The Mathematical Grammar School Cup

Physics Competition

26.06.2018.

Instructions:

1. *Duration of the competition is* 3h. *Maximum number of points is* 50.
2. *Use the answer sheet to give answers to the first* 12 *questions.*
3. *Write down the answers to questions* 13 *to* 18 *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)* Capacitors are very important in everyday life whenever we need a large pulse of electric current, for example, in camera flashes, keyboard keys or in defibrillators. After which scientist was the SI unit for capacitance of a capacitor named:

(A) Wilhelm Weber   (B) Michael Faraday   (C) Nikola Tesla   (D) James Clerk Maxwell

(E) Carl Friedrich Gauss

b) *(1 point)* How can the unit for capacitance be expressed in terms of SI base units m, s, kg, A, K, mol, cd?

(A) $\dfrac{A^2 \cdot s^2}{kg \cdot m^2}$ (B) $\dfrac{A \cdot m^2}{kg \cdot s^2}$ (C) $\dfrac{A \cdot kg \cdot m^2}{s^2}$ (D) $\dfrac{A^2 \cdot s^4}{kg \cdot m^2}$ (E) $\dfrac{kg \cdot mol^2}{cd \cdot s^2}$

2. *(1 point)* A car tire makes 400 turns per minute when the car is moving at a speed of 72 km/h (without the tires slipping on the road). What is the circumference of the tire?

(A) 12,50 m   (B) 0,95 m   (C) 1,53 m
(D) 0,48 m   (E) 3,00 m
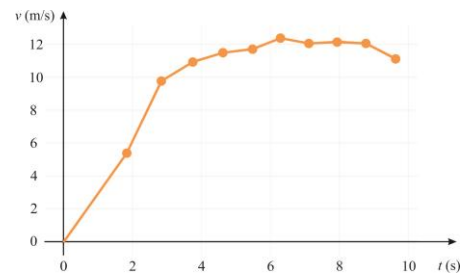
3. *(1 point)* The graph on the right shows Usain Bolt's speed vs. time in the finals of a *100* m race at the World Championship in Berlin in 2009 when he achieved the world record. Which graph below best represents the qualitative dependence of Bolt's acceleration vs. time?
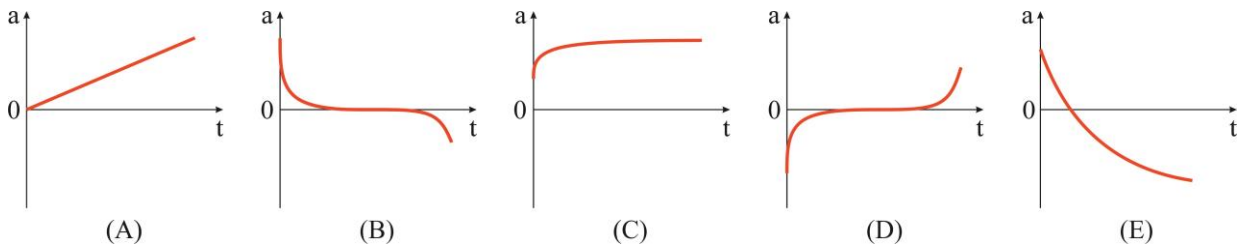
(A)   (B)   (C)   (D)   (E)

4. *(2 points)* The picture on the right shows a scheme of a periscope that contains four plane mirrors set at 45° to the horizontal through which we are looking at a penguin. What will the orientation of the penguin's image in the periscope be?
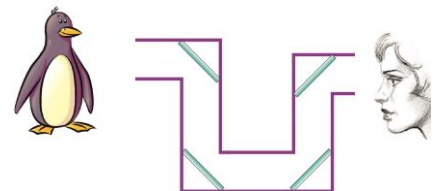
(A)   (B)   (C)   (D)   (E)

5. *(2 points)* A vessel, containing 0,6 kg of a certain liquid, is placed on a heater at time $t = 0$. Due to heating, the liquid's temperature increases as is shown in the graph on the right. What is the heater's power, if we assume that there are no losses of heat? The amount of heat needed for 1 kg of that liquid to evaporate (heat of vaporization) is 200 kJ.

(A) 1200 W   (B) 3000 W   (C) 4800 W
(D) 13300 W   (E) 2400 W
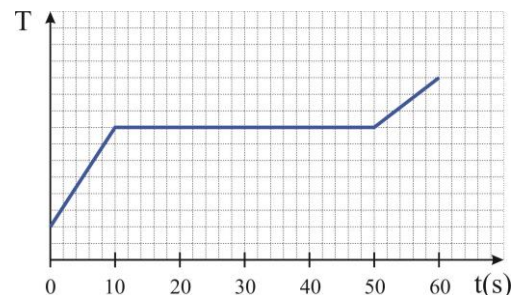
6. *(2 points)* A train is moving with constant speed while its horn is emitting a sound of constant frequency f_0. At a time t_0 the train passes through the train station. Which graph below best represents the frequency vs. time dependence that the conductor registers standing by the train tracks?

