Azonosító jel: | | | | | | | | | | | | | | | |

ÉRETTSÉGI VIZSGA • 2021. május 18.

FIZIKA
ANGOL NYELVEN

EMELT SZINTŰ ÍRÁSBELI VIZSGA

2021. május 18. 8:00

Időtartam: 300 perc

Pótlapok száma	
Tisztázati	
Piszkozati	

EMBERI ERŐFORRÁSOK MINISZTÉRIUMA

Important information

Read the instructions for the problems carefully and use your time wisely.

You may solve the problems in arbitrary order.

Resources that may be used: pocket calculator, data tables.

Should the space provided for the solution of a problem be insufficient, you may continue the solution on the empty pages of the examination paper or on auxiliary sheets. Please indicate the number of the problem on the pages.

PART ONE

Precisely one of the possible solutions for each of the following questions is correct. Write the letter corresponding to the answer you think is correct in the white square on the right. You may write calculations or draw figures on this problem sheet if necessary.)

1. A catapult mechanism that consists of a horizontal spring with spring constant *D* ejects a projectile of mass *m* with velocity *v*. What is the minimum amount, by which the spring must have been compressed?

A) $\Delta l \geq \frac{mgv}{D}$

B) $\Delta l \geq \frac{mgv}{D^2}$

C) $\Delta l \geq \sqrt{\frac{mv^2}{D}}$

2 points	

2. What is the shape of equipotential surfaces in the electric field of a point-like charge?

A) They are straight lines originating at the charge and extending radially outward.
B) They are spherical shells with the charge being in the geometrical center.
C) There are no equipotential surfaces as the electric field of a point-like charge is not homogeneous.

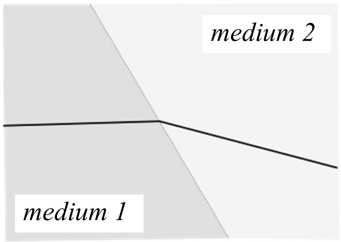
2 points	

3. A spaceship takes off from Earth, bound for the Moon. When do the astronauts within it experience weightlessness?

A) When the engines of the spaceship are not turned on.
B) At the point between Earth and Moon when the gravitational attractions of the two celestial bodies precisely cancel each other.
C) Never, as Earth's gravitational attraction extends beyond the Moon.

2 points	

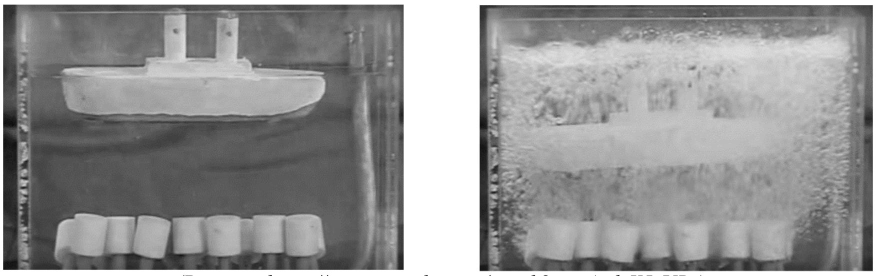
4. **The adjacent figure shows a ray of light as it travels through two different media. The material on the left has a higher refractive index, the one on the right a lower one. The creator of the figure forgot to mark the direction of propagation for the light. In which direction is the light propagating?**



A) From medium one towards medium two.
B) From medium two towards medium one.
C) It may be propagating in either direction.

2 points	

5. **The ship in the adjacent pictures is floating on the water in the tub, but if air is blown into the water from the tubes at the bottom, the ship will sink in the bubbling water. Why does the ship sink in the bubbling water?**



(Pictures: https://www.youtube.com/watch?v=nAmlvYJnURs)

A) Because the bubbling water also swirls around, so, according to Bernoulli-s law the hydrostatic pressure is smaller and therefore the buoyancy force is also smaller.
B) Because the buoyancy force is smaller in bubbling water (the force equivalent to the weight of the water displaced by the ship).
C) Because the waves reaching the surface result in the hydro-static pressure pushing the ship downward as well, so it can no longer float on the surface.

