Mathematical Grammar School

a school with the High National Distinction status

The Mathematical Grammar School Cup

Physics Competition

25.06.2019.

Instructions:

1. *Duration of the competition is* 3h. *Maximum number of points is* 72.
2. *Use the answer sheet to give answers to all the questions.*
3. *Use of calculators is allowed. If needed assume the gravitational acceleration to be* $10\ {}^{m}/_{s^2}$.
4. *It is not allowed to write on anything other than the answer sheet, notebook and the paper with questions.*
5. *When finished, turn in the answer sheet and the notebook.*

Good luck! ☺

Circle the correct answer

1. *(1 point)* After which scientist was the SI unit for pressure named:

(A) Isaac Newton **(B)** Niels Bohr **(C)** Evangelista Torricelli **(D)** Blaise Pascal **(E)** Galileo Galilei

2. *(1 point)* How can the unit for pressure be expressed in terms of SI base units m, s, kg, A, K, mol, cd?

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

3. *(1 point)* What is the proper chronological order, from earliest to latest, of the important work done by these famous scientists in developing our understanding of gravity?

(A) Cavendish, Galileo, Newton **(B)** Galileo, Cavendish, Newton
(C) Galileo, Newton, Cavendish **(D)** Newton, Galileo, Cavendish
(E) Newton, Cavendish, Galileo

4. *(1 point)* A student at MG Cup competition in physics computes a speed as $\frac{18\,mm}{3\,\mu s}$. Which one of the following choices represents the same speed?

(A) $6\frac{km}{s}$ **(B)** $6\frac{nm}{s}$ **(C)** $6\frac{m}{s}$ **(D)** $6\frac{Gm}{s}$ **(E)** $6\frac{pm}{s}$

5. *(1 point)* At which of the following temperatures does water undergo a phase transition into a solid at a pressure of $1{,}0\ atm$? (*Hint*: If you're not familiar with the Farenheit temperature scale the conversion to Celsisus scale is given by $t[\,^0C] = \frac{5}{9}(t[\,^0F] - 32\ ^0F)\ ^0C/\ ^0F$).

(A) $273\ K$ **(B)** $0\ ^0F$ **(C)** $32\ ^0C$ **(D)** $100\ ^0F$ **(E)** $0\ K$

6. *(1 point)* Which one of the following laws explains the induced electric currents due to changing magnetic flux?

(A) Gauss's law **(B)** Ampere's law **(C)** Ohm's law **(D)** Faraday's law **(E)** Volta's law

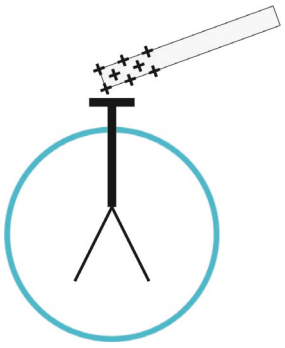
7. *(1 point)* In the following nuclear reaction ${}^4_2He + {}^9_4Be \rightarrow {}^{12}_6C + {}^A_ZX$ what is ${}^A_ZX$?

(A) a proton **(B)** an electron **(C)** a positron **(D)** an alpha particle **(E)** a neutron

8. *(1 point)* A student is investigating the transfer of heat which is a consequence of the bulk motion of a fluid. Which of the following terms best describes such heat transfer method?

(A) radiation **(B)** convection **(C)** conduction **(D)** latent heat **(E)** specific heat

9. *(1 point)* A positively charged rod is brought near a metal electroscope that is initially uncharged. There is no charge transfer between the electroscope and the rod, but still the leaves of the electroscope move apart from each other. Which one of the following explanations describes this phenomenon the best?



(A) Protons are repelled by the rod into the leaves of the electroscope.
(B) Electrons are attracted out of the leaves of the electroscope toward the rod.
(C) Protons are repelled into the leaves of the electroscope and electrons are attracted out of the leaves of the electroscope.
(D) Electrons are repelled by the rod into the leaves of the electroscope.
(E) Protons are attracted out of the leaves of the electroscope toward the rod.

