Mathematical Grammar School

4th MATH CUP

27th June - 02nd July 2016

SUPPORTED BY PIRAEUS BANK

Mathematical Grammar School

a school with the High National Distinction status

The Mathematical Grammar School Cup

Physics Competition

29.6.2016.

Instructions:

1. *Duration of competition is 3 hours. Maximum number of points is 50.*
2. *Use the answer sheet to give answers to the first 13 questions.*
3. *The answers to questions 14 to 18 write down in your notebooks.*
4. *Use of calculators is allowed.*
5. *It is not allowed to write on anything other than the answer sheet, notebook and the paper with questions.*
6. *When finished, turn in the answer sheet and the notebook.*

Good Luck! ☺

I Circle the correct answer

1. **a)** (1 point) What is the name of the scientist that the unit for absolute temperature was named after?

A) Isaac Newton B) James Joule C) James Watt D) William Thomson Kelvin
E) Anders Celsius

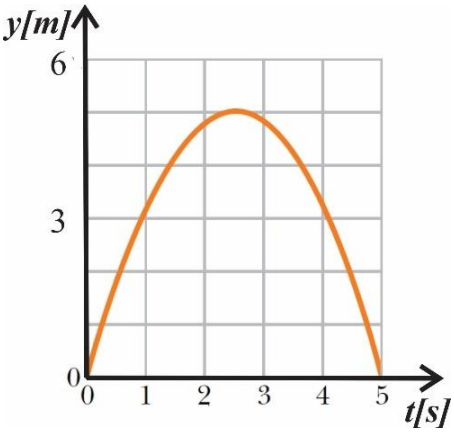
b) (1 point) How can this unit be expressed in terms of basic units of SI (International System of Units)?

A) $kg \cdot m \cdot s^2$ B) kg/s^2 C) It cannot be expressed in terms of basic SI units.
D) $kg \cdot m^2/s^2$ E) $kg \cdot m \cdot s$

2. (2 points) A ball is thrown vertically upwards from the surface of the Moon. The graph in the picture on the right shows the dependence of the ball's height (relative to the initial position) on time. Using the information given in the graph, calculate the following:

a) Intensity of the gravitational acceleration on the surface of the Moon g_M;

b) Intensity of the ball's initial velocity v_o.



A) $g_M = 0.4\,m/s^2; \upsilon_0 = 1\,m/s$ B) $g_M = 1.9\,m/s^2; \upsilon_0 = 4.8\,m/s$

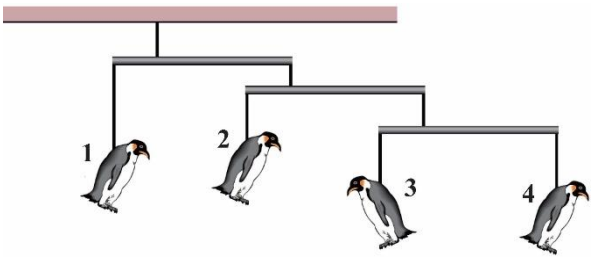
C) $g_M = 1.28\,m/s^2; \upsilon_0 = 3.2\,m/s$ D) $g_M = 2.5\,m/s^2; \upsilon_0 = 3\,m/s$

E) $g_M = 1.6\,m/s^2; \upsilon_0 = 4\,m/s$

3. (2 points) Formula 1 driver Sebastian Fetel won the last year's Hungarian Formula 1 Grand Prix. During the first thirty laps on the track "Hungaroring" Fetel drove with an average velocity of 172km/h. During the second thirty laps he averaged a velocity of 167km/h, while the final 10 laps he drove with an average velocity of 177km/h. What was the overall average velocity of Fetel's car in this race?

A) 170.50 km/h B) 170.54 km/h C) 170.57 km/h D) 170.61 km/h E) 172.00 km/h

4. (2 points) The picture on the right shows a toy with penguin figures suspended from horizontal massless rods. Each thread attached to a rod divides it in the ratio 1:3. If the mass of the toy penguin number 1 is $m_1 = 4.8\,kg$, what are the masses of the rest of the penguins?