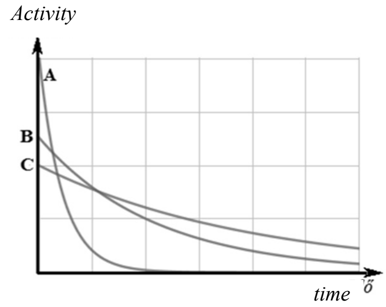
2 points	

6. **We operate a 4.5 V nominal voltage conventional light bulb with a tungsten filament using a variable voltage current source. We first operate it at 1.5 V voltage, then at 3 V, finally at 4.5 V voltage – the filament glows at higher and higher temperatures. What can we say about the current in the circuit?**

A) The current in the circuit is the same in all three cases.
B) The current increases to double, then triple its initial value.
C) The current increases, but it is not linearly proportional to the voltage.

2 points	

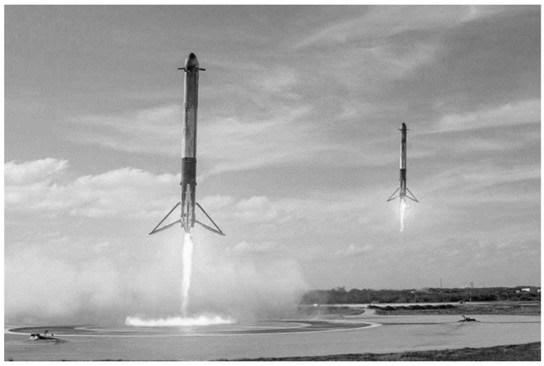
7. We investigated the decay of three radioactive samples in the lab. We plotted their activities on one graph together as a function of time. The half-life of which sample is the greatest?



A) That of sample A.
B) That of sample B.
C) That of sample C.
D) It is not possible to determine from the graph.

2 points	

8. The adjacent picture shows the landing of the two booster rockets of the SpaceX company's "Falcon Heavy" space vehicle. The booster rockets detach from the space vehicle after launch and return, landing smoothly at the base with the use of their engines. What force is acting on the landing pad closer to us at the moment depicted by the picture?



(Picture: en.wikipedia.org)

A) None as the rocket is not yet on the ground.
B) The weight of some of the propellants that burn on the landing pad.
C) A force even greater than the rocket's weight may be acting, as the rocket is decelerating.

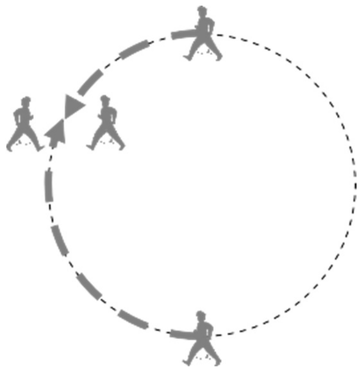
2 points	

9. We heat two wires made of the same material and observe that their lengths change by an equal amount. How is this possible?

A) It is certain that the temperatures of the wires were raised by equal amounts.
B) It is certain that the lengths of the two wires were equal before heating.
C) It is certain that the initial temperatures of the two wires were equal.
D) None of the above conditions are necessarily true.

2 points	

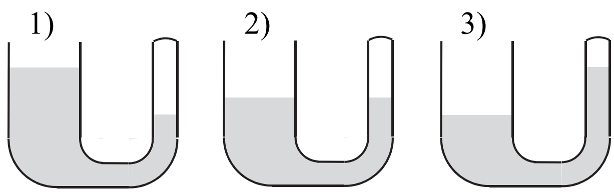
10. Two pedestrians start walking towards each other from two opposing points of a circular track at 16 o'clock precisely. They both walk with constant speeds, but their speeds are different. They first meet at 2 minutes past 16 o'clock. When will they meet for the second time, if they continue walking at the same speeds?



A) At 4 minutes past 16 o'clock.
B) At 6 minutes past 16 o'clock.
C) At 8 minutes past 16 o'clock.
D) It is not possible to determine, it depends on the speeds of the pedestrians.

2 points

11. The left branch of the U shaped vessel depicted on the picture is wider and open, while the right branch is narrower and closed. We pour water into the open branch. Which of the three drawings depicts correctly the position of the water in the vessel after equilibrium is reached?