(A) (B) (C) (D) (E)
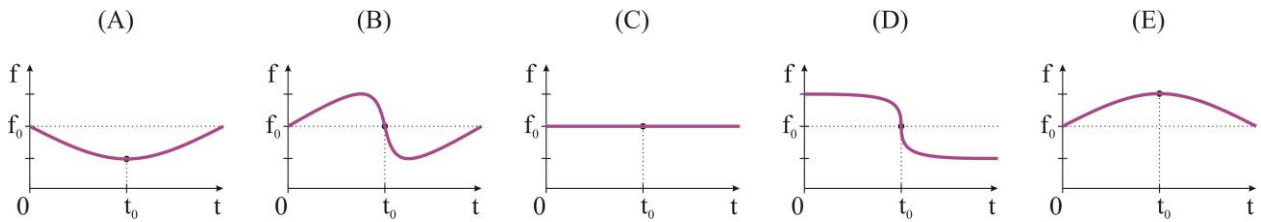
7. *(3 points)* Determine the minimal distance between an object and its real image seen through a converging lens with focal length f.

(A) *2f*   (B) *3f*   (C) *4f*   (D) $\frac{9}{4}f$ (E) there is no minimal distance

8. *(2 points)* A student who lives in the mountains has to walk downhill, uphill and through flat (horizontal) parts on his way to school and back. When walking uphill the student moves with a speed of 3 km/h, in the flat parts 3,6 km/h, and downhill 4,5 km/h. If it takes 1 h for him to get to school and on the way back 75 min, find the distance from student's home to his school.

(A) 2,25 km   (B) 3 km   (C) 4,05 km   (D) 9 km   (E) 3,7 km

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

9. In the movie „Harry Potter and the Order of the Phoenix" Harry takes a ride on a peculiar elevator in the Ministry of Magic that can move horizontally as well. Hanging from the elevator ceiling are pendulums that the passengers can hold on to (check the photo on the right). We will assume the pendulums to be simple. Now let us look at the pendulum above Harry's head that's oscillating while the elevator is still.

a) *(1 point)* How will the period of oscillations of that pendulum change if the elevator starts moving with constant velocity in horizontal direction? _____

b) *(2 points)* How will the period of oscillations of the pendulum change if the elevator starts accelerating also in horizontal direction? _____

10. *(2 points)* Two identical metallic balls charged with different charges q_1 and q_2 of the same sign are held at a certain distance. How will the intensity of the force with which they interact change if we switch the sign of the charge on the ball on the right? _____

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

11. *(2 points)* A lot of flies are put in a closed jar which is then placed on a weighing scale. Compare the readings of the scale when all the flies sit on the bottom of the jar (**A**) with the situation when the flies fly around the jar chaotically (**B**). _____
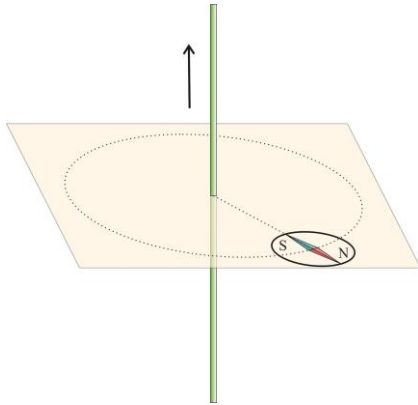
12. *(2 points)* An experiment that was a turning point in the understanding of magnetism was accidentally performed in the 19th century by a Danish physicist Ørsted. He noticed that while the current was running through a long straight wire a compass needle was turning when brought close to it. The picture on the left shows a simplified version of that experiment. There is a long vertical wire with the current running upwards and a compass whose needle points horizontally towards the wire. Taking into account that the Earth's magnetic field is also affecting the compass position, compare the magnetic induction intensity of the Earth's magnetic field (**A**) with that of the wire (**B**). _____

