Mathematical Grammar School

a school with the High National Distinction status

The Mathematical Grammar School Cup

Physics Competition

28.6.2017.

Instructions:

1. *Duration of the competition is 3 hours. Maximum number of points is 50.*
2. *Use the answer sheet to give answers to the first 11 questions.*
3. *Write down the answers to questions 12 to 17 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! ☺

Circle the correct answer

1. **a)** (1 point) A television set, which has power of 200 W, is turned on 6 hours a day, on average. How much electrical energy does this television set spend in a month, assuming that a month has 30 days?

(A) 360 MJ (B) 284.6 MJ (C) 129.6 MJ (D) 36 MJ (E) 3.6 MJ

Figure 1

b) (1 point) How can the unit for power be expressed in terms of SI base units?

(A) $\frac{kg\cdot m^3}{s}$ (B) $\frac{kg\cdot m^2}{s^2}$ (C) $\frac{kg\cdot m^2}{s^3}$ (D) $\frac{kg\cdot m^2}{s}$ E) $\frac{kg\cdot m}{s^2}$

2. (1 point) Area of an elephant's foot is about 2,200 cm^2. What is the elephant's mass if the pressure it exerts on the ground, when standing straight, is 187.5 kPa? ($g = 10$ N/kg)

(A) 165 kg (B) 1650 kg (C) 16,5 t (D) 165 t (E) 1650 t

3. (1 point) Beside the flat ones, ladies also like to use spherically shaped mirrors for observing very small facial details (Figure 2). Should these spherical mirrors be concave or convex?

(A) Concave, in order to zoom in on the face;
(B) Convex, in order to zoom in on the face;
(C) Concave, in order to zoom out on the face;
(D) Convex, in order to zoom out on the face;
(E) Both convex and concave can be used.

Figure 2

4. (2 points) For a single dish wash it is necessary to heat up 10 *l* of water in the electrical heater from 15°C to 45°C. The price of 1 kWh of electrical energy is 8 dinars (Serbian national currency). How much does a single dish wash cost (in dinars), assuming that all energy is spent exclusively on heating the water. The density of water is 1000 kg/m^3, and specific heat capacity of water 4200 J/kg°C.

(A) 4.2 (B) 3.6 (C) 2.8 (D) 1.3 (E) 0.8

5. (2 points) In the back seat of a car, moving along the same direction with constant velocity, there's a boy throwing a ball vertically upwards. How does the trajectory of the ball look like to the kid playing with it (1)? How does that same trajectory look like to an onlooker standing by the side of the road (2)? If the car starts decelerating suddenly, will the ball fall in front or behind the kid's hand, if he extends his arm to catch the ball where it would have previously fallen (3)?

(A) 1-parabolic, 2-vertical, 3-in front of kid's hand (B) 1-vertical, 2-vertical, 3-behind kid's hand
(C) 1-vertical, 2-parabolic, 3-in front of kid's hand (D) 1-vertical, 2-parabolic, 3-behind kid's hand
(E) 1-parabolic, 2-parabolic, 3-behind kid's hand

6. (2 points) Oil is dripping from a moving car's engine at regular intervals leaving a trace on the road like the one shown in Figure 3a. Which of the graphs (in Figure 3b) depicts the position (coordinate x) of the car versus time?

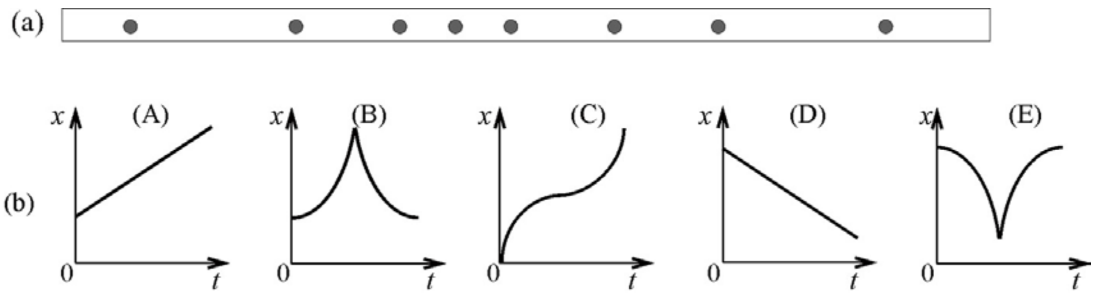

Figure 3

Answer with: it increases, it decreases, or it doesn't change

7. (2 points) A light-bulb is connected to a DC battery as shown in Figure 4. How will the brightness of the light-bulb change if a piece of demagnetized iron is inserted in the coils of a conducting wire? ________________

8. Figure 5 shows two identical metal balls with different electrical charges, q_1 and q_2, of the same polarity. The balls are hanging from the ceiling on isolating cords. In the state of equilibrium, the angle between the cords is α. If the balls are put in contact with each other, and then released:

a) (1 point) What happens to the total charge on the surface of the balls? __________________

b) (2 points) What happens to the value of the angle θ in the new equilibrium state? ______________