A) Picture one.
B) Picture two.
C) Picture three.

2 points

12. A child is swinging on a swing at the playground. At which point of its trajectory are his speed and tangential acceleration the greatest while swinging?

A) Both speed and tangential acceleration are the greatest at the lowest point of the trajectory.
B) The speed is greatest at the lowest point, the tangential acceleration is greatest at the highest point of the trajectory.
C) The speed is greatest at the highest point, the tangential acceleration is greatest at the lowest point of the trajectory.
D) Both speed and tangential acceleration are the greatest at the highest point of the trajectory.

2 points

13. A natural radioactive isotope with a high mass number spontaneously decays via α-decay. Does its neutron to proton ratio (N/Z) increase or decrease in the process?

A) It decreases.
B) It does not change.
C) It increases.
D) It is impossible to decide from the given data, it depends on the initial ratio.

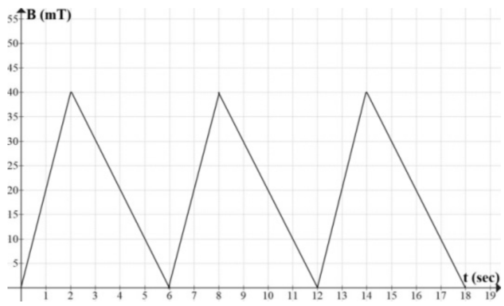
2 points	

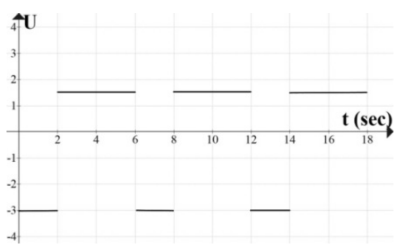
14. A moon with a small mass orbits a planet with a large mass with period *T*. What would the period *T'* of the moon be, if its mass would be doubled but its trajectory would be unchanged?

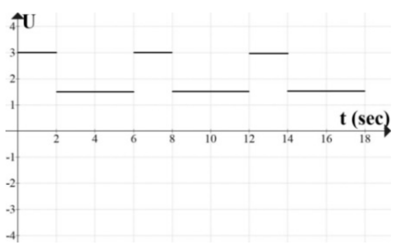
A) $T' = \sqrt[3]{2^2}\,T$
B) $T' = \sqrt{2}T$
C) $T' = 2T$
D) $T' = T$

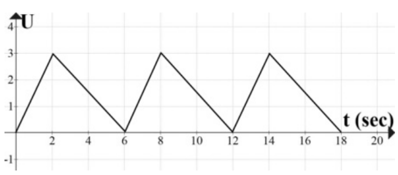
2 points	

15. The adjacent graph shows the magnitude of the magnetic induction at a certain domain in space as a function of time. We place a conducting loop into this domain. Which of the graphs below depicts correctly the voltage that is induced in the loop?









A) The graph on the left.
B) The graph in the middle.
C) The graph on the right.

2 points	

PART TWO

Choose one of the three topics below and write a coherent, 1.5-2 page long essay about it. Make sure that the phrasing is accurate and clear, the train of thought is logical and pay attention to the spelling, as this will also affect the evaluation. You do not necessarily have to formulate your thoughts in the exact order of the aspects given. The essay may be written on the following pages.

