ÉRETTSÉGI VIZSGA • 2021. május 18.

# FIZIKA
# ANGOL NYELVEN

# EMELT SZINTŰ
# ÍRÁSBELI VIZSGA

# JAVÍTÁSI-ÉRTÉKELÉSI
# ÚTMUTATÓ

EMBERI ERŐFORRÁSOK MINISZTÉRIUMA

The examination papers should be evaluated and graded clearly, according to the instructions of the evaluation guide. Markings should be in red ink, using the conventional notations.

## PART ONE

For the multiple choice questions, the two points may only be awarded for the correct answer given in the evaluation guide. Enter the score (0 or 2) in the gray rectangle next to the question as well as the table for total scores at the end of the exam paper.

## PART TWO

The student should explicate the answers to the questions as a continuous text in whole sentences, so sketchy outlines are not to be evaluated. The only exception is any explanatory text or label of a drawing. Scores for facts or information mentioned in the evaluation guide may only be awarded if the student explains it in proper context. Partial scores must be written on the margin with indication as to which item of the evaluation guide is the basis of awarding it. The evaluated statement in the text must be ticked. The scores must also be entered in the table following the questions of the second part.

## PART THREE

***Principles for dividing allocated scores:***

- The sentences printed in italics in the evaluation guide define the steps necessary for the solution. The scores indicated here may and should be awarded if the action or operation described by the text in italics can be clearly identified in the work of the student and is basically correct and complete.
- The „expected solution" is not necessarily complete; its purpose is to indicate the nature and extent of the expected solution, and the depth of detail required from the student. Comments in brackets that follow provide further guidance on the evaluation of possible errors, differences or incomplete answers.

***Principles for evaluating alternative trains of thought:***

- Correct answers that differ from the reasoning of the one (ones) given in the evaluation guide are also acceptable. The lines in italics provide guidance in allocating scores, e.g. what part of the full score may be awarded for a correct interpretation of the question, for stating relationships, for calculations, etc.
- Should the student combine some steps, or carry on calculations algebraically, he/she may skip the calculation of intermediate results shown in the evaluation guide. If these intermediate results are not being explicitly asked for in the original problem, the scores indicated for them should be awarded if the reasoning is otherwise correct. The purpose of indicating scores for intermediate results is to make the evaluation of incomplete solutions easier.

***Principles for the avoidance of multiple deductions:***

- For errors that do not affect the correctness of reasoning (miscalculations, clerical errors, conversion errors, etc.) deduce points only once.
- Should the student display multiple attempts at solving the problem, and does not indicate clearly which one of those he/she wants evaluated, the last one should be considered (i.e. the one at the bottom of the page if there is nothing to indicate otherwise). If the solution contains a mixture of two different trains of thought, the elements of only one of them should be evaluated: that one which is more favorable for the student.
- If an action or operation defined in the evaluation guide is completed, but the results are incorrect due to errors committed previously, full points allocated for this action are to be awarded. If the action can be broken down into steps, partial scores are indicated beside each line of the expected solution.

***Principles regarding the use of units:***

- The lack of units during calculation should not be considered a mistake – unless it causes an error. However, the results asked for in the problem are acceptable only with proper units.
- Graphs, diagrams and notations are acceptable only if they are unambiguous (it must be clear what the graphs show, markings should be in place, unconventional notations must be explained, etc.). The lack of units on the axis labels of graphs should not be considered a mistake however, if the units are otherwise obvious (e.g. quantities given in a table must be plotted, all with the same units).

After evaluation, the appropriate scores should be entered in the summarizing tables.

# PART ONE

**1. C**
**2. B**
**3. A**
**4. C**
**5. B**
**6. C**
**7. C**
**8. C**
**9. D**
**10. B**
**11. A**
**12. B**
**13. C**
**14. D**
**15. A**

Award ***2 points*** for each correct answer**.**

**Total: 30 points**

# PART TWO

***Each of the scores may be divided for all three topics.***

## 1. The electron shell

*a)* *Explaining Planck's photon hypothesis:*

**1 point**

*b)* *Reviewing the Bohr model:*

atomic nucleus + electrons on discrete orbits around it

**1+1 points**

*c)* *Explaining the significance of quantization:*

discrete energy jumps + absorption, emission

**1+1 points**

*d)* *Explaining how absorption and emission spectra appear:*

**1+1 points**

*e)* *Discussing the relationship between spectral lines in absorption and emission spectra:*