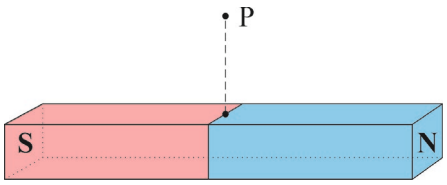
10. *(1 point)* Which is the correct relationship for the speed (v) of the following three electromagnetic waves in vacuum? The waves are: X-rays, UV rays and radio waves.

(A) $v_X < v_{radio} < v_{UV}$ **(B)** $v_{UV} < v_{radio} < v_X$
(C) $v_{radio} < v_{UV} < v_X$ **(D)** $v_X < v_{UV} < v_{radio}$
(E) $v_X = v_{radio} = v_{UV}$

11. *(1 point)* An object connected to an ideal spring oscillates with a period T when it is released from rest at a distance A from equilibrium position. What will be the period of oscillations of the same object if it released from rest at a distance $2A$ from equilibrium?

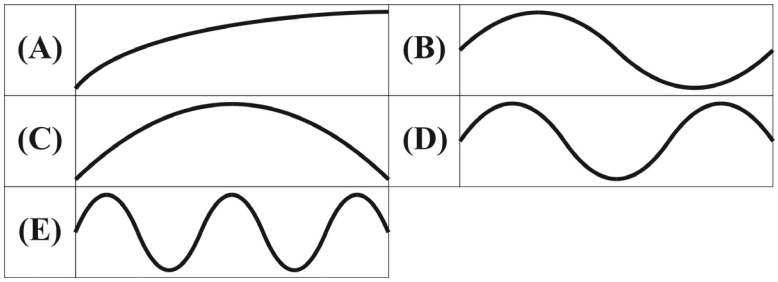
(A) $\frac{1}{4}T$ **(B)** $\frac{1}{2}T$ **(C)** T **(D)** $2T$ **(E)** $4T$

12. *(1 point)* For the bar magnet shown in the figure, which choice best describes the direction of the magnetic field at the point P located directly above the center of the magnet?



(A) Up, in the plane of the page **(B)** To the right
(C) Down, in the plane of the page **(D)** To the left
(E) Out of the plane of the page toward us

13. *(2 points)* A wave of frequency $4\,Hz$ is traveling at $8\frac{m}{s}$ on a string. Which one of the following figures best represents what a one-meter section of the string could look like at one instant in time?

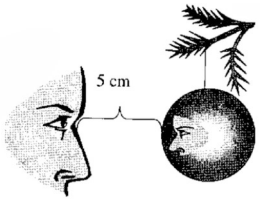


14. *(2 points)* The table at right lists the finish times for the 2008 Men's Olympic 100 m butterfly swim final in Beijing. Using the provided data estimate what was the distance between the runner-up Čavić and the winner Phelps at the finish.

(A) 0.2 cm **(B)** 2 cm **(C)** 5 cm
(D) 10 cm **(E)** 20 cm

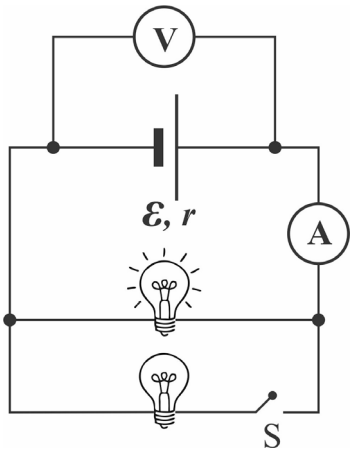
100 m Men's Butterfly Swim		
1	Michael Phelps	50.58 s
2	Milorad Cavic	50.59 s
3	Andrew Lauterstein	51.12 s
4	Ian Crocker	51.13 s
5	Jason Dunford	51.47 s
6	Takuro Fujii	51.50 s
7	Andrii Serdinov	51.59 s
8	Ryan Pini	51.86 s

15. *(2 points)* While admiring the Christmas ornaments Luka was observing the image of his eye in the ornament with a diameter of 5 cm. If his eye was 5 cm from the closest point on the ornament what was the magnification?