1. The electron shell

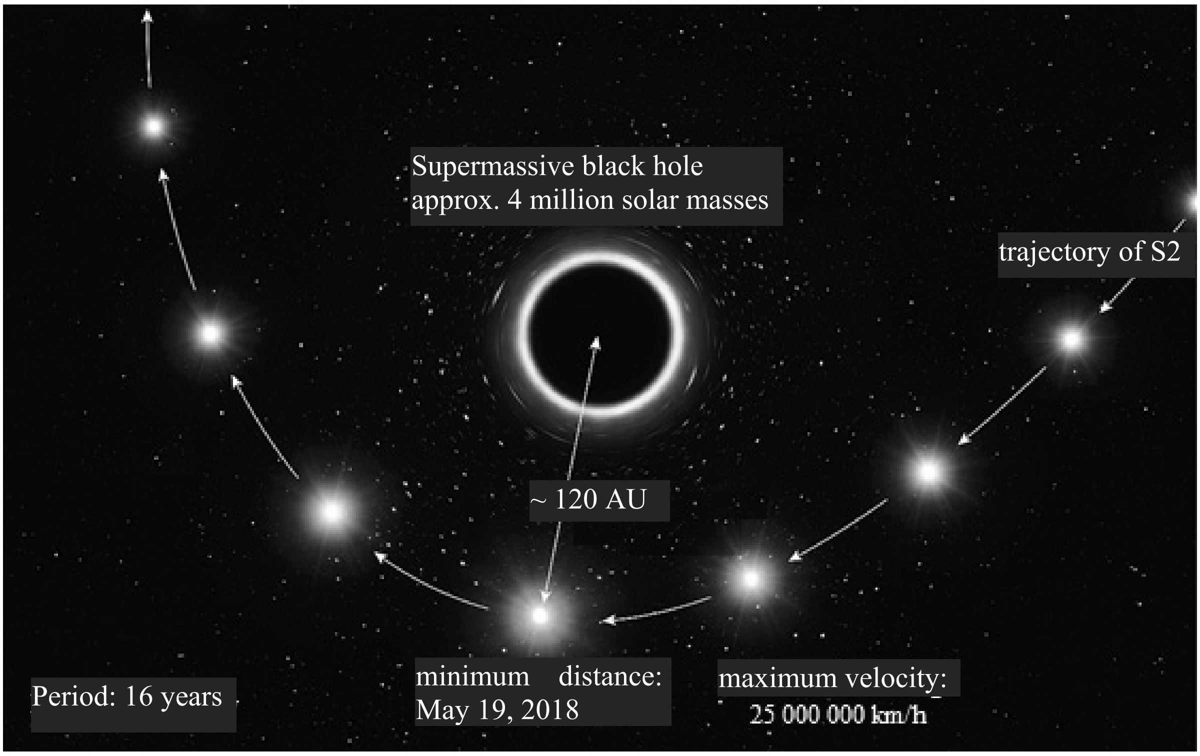
Pauli was a really excellent theoretical physicist. For his friends, his name will always be inseparable from the mysterious phenomenon called the Pauli effect. It is well known that theoretical physicists are all very clumsy with experimental equipment, breaking expensive, complicated instruments as soon as they touch them. Pauli was such an excellent physicist that instruments broke just as soon as he stepped into the laboratory.

Gamow:*The history of physics*. Budapest, 1965

Explain what we mean by a photon. Review Bohr's model of the atom. Show how the idea of energy quantization appears in the model. Explain the concepts of emission and absorption spectra based on the above. Explain the connection between the two spectra. How can we gain information about the composition of a material sample using spectroscopy?
Review the concepts of the principal and orbital quantum numbers, the magnetic and spin quantum numbers. Discuss the order in which the electron orbits are filled as the atomic number of the element increases. State Pauli's exclusion principle and Hund's rule.
What do the names s-, p-, d- and f-block mean in the periodic table?
Why is the electron structure of noble gases special?

2. The black hole

The ***black hole*** *is a domain in space-time from which no information, not even light can leave due to strong gravitation. A picturesque, though somewhat simplistic definition is that this is a celestial body, where the escape velocity on the surface is equal to or greater than the speed of light. The expression "hole" should not be considered in the conventional sense, it is more like a domain of space which absorbs everything due to its gravitation and from which there is no return. Black holes may be created at the end of the evolution of massive stars as possible final states, via supernova explosions, provided the star is massive enough for the neutron star left after the explosion to collapse due to the enormous gravity. As no radiation may leave a black hole, their existence, their properties may only be inferred from the effects of their enormous gravitation on their surroundings. We can deduce, from the movement of stars orbiting the center of our galaxy, that a supermassive object with a mass of about 4 million solar masses is located at the center of the Milky Way, which is highly likely to be a black hole. We can also detect here on Earth the gravitational waves which are emitted when two black holes collide and merge.*