**1 point**

*f)* *Reviewing the concept of the electron shell:*

**1 point**

*g)* *Introducing the principal, orbital, magnetic and spin quantum numbers:*

**1+1+1+1 points**

*h)* *Explanation of the order of filling of electron orbits using the principle of minimum energy:*

**1 point**

*i)* *Reviewing Pauli's principle:*

**1 point**

*j)* *Reviewing Hund's rule:*

**1 point**

*k)* *Explanation of the naming of blocks in the periodic table:*

**1 point**

*l)* *Characterizing the electron structure of noble gases:*

**1 point**

**Total: 18 points**

## 2. The black hole

a) *Defining the factors that influence the surface gravitational acceleration and naming the dependence:*

***2 points***

$g \sim M$ , where $M$ is the mass of the celestial body (1 point) and

$g \sim 1/R^2$ , where $R$ is the radius of the celestial body (1 point).

b) *Defining the cosmic velocities:*

***2 points***

The first cosmic velocity is the velocity required for a circular orbit of radius $R$ (1 point), while the second one is the velocity required for escaping the gravitational field (1 point).

c) *Giving the laws that govern the orbit of the star:*

***4 points***

According to Kepler's first law, the trajectory is an elliptical orbit with the black hole in one of its focal points (2 points).

According to Kepler's second law, the segment joining the star and the black hole sweeps out equal distances during equal time intervals (2 points).

(Full points are to be awarded if the descriptions are accurate, even if Kepler's laws are not named. If the student states for the velocity only that the star moves slower when it is farther away and faster when it is closer, 1 point is to be awarded.)

d) *Naming the observable effect of the black hole:*

***2 points***

We can infer its existence from the <u>movement of celestial bodies (stars)</u> around it.

(Simply mentioning the "gravitational effect" without any explanation is not sufficient.)

e) *Naming the observable effect of merging black holes:*

***2 points***

<u>Gravitational waves</u> emitted during the merging can be detected.

f) *The correct interpretation of the picture and determining the velocity:*

***6 points***

The required data can be read from the picture: $R_{\text{min}}$ = 120 AU (1 point),

$v_{\text{max}}$ = 25 000000 km/h (1 point).
As Kepler's second law states:

$$v_{max} \cdot R_{min} = v_{min} \cdot R_{max} \Rightarrow v_{min} = \frac{120}{1000} \cdot 25000000 \ \frac{\text{km}}{\text{h}} = 3000000 \ \frac{\text{km}}{\text{h}}.$$

(formula + rearranging + calculation, 2 + 1 + 1 points)

**Total: 18 points**

## 3. The condensation of vapor

*a) Reviewing the concepts of relative humidity and saturated vapor:*

***4 points***

Relative humidity is the density of water vapor in air of a given temperature, expressed as a percentage of the density of saturated vapor (2 points).
Water vapor is saturated if, in the presence of open liquid surface, evaporation and condensation are in a (dynamical) equilibrium (2 points).

*b) Describing how humidity can be changed:*

***1 point***

The amount of vapor in the apartment can be decreased by venting (letting air with a lower humidity inside).

*c) Describing how relative humidity can be changed:*

***1 point***

Relative humidity can also be decreased by increasing the temperature.

*d) Determining the effect of temperature change:*

***2 points***

Increasing the temperature does not change absolute humidity (1 point), but it decreases relative humidity (1 point).

*e) Reviewing the concept of dew point:*

***2 points***

Dew point is the temperature where the relative humidity of air with a given absolute humidity becomes 100%.

*f) Determining the temperature of the window:*

***3 points***

As determined from table one, it is 12 °C at most (3 points).

*g) Determining the density of water vapor and giving the relative humidity corresponding to 20 °C:*

***5 points***

According to the second table, the density of saturated water vapor is 20.6 g/m$^3$ at 23 °C (1 point), so a density of 10.3 g/m$^3$ (1 point) corresponds to 50% relative humidity.
This vapor density is about 60% of the 17.2 g/m$^3$ density of 20 °C saturated water vapor (1 point), so the relative humidity is 60 % ( 2 points).

or

The relative humidity at 20 °C can be obtained directly from the upper table. That is because the same value of vapor density (the same dew point) corresponds to entries with the same temperature (2 points). Water vapor with 50 % relative humidity at 23 °C becomes saturated at 12 °C (1 point). The same temperature value can be found at 20 °C for 60 % relative humidity (2 point).

