=19{,}5\ {}^0\mathrm{C}$

B) $\frac{\Delta T}{\Delta t}=0{,}3\frac{\mathrm{K}}{\mathrm{h}}$; $T_{sr}=292{,}5\,\mathrm{K}$; $T_{sr}=19{,}5\ {}^0\mathrm{C}$

C) $\frac{\Delta T}{\Delta t}=273{,}3\frac{\mathrm{K}}{\mathrm{h}}$; $T_{sr}=292{,}5\,\mathrm{K}$; $T_{sr}=19{,}5\ {}^0\mathrm{C}$

D) $\frac{\Delta T}{\Delta t}=0{,}3\frac{\mathrm{K}}{\mathrm{h}}$; $T_{sr}=19{,}5\,\mathrm{K}$; $T_{sr}=292{,}5\ {}^0\mathrm{C}$

E) $\frac{\Delta T}{\Delta t}=273{,}3\frac{\mathrm{K}}{\mathrm{h}}$; $T_{sr}=-253{,}5\,\mathrm{K}$; $T_{sr}=19{,}5\ {}^0\mathrm{C}$

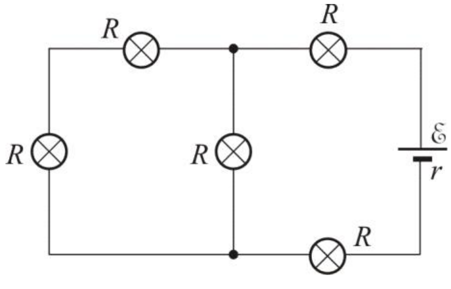


3. (2 points) There's a black cat M crossing the street, 9m wide, with velocity $\upsilon_1=1\,\mathrm{m/s}$ (picture). On the other side of the street there's a girl D walking on the sidewalk. She spots a cat when it is 15m away from her. What is the minimum velocity the girl needs to start moving at so that the black cat doesn't cross her path?

A) 1,33 m/s B) 1,67 m/s C) 1 m/s D) 4 m/s E) 2 m/s

4. (2 points) In a big fish aquarium there's 20 liters of water at a temperature of 20 ^{0}C. Catherine thinks that the fish in the aquarium are cold, so she wants to heat up their life environment by adding warm water at a temperature of 60 ^{0}C. What is the maximum volume of water in liters she can pour in if the highest temperature fish can live at is 35 ^{0}C? Assume that the heat exchange happens only between the warm and the cold water.

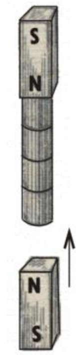
A) 15 B) 33,3 C) 20 D) 12 E) 53,3



5. (2 points) Electric circuit consists of five identical light bulbs, each with resistance $R=6\,\Omega$, and a battery with emf $\varepsilon=19\mathrm{V}$ and an internal resistance $r=3\,\Omega$. Light bulb lights up if there's an electric current $I\geq\frac{2}{3}\mathrm{A}$ flowing through it. How many of the light bulbs lights up in this electric circuit?

A) 1 B) 2 C) 3 D) 4 E) 5 F) zero

6. (1 point) Strong magnet, placed vertically, attracted several short cylinders made of soft iron so that they are hanging off it as is shown in the picture. From below another strong magnet is being moved closer. What will happen with the cylinders if the magnets are oriented in such a way that their north poles face each other? (Soft iron is easily magnetized as well as demagnetized.)



A) nothing will happen

B) they will stick even more strongly to the upper magnet

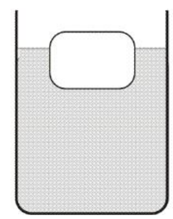
C) they will demagnetize and just fall down randomly

D) they will start detaching and sticking to the lower magnet

7. (1 point) Marco is looking at his image in the plane mirror. He closes his left eye (L) and sticks a coin to the mirror surface covering the image of his closed eye. Then, while staying still, he opens his left eye and closes his right eye (D). At that point he sees the coin to be:

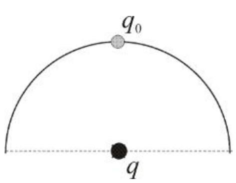
A) to the left of L Б) to the right of D C) between L and D Д) covering L E) covering D

II Answer with: INCREASES, DECREASES or STAYS CONSTANT



8. (2 points) a) There's an ice cube floating in a glass of water (picture). How does the height of water in the glass change when all of the ice melts? ______________________

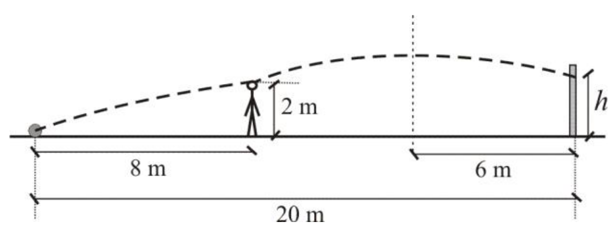
b) Inside the ice cube there's a piece of iron. How does the height of water in the glass change after the ice melts? _____________________