(Picture: https://upload.wikimedia.org/wikipedia/commons/)

a) What does the gravitational acceleration on the surface of a celestial body depend on and how?
b) What do we mean by first and second cosmic velocity?
c) Let us assume that a small star is orbiting around a massive black hole. Its distance from the black hole is not constant, but it does not fall into the black hole. What kind of trajectory can the star follow? What can we say about the varying of its speed along its trajectory?
d) How can we detect a black hole?
e) From what can we draw conclusions on the merging of two black holes?
f) The artists drawing shown depicts a part of the trajectory of the star marked by S2, which orbits the center of our galaxy along an elongated elliptical orbit, as reconstructed from the most recent measurements. The drawing depicts the section of the trajectory closest to

the central black hole. Approximately what is the speed of the star at the farthest point of the trajectory, which is at a distance of about 1000 AU from the black hole (astronomical units = the Earth-Sun distance)?

3. The condensation of vapor

As part of renovation works on an apartment, the windows are replaced. Windows with good insulation can reduce heating costs a great deal, but the absence of venting creates other problems. One of these is the dampening of the apartment, which can lead to the appearance of mildew. The prime reason for dampening is the water vapor exhaled by the inhabitants, which, in the absence of venting, increases air humidity in the apartment. A further important factor is the low temperature of walls during wintertime. Humid air is cooled by the walls to below dew point and water condenses on the walls. Dampening of the walls thus depends on the humidity of air and the temperature of the walls. The table below contains the dew point temperature for air with various relative humidity and temperature values. For example, the dew point for air with temperature 21 °C and 40 % relative humidity is 6.9 °C, i.e. water will condense from this air on any surface colder than 6.9 °C.

	30%	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
25 °C	6.2	10.5	13.9	16.7	19.1	21.3	23.2
24 °C	5.4	9.6	12.9	15.8	18.2	20.3	22.3
23 °C	4.5	8.7	12.0	14.8	17.2	19.4	21.3
22 °C	3.6	7.8	11.1	13.9	16.3	18.4	20.3
21 °C	2.8	6.9	10.2	12.9	15.3	17.4	19.3
20 °C	1.9	6.0	9.3	12.0	14.4	16.4	18.3
19 °C	1.0	5.1	8.3	11.1	13.4	15.5	17.3
18 °C	0.2	4.2	7.4	10.1	12.5	14.5	16.3

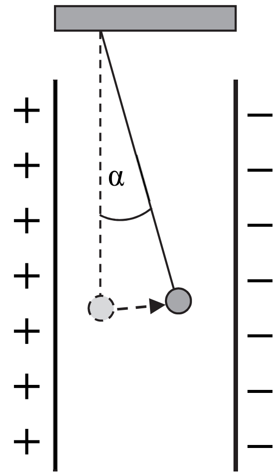
a) Review the concept of relative humidity. When do we say that water vapor is saturated?
b) How can we decrease the vapor content of air inside the apartment?
c) How can we decrease the relative humidity inside the apartment?
d) How does increasing temperature change absolute and relative humidity?
e) What is the dew point temperature?
f) The relative humidity inside an apartment is 50 % at a temperature of 23 °C. At most what is the temperature of the window pane if water condenses forming droplets running down its surface?
g) What is the density of water vapor in the air of an apartment with 50 % relative humidity and 23 °C temperature? Approximately what would be the relative humidity of the air if its temperature decreased to 20 °C?

Temperature (°C)	Saturated vapor density (g/m^3)
10	9.4
11	10
12	10.7
13	11.4
14	12.1
15	12.8
16	13.6
17	14.4
18	15.3
19	16.2
20	17.2
21	18.3
22	19.4
23	20.6
24	21.8
25	23.0

Content	Presentation	Total
18 points	5 points	23 points

PART THREE

Solve the following problems. Justify your statements using calculations, diagrams or explanations, depending on the nature of the questions. Make sure that the notations you use are unambiguous.



1. **We use the setup depicted on the adjacent drawing to measure the electric charge on a small ball of known mass. We hang the ball between the plates of a capacitor and slowly increase the voltage between the plates to $U = 3$ kV. The distance between the capacitor plates is $d = 8$ cm, the mass of the ball is 3 grams.**

   a) What is the direction and magnitude of the electric field between the plates due to the applied voltage?
   b) What is the charge on the small ball if the string supporting it encloses an $\alpha = 15°$ angle with the vertical?
   c) What is the force arising in the string when the ball is in equilibrium?