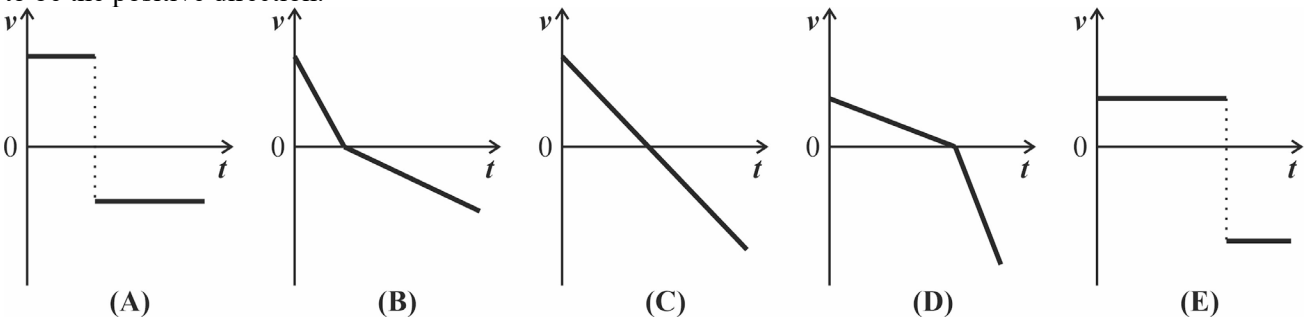
(A) 0,2 **(B)** 4 **(C)** 0,33 **(D)** 0,5 **(E)** 4

16. *(2 points)* How will the readings of the ammeter and voltmeter shown in the circuit on the right change when we close the switch S? The circuit has two light bulbs and a battery with EMF ε and internal resistance r.



	ammeter	voltmeter
(A)	decreases	stays constant
(B)	increases	decreases
(C)	increases	stays constant
(D)	decreases	increases
(E)	stays constant	decreases

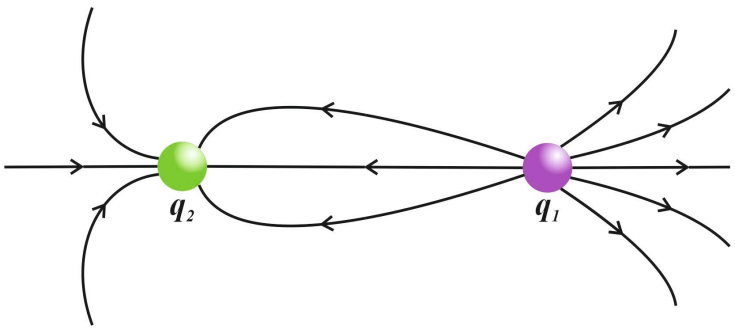
17. *(2 points)* A block slides up and then back down a rough incline. Which of the following graphs could represent the velocity of the block as a function of time? All graphs use the same scale and uphill is taken to be the positive direction.



18. *(2 points)* Estimate the thickness of this very page in micrometres.

(A) 0,1 **(B)** 1 **(C)** 10 **(D)** 100 **(E)** 1000

19. *(2 points)* What is the ratio of charges q_2/q_1, whose total electric field lines are shown in the diagram below?