A) $m_2 = 1.2\,kg;\ m_3 = 0.3\,kg;\ m_4 = 0.1\,kg$

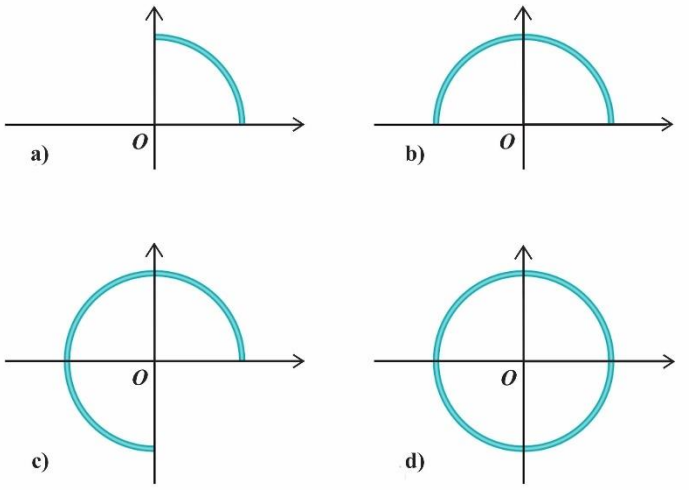
B) $m_2 = 3.6\,kg;\ m_3 = 2.7\,kg;\ m_4 = 8.1\,kg$ C) $m_2 = 2.4\,kg;\ m_3 = 1.6\,kg;\ m_4 = 0.8\,kg$

D) $m_2 = 0.4\,kg;\ m_3 = 1.2\,kg;\ m_4 = 3.6\,kg$ E) $m_2 = 1.6\,kg;\ m_3 = 0.4\,kg;\ m_4 = 0.1\,kg$

5. (1 point) During earthquakes, mechanical waves are formed, which are called the seismic waves, that propagate through the Earth's crust. Longitudinal seismic waves have the largest velocity of propagation, which is why they are called primary or p-waves. P-waves in general have low frequencies, and here we will examine the propagation of one such wave with a frequency of 0,05Hz. If its wavelength is equal to 160km, what is its speed of propagation?

A) 8 km/s B) 3200 m/s C) 8 m/s D) 4 km/s E) 3,2 m/s

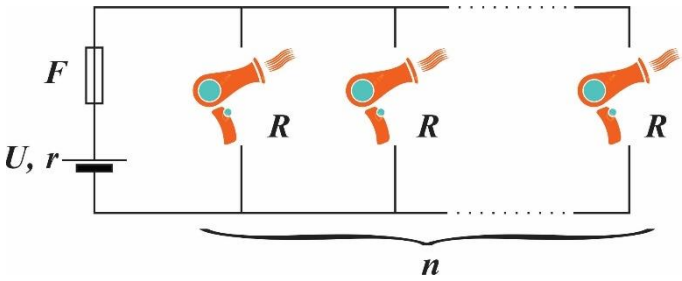
6. (2 points) Picture a) shows a plastic rod which was bent to a shape of a quarter of a circle. When charged uniformly with a charge $+Q$, it creates an electric field in the center of an imaginary circle (origin O) whose intensity we shall denote as E. In the remaining three configurations b), c) and d), identical rods with the same charge $+Q$ are added each time until a full circle is created. We will also consider an additional fifth configuration, identical to the one shown in picture d) with the only difference being that the rod in the fourth quadrant is charged with a charge $-Q$. If we denote the intensities of the electric field at the origin O in cases a), b), c) d) and e) with E_a, E_b, E_c, E_d i E_e respectively, which of the following is correct?



A) $E_d<E_a<E_c<E_b=E_e$ B) $E_d=E_e<E_a<E_c<E_b$ C) $E_a<E_e<E_d<E_b<E_c$ D) $E_d<E_a=E_c<E_b<E_e$

E) $E_a=E_c<E_d<E_e<E_b$

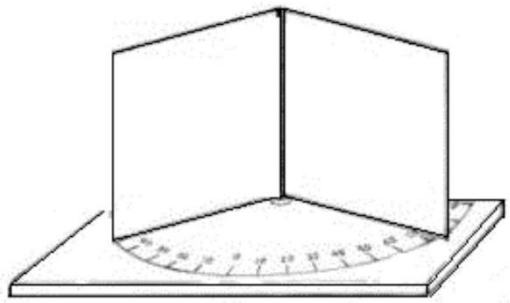
7. (2 points) Aleksandra and Ivan have decided to open a hairdresser's salon in which they plan on using a lot of hair dryers. Every hair dryer is acting as a resistor with resistance R=200Ω. In order not to overload the circuitry, Ivan thought of connecting the hair driers to a voltage source $U = 220\,\mathrm{V}$, with an internal resistance of $r = 2{,}5\,\Omega$, through an electric fuse F with a negligible resistance. Electric fuse is a special element used in electric circuits in order to limit the máximum electric current allowed. When the current reaches the máximum value fuse blows, behaving like an open switch thus disabling the current flow. Maximum electric current allowed by the fuse Ivan and Aleksandra used in their hair salón is $I_{\mathrm{kr}} = 16\,\mathrm{A}$.