9. (1 point) Semicircle is made out of a thin insulating wire (picture). In the centre of the semicircle there's a fixed charged ball (with electric charge q), and on top of the semicircle there's a charged liquid droplet (with electric charge q_0). How does the electric force with which the liquid is acting on the ball change if the droplet spreads along the length of the semicircle? ________________________

III Give an answer in the following form: $A < B$, $A > B$ or $A = B$

10. Soccer player performs a free kick from a distance of 20m from the goal. Defensive wall of the opposing team is 8m from the ball. The ball hits the top of the defensive wall 2m in height and bounces off so that its trajectory's highest point is 6m away from the goal (picture).



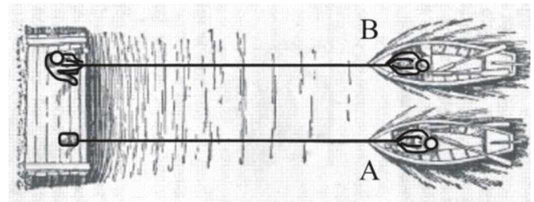
Because of the improper distance of the defensive wall free kick is being repeated and this time the distance of the defensive wall is being set a proper distance of 9,15m from the ball. While performing the free kick, soccer player kicks the ball in the same way as in the first case. This time the ball flies just above the defensive wall (without touching it) and reaches its maximum height at a distance 5,425 m away from the goal.

a) (2 point) Compare the heights (h) at which the ball reaches the goal line after the first free kick (A) and after the second one (B). ____________

b) (1 point) Assuming that none of the players in the defensive wall moved in any way before the ball came in contact with them (in the first case), compare the velocities of the ball when it reaches the goal after the first free kick (A) and after the second one (B). __________

Neglect air resistance.

11. (1 point) Two identical boats are moving towards the dock with two fishermen in them of equal mass. The boats are moving because each of the fishermen is pulling on one end of a rope he's holding; the other end of one rope (A) is tied to a column on the dock, while the other end of the second rope (B) is being pulled on by a man on the dock (picture). If all three men are pulling on the rope with equal forces, compare the times it takes the boats A and B to reach the shore. ________________

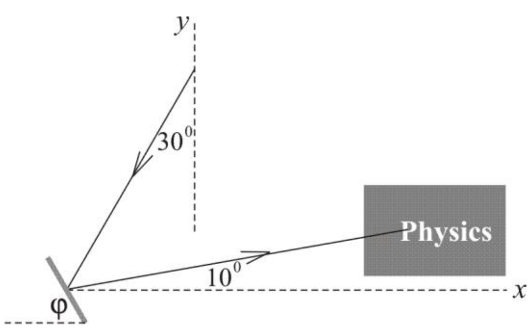


12. Alexandra and Branko have identical kettles in which they pour the same amount of tap water. Then they heat the water up to a boiling point. Alexandra has an electric heater with power of 2kW in her kettle, while the power of Branko's electric heater is 1,5 kW. Compare the electric energies that Alexandra (A) and Branko (B) will spend:

a) (1 point) if their kettles can be considered to be ideal heat insulators; ____________

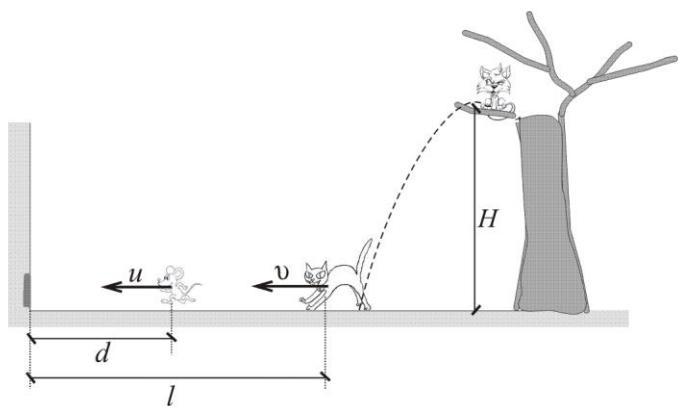
b) (2 points) in real conditions. ____________