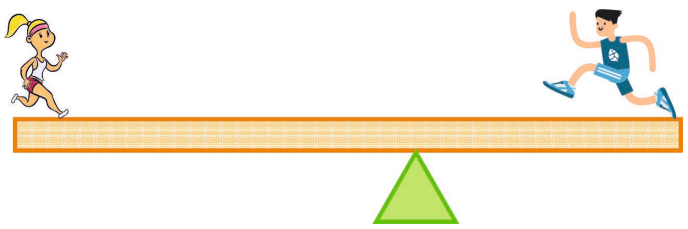


(A) $-3/2$ **(B)** $2/3$

(C) $3/2$ **(D)** $-2/3$

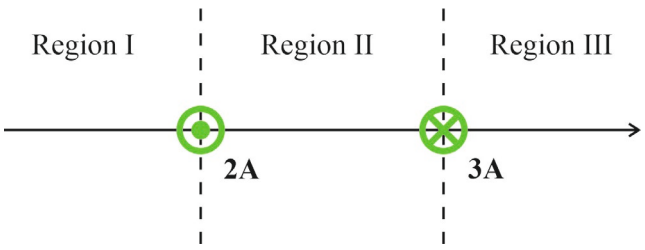
(E) 1

20. *(2 points)* A girl Nevena and a boy Igor initially stand at the ends of a $20\,m$ long homogeneous beam, with mass $130\,kg$, which is in equilibrium. Suddenly Igor starts running towards Nevena wanting to surprise her, but Nevena immediately decides to counter that by running towards Igor in order to keep the beam in equilibrium. If Igor, having a mass of $70\,kg$, runs with speed of $15\ km/h$ how fast should Nevena run to stop the beam from tilting? Nevena's mass is $50\,kg$.



(A) $3\frac{km}{h}$ **(B)** $17\frac{km}{h}$ **(C)** $21\frac{km}{h}$ **(D)** $12\frac{km}{h}$ **(E)** $30\frac{km}{h}$

21. *(2 points)* Two long and straight wires are fixed in space so that the current in the left wire ($2\ A$) comes out of the plane of the page and the current in the right wire ($3\ A$) goes into to the plane of the page. Knowing that the magnetic field strength of a straight wire is directly proportional to the current and inversely to the distance away from the wire determine in which region(s) shown in the figure is there a place on the x-axis (aside from infinity) at which the magnetic field is equal to zero?

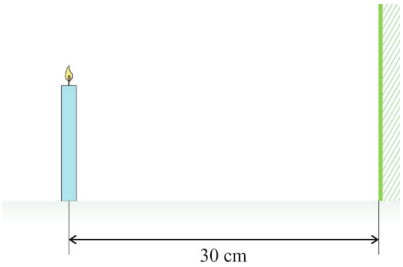


(A) Only in Region I **(B)** In both Regions I and II **(C)** Only in Region II
(D) In both Regions I and III **(E)** In both Regions II and III

22. *(2 points)* A child's balloon is filled with a noble gas Xenon ($^{131}_{54}Xe$). This balloon is then released from rest. Which one of the following choices best describes what will happen?

(A) The balloon floats gently in the air, essentially hovering at the same height for at least a day.
(B) The balloon immediately falls toward the ground.
(C) The balloon very, very slowly and gently rises upward.
(D) The balloon rapidly rises into the sky.
(E) The balloon floats gently in the air, finally reaching the ground after several minutes.

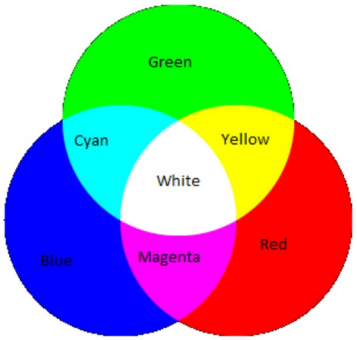
23. *(3 points)* The figure on the right shows a candle and a screen placed 30 cm apart. There are two locations at which a thin converging lens can be placed to produce a focused real image. One real image of the candle appears on the screen when the lens is located 12 cm from the candle. How should the lens be moved from this position in order to produce a second real image of the candle on the screen?



(A) 3 cm toward the screen **(B)** 6 cm toward the candle **(C)** 9 cm toward the candle
(D) 6 cm toward the screen **(E)** 9 cm toward the screen

24. *(3 points)* An object appears yellow when illuminated with white light. What colour does the object appear in the cyan light?

(A) magenta **(B)** yellow **(C)** red
(D) blue **(E)** green



25. *(3 points)* Third tallest waterfall in Serbia is located on the mountain Kopaonik some 300 km south of Belgrade. The waterfall is 71 m tall with an average volume flow rate of 25 $\frac{l}{s}$. What is the average electric power that can be obtained from the kinetic energy of falling water if the efficiency coefficient of the turbines (used to convert kinetic into electric energy) is 0,4. Density of water is 1000 $\frac{kg}{m^3}$.