Ivan asked Aleksandra to calculate the máximum number of hair dryers that can work simultaneously without causing the fuse to blow. What answer did Aleksandra give to Ivan?

A) 16 B) 17 C) 18 D) 19 E) 20

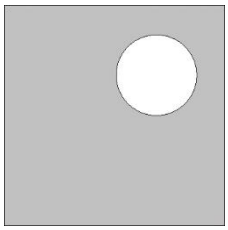
8. (2 points) The picture shows two planar mirrors connected along one edge so that the angle between them can be adjusted using a protractor. If we set that angle to 60^0 and position an object between them, how many images of that object will we see in the mirrors?



A) 7 B) 5 C) 2 D) 6 E) 4

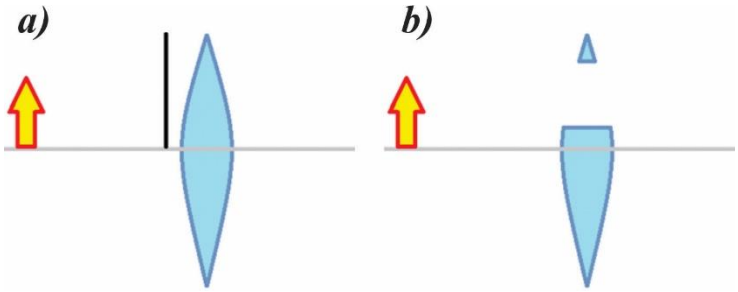
II Answer with: INCREASES, DECREASES or STAYS CONSTANT

9. (2 points) A ship full of pumpkins (as shown in the picture on the right) is floating on a steady lake. In order to make the ship lighter, sailors started dropping pumpkins into the lake. What happend to the level of the water in the lake? _____

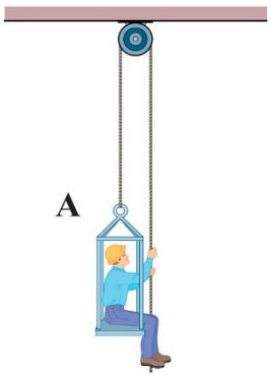


10. (2 points) Picture on the left shows a metal plate with a circular hole cut through it. How will the surface area of the hole change while the plate is being heated?
_____

11. An object is placed in front of a thin lens, and its real image is formed behind the lens.
a) (1 point) How will the illumination of the image (intensity of light forming the image) change if we cover one part of the lens?_____
b) (1 point) How will the size of the image change, if we remove the cover from part a) and cut out a piece of the lens?_____

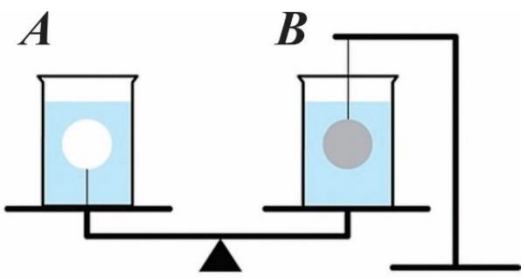


III Give an answer in the following form: A>B, A<B or A=B



12. (2 points) Picture on the right shows a construction worker sitting in a busun's chair which is hanging on a light rope going over a frictionless pulley. Compare the minimal force the worker needs to apply downwards to the other end of the rope in order to make the bosun's chair go upwards (A) with a minimal force his colleague on ground needs to apply to the same end of the rope in order to lift other worker (who is not holding the rope anymore) (B). _____

13. (2 points) Two identical glasses are placed on the scales and filled with the same amount of water. The scales are initially held still. Two balls of the same volume are placed into the glasses, the only difference being that the density of the first one is less, and the density of the second one is greater, than that of water. The first ball is tied to the bottom of the first glass with a massless thread, and the second one is suspended from a stand next to the scales, as shown in the picture. Compare the weight of the left (A) and the right glass (B), which the scales will show once released. _____