## Solve the following problems

13. *(3 points)* The picture on the right show a sequence of photographs of a car, whose length is 4,44 m, decelerating to a stop. Knowing that the photos were taken in intervals of 0,333 s determine the car's acceleration.
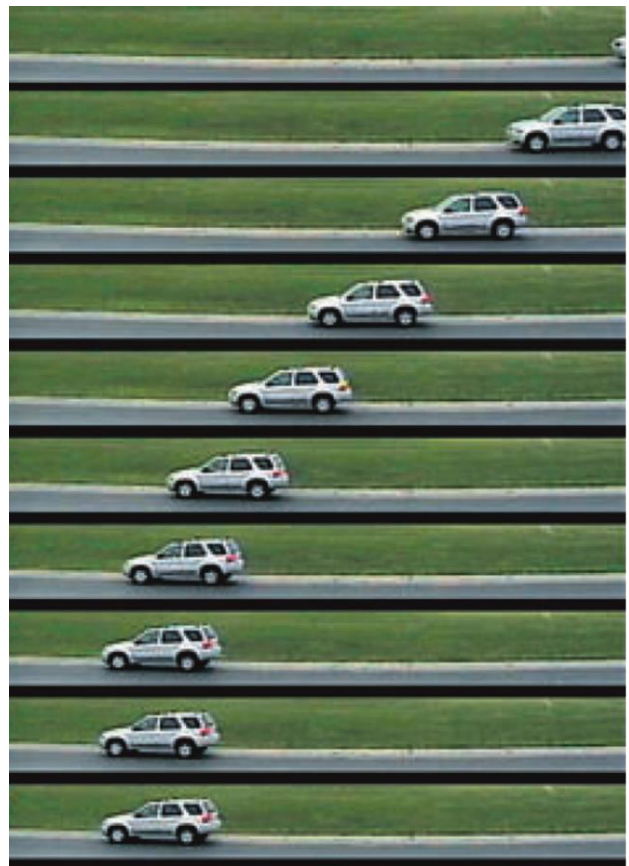
14. *(4 points)* A vessel of negligible mass is filled with liquid of mass $2m$ and placed on a homogeneous beam of mass $10m$ as is shown in the picture below. A small toy of mass m is then put in the liquid hanging from a thread going over a pulley. What should the mass of the boat toy m' be, which is attached to the other end of the thread so that the whole system is balanced? Neglect any friction in the pulley or in the beam's support. Consider the coloured parts of the beam to be of the same length.
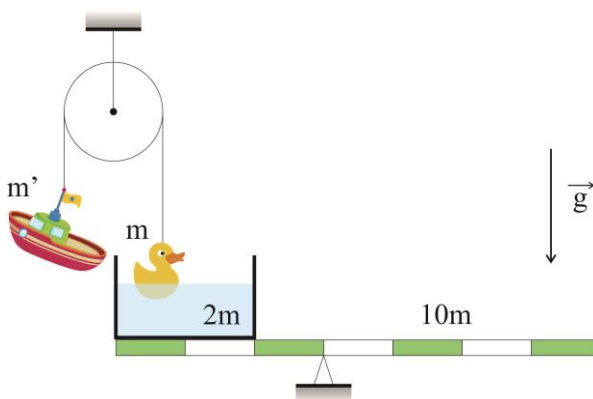
15. *(4 points)* An electric circuit shown in the picture on the right in the shape of an octahedron consists of four identical resistors, an ideal battery of constant emf and an ideal ammeter showing the electric current of 2 A. If the ammeter is replaced with an ideal voltmeter it shows a voltage of 12 V. Find the emf of the battery as well as the resistance of one of the resistors.
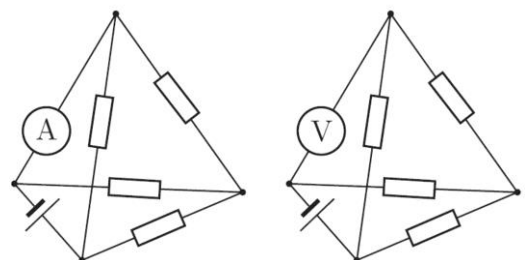
Answer the following questions and provide an explanation

16. *(3 points)* If we pass a comb through dry hair a couple of times and then bring close to running water from a tap, the water bends toward the comb. Why does that happen? How do you think the increase in the temperature of water affects what happens in the experiment?

17. *(5 points)* Idea for the following experiment is thought to have come from Rene Descartes and was performed for the first time in 1648. A small tube turned upside down is placed in a plastic bottle filled to the brim with water so that some air stays in the tube. Then we close the bottle and squeeze it. How will that change the position of the tube and why?
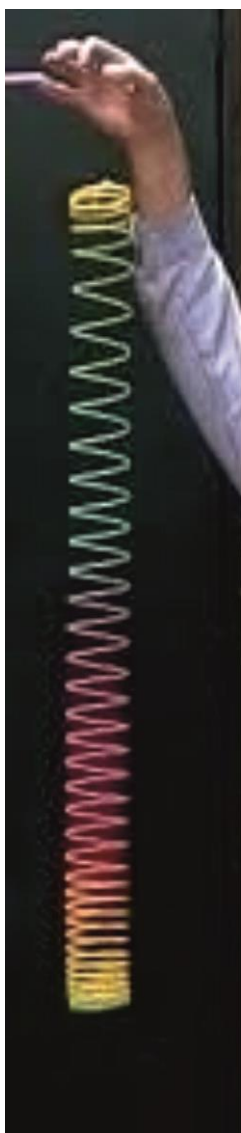
18. *(7 points)* The picture on the left shows an elastic spring i.e. slinky. Describe in as much detail the way it freefalls. Try to justify your explanation with mathematical expressions and/or drawings.

The end!