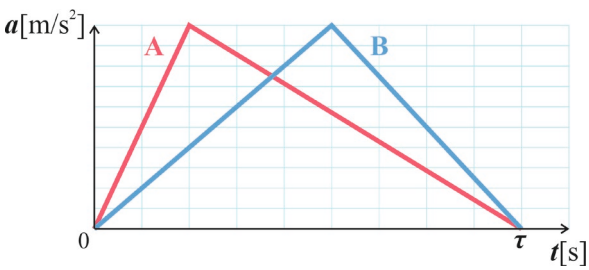
(A) 12000 W **(B)** 3600 W **(C)** 7,1 kW **(D)** 15,3 W

(E) 3,6 MW

26. *(3 points)* A resonance i.e. forming of a standing wave in an air column of length 39 cm happened while the tuning fork oscillated at the open end of the air column. The next highest resonance occurred when the length of the air column was 65 cm. What is the frequency of the tuning fork? Assume that the speed of sound is 343 $\frac{m}{s}$.

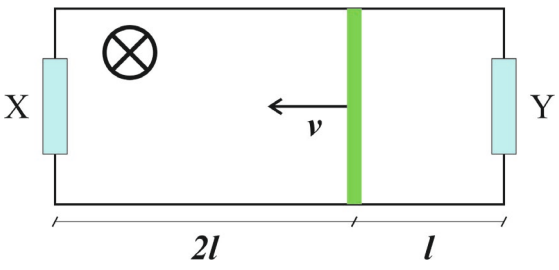
(A) 329,8 Hz **(B)** 527,7 Hz **(C)** 659,6 Hz **(D)** 879,5 Hz **(E)** 1319 Hz

27. *(3 points)* Two cars, A and B, each start from rest and move along a straight road. The acceleration vs. time graph for both cars is shown on the right. Which one of the following options correctly describes the relationship of their speeds v_A and v_B as well as distance travelled s_A and s_B by the cars after a time τ?



	speeds	distances
(A)	$v_A = v_B$	$s_A > s_B$
(B)	$v_A > v_B$	$s_A > s_B$
(C)	$v_A = v_B$	$s_A = s_B$
(D)	$v_A < v_B$	$s_A < s_B$
(E)	$v_A = v_B$	$s_A < s_B$

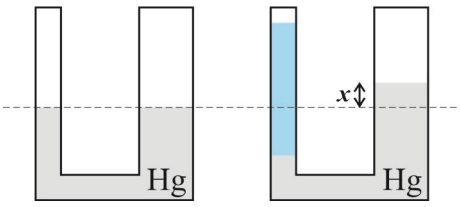
28. *(3 points)* A metal bar is moving to the left over a set of frictionless conducting rails. Throughout the region between the rails there is a uniform magnetic field directed into the plane of the page. The rails are connected on the left and on the right through identical resistors labelled X and Y. Which one of the following options correctly indicates the direction of the current in the resistors as well as the relation between the magnitude of the currents through each resistor at the instant shown in the figure?



	current through X	current through Y	relation between currents
(A)	up the plane of the page	up the plane of the page	$I_X > I_Y$
(B)	up the plane of the page	up the plane of the page	$I_X = I_Y$
(C)	up the plane of the page	down the plane of the page	$I_X > I_Y$

(D)	down the plane of the page	down the plane of the page	$I_X = I_Y$
(E)	down the plane of the page	down the plane of the page	$I_X > I_Y$

29. *(3 points)* A U-tube is filled with mercury (density 13,6 $\frac{g}{cm^3}$) as shown in the left-most figure. Water of mass 800 g is added to the left-hand side of the tube. When equilibrium is re-established, the tube appears as shown in the right-most figure. The cross-sectional area of the left tube is 6,50 cm^2 while the right tube has cross-sectional area 15 cm^2. What is the height x above the original equilibrium level that the mercury rises in the right tube?