IV Solve the problems

14. Electrical measurements have shown that the Earth surface is charged negatively when the weather is nice, while the ionosphere has a positive charge. In this problem following constants might be useful: electrical permeability of vacuum/air $\varepsilon_o = 8{,}854 \cdot 10^{-12}\ C^2/(Nm^2)$ and the Earth's radius is $R_z = 6400$ km.

a) (2 points)) If we consider that the mean value of the electric field intensity on the Earth's surface is 130 V/m, estimate the charge of the Earth, taking it to be uniformly distributed on its surface.

b) (1 point) Air in the atmosphere, however, it is not an isolator. It can conduct electricity due to presence of ions formed by the action of cosmic radiation (high energy protons and atomic nuclei that came from the depths of cosmos) and from naturally occurring radioactivity. As a consequence, there is small electric current flowing between the Earth's surface and the ionosphere that tends to discharge the Earth. Knowing that the intensity of the current per 1 m^2 is $2 \cdot 10^{-12}$ A, find the time it would take for the Earth to completely discharge.

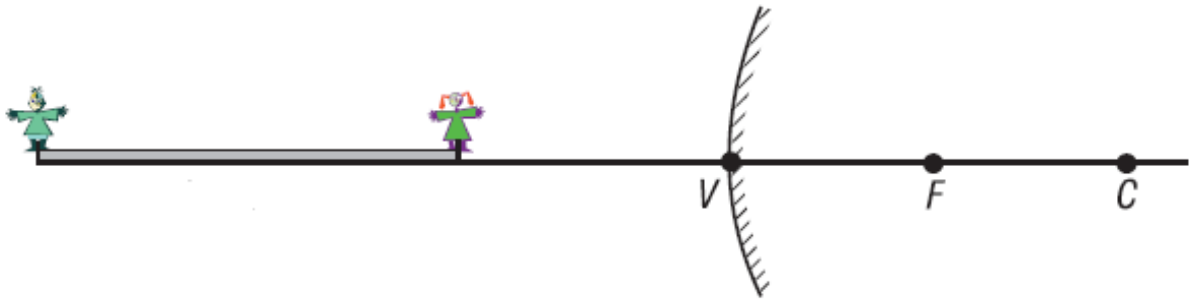
c) (1 point) Determine the electrical resistance of the atmosphere considering the average voltage between ionosphere and the Earth surface is approximately 300000V.

d) (1 point) Still, the charge on the Earth's surface stays constant. For a long time, this fact was an enigma for scientists, but nowadays we believe that intense electrical discharges all over the Earth (lightning) are responsible for keeping the negative charge on its surface constant. If the electric current of an average lightning is 25 kA, and its duration 10 ms, estimate how many thunders hit the ground each day.

15. A meterstick, 1m in length, lies along the optical axis of a convex mirror of focal length 40 cm, with its near end 60 cm from the mirror surface. Five-centimeter long toy figures stand erect on both the near and far ends of the meterstick.

a) (2 points) How long is the virtual image of the meterstick?

b) (3 points) How tall are the toy figures in the image, and are they erect or inverted?

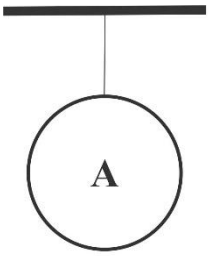


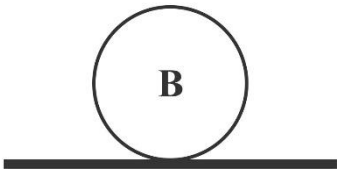
V Answer the question and give an explanation

16. (4 points) This photograph was taken during the swimming comeptition at he 2012. Olympic games in London. The photograph was taken with a camera placed at the bottom of the swimming pool, and there's an interesting effect that can be noticed on it. Namely, there's a prominent „see-through" cricle inside of which we notice the reflectors onceiling of the swiming center. Outside of this circle one can notice the reflected image of the bottom of the pool. Explain this effect.

17. (4 points) Picture on the left shows a stationary car. Inside a car there's a helium filled baloon attached to the fron seat. What will happen to the baloon if the car starts accelerating to the left? Explain your conclusion and give arguments for it.

18. (7 points) Consider two identical homogenous balls, A and B, with the same initial temeprature. One of them, A, hangs on a thread while the other is at rest on a horizontal plane. If the same amount of heat is transfered to both balls will their final temperatures be the same or not? Justify your answer. Neglect any kind of heat loss.





The end. ☺