**Total: 18 points**

**Evaluation of the style of the presentation based on the exam description, for all three topics:**

*Lingual correctness:* ***0–1–2 points***

- The text contains accurate, comprehensible, well-structured sentences;
- there are no errors in the spelling of technical terms, names and notations.

*The text as a whole:* ***0–1–2–3 points***

- The review as a whole is coherent and unified;
- individual parts, subtopics relate to each other along a clear, comprehensible train of thought.

No points may be awarded for the style of presentation if the review is no more than 100 words in length.

If the student's choice of topic is ambiguous, the content of the last one written down should be evaluated.

# PART THREE

*When evaluating the calculations, care must be taken to deduce points for errors that do not affect the correctness of reasoning (miscalculations, clerical errors) only once. If the student uses a previously miscalculated result in further steps of the solution correctly, full points are to be awarded for these steps. Thus it may be possible that full points are due at certain steps for solutions that differ from the values given in the evaluation guide.*

## Problem 1

Data: $m = 3$ g, $d = 8$ cm, $U = 3$ kV, $\alpha = 15°$, $g = 9.8$ m/s$^2$.

a) *Determining the magnitude and direction of the electric field between the plates:*

**3 points**
***(may be divided)***

$E = \frac{U}{d} = \frac{3000}{0.08} = 37500\ \frac{\text{V}}{\text{m}}$ (formula + calculation, 1 + 1 points).

The vector of the field strength points to the right (1 point). (Any correct definition is acceptable, e.g. towards the negatively charged plate, etc.)

b) *Naming or sketching the forces that act on the ball:*

**2 points**
***(may be divided)***

The forces acting on the ball are the vertical force of gravity $G$ (1 point) and the horizontal electrostatic force $F_E$ (1 point). (A suitable sketch is worth full points.)

*Determining the charge on the ball:*

**4 points**
***(may be divided)***

As $F_E = E \cdot q$ (1 point) and for the angle between the string and the vertical: $\tan(\alpha) = \frac{F_E}{G}$ (1 point),

$q = \frac{G \cdot \tan(\alpha)}{E} = \frac{9.8 \cdot 3 \cdot 10^{-3} \cdot \tan(\alpha)}{37500} = 2.1 \cdot 10^{-7}$ C (rearranging + calculation, 1 + 1 points).

c) *Determining the force in the string:*

**2 points**
***(may be divided)***

$F_k = \frac{G}{\cos(\alpha)} = 0.03$ N (formula + calculation, 1 + 1 points).

**Total: 11 points**

## Problem 2

Data: $m$ = 0.2 kg, $R$ = 1 m, $g$ = 9.8 m/s$^2$.

a) *Interpretation of the dynamical situation at the highest point of the trajectory:*

***2 points***

At the highest point of the trajectory $K = 0$, i.e. the centripetal force required for the ball to remain on the circular orbit is precisely the gravitational force: $F_{cp} = G$ or $a_{cp} = g$ (2 points).

*Expressing the ball's velocity at the highest point of the trajectory:*

***2 points***
***(may be divided)***

At the highest point $m \cdot g = F_{cp} = m \cdot \dfrac{v_{top}^2}{R} \Rightarrow v_{top} = \sqrt{gR} = 3.13\dfrac{\text{m}}{\text{s}}$

(formula + rearranging, 1 + 1 points)

*Expressing the conservation of mechanical energy and determining the initial velocity:*

***3 points***
***(may be divided)***

$$\frac{1}{2}m \cdot v_{bottom}^2 = 2 \cdot m \cdot g \cdot R + \frac{1}{2}m \cdot v_{top}^2 \Rightarrow v_{bottom} = \sqrt{4gR + v_{top}^2} = \sqrt{5gR} = 7\frac{\text{m}}{\text{s}}$$

(formula + rearranging + calculation, 1 + 1 + 1 points)

b) *Expressing the conservation of mechanical energy for the velocity at the middle position:*