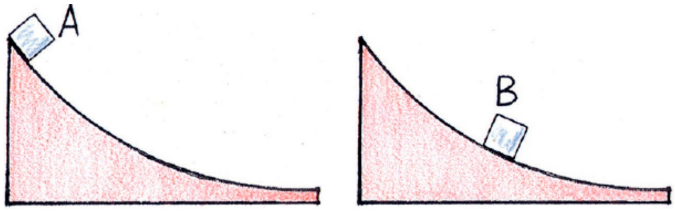


(A) 1,96 cm **(B)** 2,74 cm **(C)** 3,92 cm **(D)** 4,92 cm **(E)** 9,2 cm

30. *(3 points)* While passing through a train station with constant speed v_s, a high speed train emits a constant frequency sound. If the conductor, standing right next to the train tracks, registers an increase in wavelength of waves by a factor of 1,5 from the moment when the train was approaching till the moment the train was leaving the station, what was the speed of the train in terms of the speed of sound v?

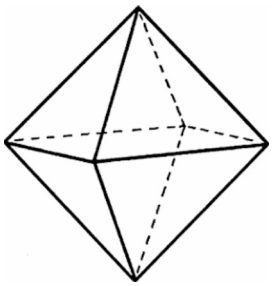
(A) $\frac{1}{5}v$ **(B)** $\frac{1}{4}v$ **(C)** $\frac{1}{3}$v **(D)** $\frac{1}{2}v$ **(E)** $\frac{2}{3}v$

31. *(4 points)* Ice cubes A and B slide down identical frictionless circular-curved ramps. Cube A begins its slide at the top of the ramp. Cube B begins its slide half way up the ramp. Which of the following choices describes best what happens when both cubes are released simultaneously from rest?



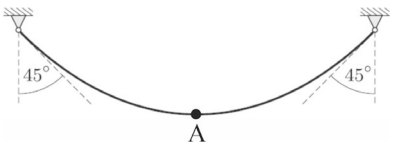
(A) Cube B reaches the bottom in $^1/_4$ the time it takes cube A to do the same.
(B) Cube B reaches the bottom in $^1/_2$ the time it takes cube A to do the same.
(C) Both cubes reach the bottom at nearly the same time.
(D) Cube B reaches the bottom in $^1/_{\sqrt{2}}$ the time it takes cube A to do the same.
(E) None of the above.

32. *(4 points)* Curious physics students, who like mathematics, took 12 identical capacitors with capacitance C each and connected them in the shape of octahedron. They were wondering what the equivalent capacitance of such a network would be if measured between two adjacent nodes.



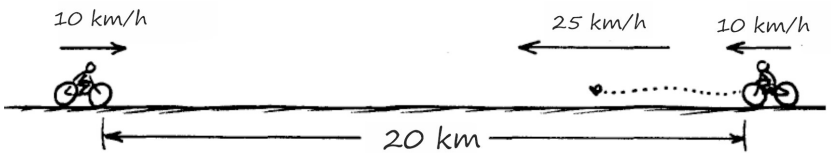
(A) $\frac{2}{3}C$ **(B)** $\frac{6}{5}C$ **(C)** $\frac{12}{7}$C **(D)** $\frac{4}{3}C$ **(E)** $\frac{12}{5}C$

33. *(4 points)* The figure on the right shows a homogeneous rope of mass m and length l. What is the tension force in the lowest part of the rope (point A) equal to?



(A) mg **(B)** $mg\sqrt{2}$ **(C)** $mg/4$ **(D)** $mg/2$ **(E)** $^{mg}/_{\sqrt{2}}$

34. *(4 points)* Two bicyclists travel at a uniform speed of 10 $\frac{km}{h}$ toward each other. At the moment when they are $20\,km$ apart, a bumblebee flies from the front wheel of one of the bikes at a uniform speed of 25 $\frac{km}{h}$ directly to the wheel of the other bike. It touches it and turns around in a negligibly short time and returns at the same speed to the first bike, whereupon it touches the wheel and repeats the back-and-forth trip over and over again until the bikes collide. What was the distance the bee flew in its many back-and-forth trips?



(A) 75 km **(B)** 20 km **(C)** 50 km **(D)** 25 km **(E)** more than 75 km

The end!