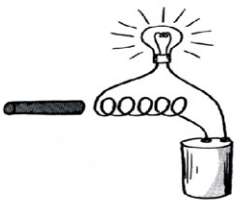

Figure 4

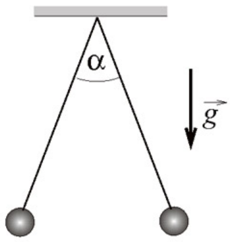

Figure 5

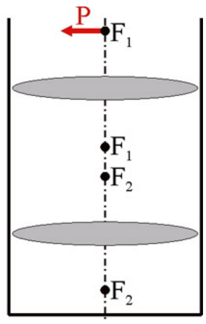

Figure 6

9. Two identical converging lenses, with focal length *f*, are placed inside a vertical vessel as shown in Figure 6. Distance from the ends of the vessel to the closer lens is larger than *f*, while the distance between lenses is larger than *2f*. A luminous object P is placed at the focus of the upper lens. After the rays of light, originating from the object P, pass through the system of lenses an image is formed below the second lens.

a) (1 point) How does the distance of the image from the second lens change if we move this lens downwards? ________________________

b) (2 points) How does the size of the image change if we move the second lens downwards? _____________________

c) (2 points) The vessel is filled with water up to the middle of the second lens. How does that affect the distance of the image from the second lens? _________________________

Answer with A<B, A>B or A=B

10. (3 points) Two balls, with the same mass, attached to each other by a light elastic spring, are held as is shown in Figure 7. Compare the accelerations of the upper (**A**) and the lower ball (**B**) at the moment they are released to fall freely. _______________________________

Figure 7

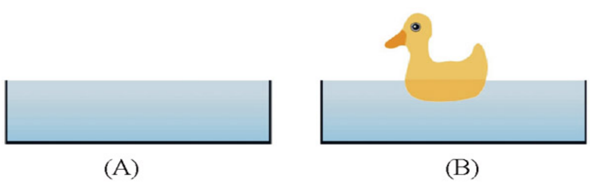

Figure 8

11. (2 points) Figure 8 shows two open-top containers filled to the brim with water. There's only water in the first container (**A**), while there's a toy duck floating in the second container (**B**). Compare the weights of the two containers. _____________________

Solve the following problems

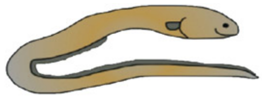

Figure 9

12. (5 points) Electric eel (Figure 9) that inhabits the rivers of South America feeds on prey it stuns by producing electric shocks. The eel generates electric voltage in special groups of cells called *electroplaques*. There are approximately 700 000 electroplaques in an average sized eel. Each electroplaque can be modeled with a battery with $E_e = 0.05\,\mathrm{V}$ emf and internal resistance $r_e = 0.45\,\Omega$. Assuming that all electroplaques are distributed evenly across the eel's bottom and top side (i.e. in two lines), find the electric current an eel can produce through water from its head to its tail. Take the resistance of water to be $R_v = 800\,\Omega$. Could that current paralyze human muscles, if the minimum current needed for this is 10 mA?

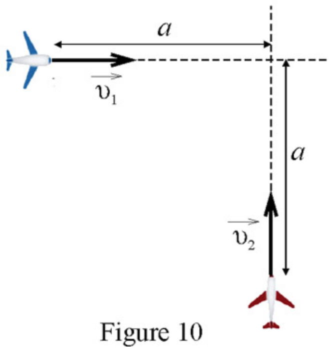

Figure 10

13. (5 points) Two airplanes are flying at the same height with constant velocities $\upsilon_1 = 800\,\mathrm{km/h}$ and $\upsilon_2 = 600\,\mathrm{km/h}$. They are approaching one another along the perpendicular trajectories as is shown in Figure 10. At a given instant both airplanes are *a*=20km away from the intersection of their trajectories. Find the minimal distance between the airplanes.

14. (5 points) How many times greater is the amount of heat released in the collision of a droplet made of mercury with an umbrella, as opposed to the case in which the droplet is made of water? Density of mercury is 13.6 g/cm^3, while water's density is 1.0 g/cm^3. Assume that in both cases drops fall from the same height that is sufficiently big. Also assume that the drops are all of the same size and that they experience resistance force proportional to their speed*v*, $F_{\mathrm{ot}} = k\upsilon$ (take the constant *k* to be the same for water and mercury) and that 40% of each raindrop's kinetic energy just before they hit an umbrella transforms into heat.

Answer the following questions and provide an explanation

15. (2 points) How can you, without using any measuring instruments, empty exactly one half of a full cylinder shaped vessel previously filled to the brim with liquid?

16. (3 points) Why does an energy-supplying network for tram-cars have just one conducting line, whereas an energy-supplying network for trolleys has two conducting lines (Figure 11)?

Figure 11

Figure12

17. (5 points) You probably had a chance to notice the following phenomenon. In hot summer days, if you look in the distance right above the sand it looks like the air is simmering and the objects become slightly blurred. If you haven't noticed this at the beach maybe you could have seen it at a barbeque. There's specific undulatory motion of the image seen close to the barbeque fire. Try explaining these phenomena using physical laws and reasonable assumptions. You might additionally justify your explanation using a suitable sketch. Figure 12 shown on the right depicts the same effect seen from afar on hot asphalt.

The end.