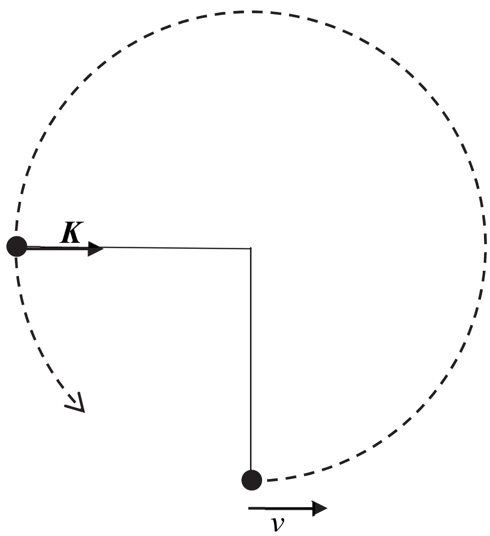
$g = 9.8\ \dfrac{\text{m}}{\text{s}^2}$.

a)	b)	c)	Total
3 points	6 points	2 points	11 points

2. A small ball with mass *m* = 0.2 kg is tied to a 1-meter-long string and is moving on a circular trajectory that lies in a vertical plane. It is started with a horizontal initial velocity at the bottom of the trajectory that is just sufficient for the ball to remain on the circular orbit at the top. (Thus the force arising in the string that constrains the ball to the circular trajectory is *K* = 0 at the highest point.)

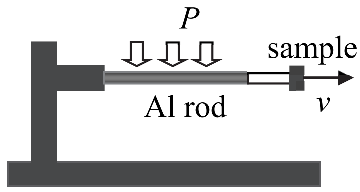
a) What is the initial velocity of the ball?
b) What is the force in the string when, after covering three-fourths of a complete revolution the string is horizontal?
c) What is the net acceleration of the ball at this point?

$g = 9.8\ \frac{\text{m}}{\text{s}^2}$



a)	b)	c)	Total
7 points	5 points	2 points	14 points

3. A material sample must be moved very slowly with a given velocity in an experiment. The problem is solved by fixing the sample to the end of a rod whose central 30 cm long section is made of aluminum and has a circular cross-section. This section is heated with a constant power.



a) What is the temperature change per second that we must realize for the sample to move with a velocity of 36 nm/s?
b) What is the heating power necessary for this? (Heat losses can be neglected.)

The linear thermal expansion coefficient of aluminum is $2.4 \cdot 10^{-6}$ 1/°C, the diameter of the aluminum rod is 1 cm, the density of aluminum is 2700 kg/m^3, it specific heat is 900 J/kg°C.

a)	b)	Total
5 points	6 points	11 points

4. In an electron microscope, electrons are accelerated to 10% of the light speed (thus relativistic effects are negligible). The resolution of a microscope is the smallest distance *d* such that two points that are located at this distance from each other are distinguishable by the observer. The smaller the distance *d*, the better the resolution. The distance *d* is proportional to the wavelength of the wave used during the imaging process: $d \sim \lambda$ **.**

a) What is the accelerating voltage that accelerates the electrons in the microscope?
b) Calculate the de Broglie wavelength of electrons accelerated to 10% of the light speed.
c) How many times is the resolution of the electron microscope in this problem better, than that of a conventional microscope using light with 500 nm wavelength?

$c = 3 \cdot 10^8$ m/s, $e = 1.6 \cdot 10^{-19}$ C, $m_e = 9.1 \cdot 10^{-31}$ kg

a)	b)	c)	Total
4 points	4 points	3 points	11 points

To be filled out by the examiner evaluating the paper!

	score	
	maximum	attained
I. Multiple-choice questions	30	
II. Essay: content	18	
II. Essay: presentation	5	
III. Complex problems	47	
Total score for the written exam	**100**	

date

examiner

	pontszáma **egész számra** kerekítve	
	elért	programba beírt
I. Feleletválasztós kérdéssor		
II. Témakifejtés: tartalom		
II. Témakifejtés: kifejtés módja		
III. Összetett feladatok		

dátum

dátum

javító tanár

jegyző