***2 points***
***(may be divided)***

$$\frac{1}{2}m \cdot v_{bottom}^2 = mgR + \frac{1}{2}m \cdot v_{middle}^2 \Rightarrow v_{middle}^2 = 3gR$$

(formula + rearranging, 1 + 1 points)

*Determining the force in the string in the middle position:*

***3 points***
***(may be divided)***

The horizontal force in the string is equal to the centripetal force at this position, i.e. :

$$K = m \cdot \frac{v_{middle}^2}{R} = m \cdot \frac{3 \cdot g \cdot R}{R} = 5.9 \text{ N}$$

(formula + rearranging + calculation, 1 + 1 + 1 points)

c) *Determining the net acceleration of the body:*

***2 points***
***(may be divided)***

The centripetal acceleration is horizontal, while the tangential acceleration is vertical and equal to $g$. Thus the magnitude of the net acceleration is: $|a_e| = \sqrt{(3g)^2 + g^2} = 31\dfrac{\text{m}}{\text{s}^2}$.

(formula + calculation,1 + 1 points)

**Total: 14 points**

## Problem 3

Data: $\alpha = 2.4 \cdot 10^{-6}$ 1/°C, $d$ = 1 cm, $l$ = 30 cm, $\rho$ = 2700 kg/m$^3$, $C$ = 900 J/(kg°C), $v$ = 36 nm/s.

a) *Writing down the formula for the thermal expansion of the aluminum rod and determining the temperature change during one second:*

***5 points***
***(may be divided)***

$\Delta l = \alpha \cdot l \cdot \Delta t$ (1 point), which, for $\Delta t = 1\ °\mathrm{C}$ becomes $\Delta l = 720\ \mathrm{nm}$ (2 points).

Thus the temperature change per second necessary for the 36 nm/s velocity:
$\Delta t = 0{,}05\ °\mathrm{C}$ (2 points).

b) *Determining the mass of the aluminum rod and calculating the necessary power:*

***6 points***
***(may be divided)***

The mass of the aluminum to be heated is:

$$m = \left(\frac{d}{2}\right)^2 \cdot \pi \cdot \rho \cdot l = \frac{0.01^2 \cdot \pi \cdot 0.3 \cdot 2700}{4} = 63.6\ \mathrm{g}$$

(formula + substitution of data + calculation, 1 + 1 + 1 points),

so the amount of heat to be transferred per second:

$Q = C \cdot m \cdot \Delta t = 2.9\ \mathrm{J}$ (formula + calculation, 1 + 1 points).

Therefore, the necessary heating power:

$P$ = 2.9 W (1 point).

**Total: 11 points**

## Problem 4

Data: $v = 3\cdot10^{7}$ m/s, $e = 1.6\cdot10^{-19}$ C, $m_e = 9.1\cdot10^{-31}$ kg, λ = 500 nm.

a) *Applying the work energy theorem for the acceleration of the electron and determining the accelerating voltage:*

***4 points***
***(may be divided)***

$$e\cdot U = \frac{1}{2}m_e v^2 \rightarrow U = \frac{m_e v^2}{2e} = \frac{9.1\cdot10^{-31}\cdot(3\cdot10^{7})^2}{2\cdot1.6\cdot10^{-19}} = 2560\text{ V}$$

(formula + rearranging + calculation, 2 + 1 + 1 points)

b) *Determining the de Broglie wavelength of the electrons and the comparison with light:*

***4 points***
***(may be divided)***

The wavelength of the electrons:

$$\lambda_e = \frac{h}{m\cdot v} = \frac{6.63\cdot10^{-34}}{9.1\cdot10^{-31}\cdot3\cdot10^{7}} = 2.4\cdot10^{-11}\text{m}$$

(formula + calculation, 1 + 1 points)

$\frac{\lambda_f}{\lambda_e} = \frac{500\cdot10^{-9}}{2.43\cdot10^{-11}} = 2.1\cdot10^{4}$, i.e. the wavelength of the electrons is about 20000 times smaller than that of the light (2 points).

c) *Comparing the resolution of the microscopes:*

***3 points***
***(may be divided)***

As the resolution is <u>proportional to the wavelength</u> (1 point) used for imaging, the resolution of the electron microscope is about <u>20000 times better</u> (2 points) than that of the conventional microscope using light.

**Total: 11 points**