IV Solve the problems

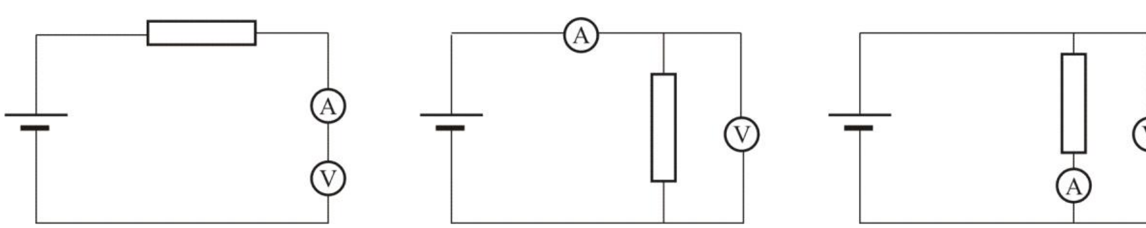


13. (3 points) Sunlight is falling at an angle of 30^0 to the vertical (y-axis in the picture). One ray of light passes through a small hole in the wall into a classroom which inspired Stephen to have some fun with it. He placed his watch (whose surface acts as a plane mirror) in such a way so that the reflected ray falls on letter P of the word the teacher just wrote on the black board. Using the data shown in the picture (x-axis is horizontal), determine the angle φ at which Stephen had to place the surface of his watch.

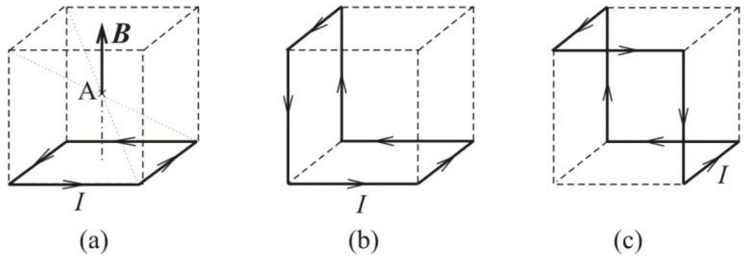
14. (5 points) There's a cat sitting on a tree branch at a height $H = 10\ \text{m}$. At a certain moment the cat spots a mouse on the ground in the backyard and jumps off a branch with a velocity 5m/s. When the cat lands on the ground it is $l = 30\ \text{m}$ away from the wall, while the mouse is $d = 12\ \text{m}$ away from it. Then the cats starts chasing the mouse with constant velocity that is 1,5 times less than the one it landed on the ground with. What is the minimum velocity the mouse needs to run with so that it can reach a hole in the wall and save itself? Neglect the air resistance, dimensions of the cat and the mouse and assume that $g = 10\ \text{m/s}^2$.



15. (5 points) One group of students got an experimental task to determine the resistances of an ammeter, voltmeter and a resistor. Aside from these three elements they had a source of electric current of constant but unknown emf at their disposal. They managed to solve the problem by connecting the elements in three different ways shown in the picture. Each time they recorded the measured values and then they calculated the resistances they were looking for. How?

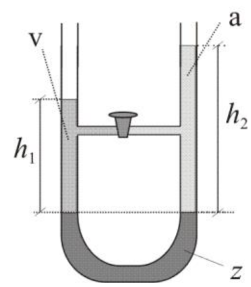


16. (8 points) Out of a thin conducting wire a square was made which could be considered as one side of a cube shown in picture (a) drawn with dashed lines. When there is an electric current I flowing through the square contour, magnetic field with magnitude $B = 5\,\mathrm{mT}$ appears in the centre of the cube with a given direction shown in the picture. Determine the magnitude of the magnetic field in the centre of a cube when the same electric current I flows through contours shown in pictures (b) and (c) made out of the same wire as contour (a).



V Answer the question and give an explanation

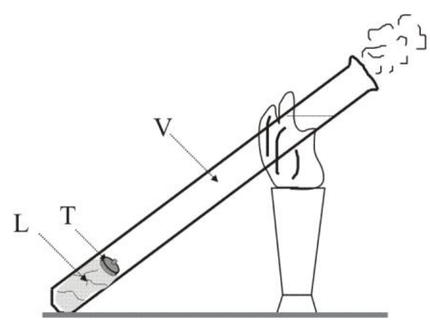
17. (4 points)



The branches of a U-tube are connected through a horizontal tube with a closed faucet (picture). Water (v), mercury (z) and alcohol (a) are poured into the U-tube and when in equilibrium the liquids are positioned as is shown in the picture.

How will the liquids move immediately after opening the faucet on the horizontal tube?

18. (6 points)



When you get the chance, try replicating the following experiment in your school's lab (picture).

Put some ice (L) at the bottom of a test-tube, a small weight (T) over it and then pour some water (V) on top. The weight should be big enough not to let the ice float up to the surface of the water, but at the same time not too big to prevent the water from coming in contact with the ice. Place the test-tube in such a way that its open end is in flame, as is shown in the picture. What will happen?

Miracle will happen: water in the test-tube will evaporate, and the ice at the bottom will stay, the water will be hot while ice won't melt!

Explain how that is possible.

GOOD LUCK!

First-year students Katarina Cimeša, Katarina Petrović, Marko Šušnjar, Dino Ćerimagić, Stefan Đorđević i Dušan Đorđević participated in the making and the selection of the questions and problems for this competition as well as their teacher Nataša Čaluković. Problems were checked and translated by teachers Dragica Ivković and Ivan Stanić.