ÉRETTSÉGI VIZSGA • 2006. május 15.

FIZIKA
ANGOL NYELVEN
PHYSICS

EMELT SZINTŰ ÍRÁSBELI ÉRETTSÉGI VIZSGA
HIGHER LEVEL FINAL EXAMINATION

JAVÍTÁSI-ÉRTÉKELÉSI ÚTMUTATÓ
EVALUATION GUIDE

OKTATÁSI MINISZTÉRIUM
MINISTRY OF EDUCATION

In marking the examination papers follow the instructions of the evaluation guide, making clear corrections and comments. Do all marking in red ink (in case of the second correction green) using the conventional notations.

PART ONE

In the multiple choice questions, the 2 points are only due for the correct answer as given below. Enter the scores (0 or 2) in the grey rectangles next to the individual questions as well as the total score in the table at the end of the question paper.

PART TWO

The candidate should expound his opinions about the chosen topic in a continuous, coherent composition using whole sentences, thus sketchy answers cannot be accepted. The only exceptions are the labels of sketches or the explanatory notes added to figures. Points can only be awarded for the facts or data pointed out in the evaluation guide if they are mentioned in the appropriate context. Tick the correct statements, and write the awarded points to the margin of the sheet, as well as indicate the point in the evaluation guide according to which the credits were given. Also enter the scores in the table below part two.

PART THREE

The lines in the evaluation guide printed in italics define the steps necessary for the solution. The indicated number of points are due if the activity or operation described in italics can be clearly identified in the work of the candidate, and it is basically correct and complete. Where the activity can be divided into smaller steps, the subtotals are indicated next to each line of the expected solution. The sample solution as given in the evaluation guide is not necessarily complete. It aims to illustrate what kind of solution (length, types, depth, details, etc.) is expected of the candidate. The remarks in brackets at the end of the unit give further guidance in the judgement of the possible errors, differences and incomplete answers.

Correct solutions using a different reasoning from the one(s) given in the evaluation guide are also acceptable. The lines in italics help in judging the appropriate proportions, i.e. what part of the full score can be awarded for the correct interpretation of the question, for setting up relationships between quantities, for calculation, etc.

If the candidate combines steps and expresses the results algebraically without calculating quantities shown by the evaluation guide but not asked for in the original problem, award full mark for these steps, provided that the reasoning is correct. The purpose of giving intermediate results and the corresponding subtotals is to make the marking of the incomplete solutions easier.

Take off points only once for errors not affecting the correctness of reasoning (e.g. miscalculations, slips of the pen, conversion errors, etc.)

If the candidate's response contains more than one solution or more than one attempt without making clear which one they want to be assessed, assume that the last version is the final version (i.e. the one at the bottom of the page if there is no other way to decide the order.) If the candidate's response contains a mixture of elements of two different chains of reasoning, evaluate only one of the two. Select the one that is more favourable for the candidate.

The lack of units during calculation should not be considered a mistake if it does not cause an error in the result. The answers to the questions asked by the problem, however, are only acceptable with the appropriate units.

PART ONE

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

Award **2 points** for each correct answer

Total **30 points**

PART TWO

In all the three topics the subtotals, which are greater than one, can be further divided.

Topic 1.

a) *Comparing the forces exerted between two point-like masses and between two point-like charges:*

The gravitational force can only be attractive, while the electric force can either be attractive or repulsive.

1 point

Stating the force laws:

1+1 point

(Verbal reasoning or the correct formulae are acceptable and the 1-1 point is due for each.)

Stating the similarities:
Both forces are inversely proportional to the square of the distances.

1 point

Both forces act along the straight line which joins the bodies.

1 point

b) *Comparing the orders of magnitude of the gravitational and the electric forces exerted between two protons:*

2 points

$m_p = 1.67 \cdot 10^{-27}\,\text{kg};\ \ e = 1.6 \cdot 10^{-19}\,\text{C};\ k = 9 \cdot 10^9\,\frac{\text{Nm}^2}{\text{C}^2};\ \ f = 6.67 \cdot 10^{-11}\,\frac{\text{Nm}^2}{\text{kg}^2}.$

Only the order of magnitude of the ratio of the two forces, using the constants *k* and *f*, the mass and the charge of the proton, should be given. It is enough to give the result – 36 orders of magnitude– detailed explanation is not necessary.

c) *Describing the fields around a point-like charge and around a point-like mass:*
Realizing that the structure of both field lines is radial:

2 points

(Verbal reasoning or a correct sketch can be accepted. Only 1 point is due if the directions (either inward or outward) are not mentioned.)

Determining the electric field and the gravitational acceleration:

1+1 point

$$E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2};\quad g = \gamma\frac{M}{r^2}.$$

Realising that the gravitational acceleration and the electric field are the analogues of each other:

2 points

d) *Comparing the uniform electric and the uniform gravitational fields:*

1 point

(Showing the structure of field lines either in a sketch or with verbal reasoning.)
Determining the works done by the uniform electric and magnetic fields:

1+1 point

(Formula, or verbal reasoning can be accepted.)

Stating that both fields are conservative:

2 points

(It is enough to state that the work done by the field (in both cases) is independent of the path taken, mentioning the word *conservative* is not necessary.

Total **18 points**

Topic 2.

a) *Describing the kinetic theory of ideal gases.*

1+1+1+1+1 point

(Maximum point is due if following characteristics are all mentioned:
- the gas contains a large amount of tiny particles;
- the particles are far apart (the particles can move freely);
- the speed of the particles is high;
- the particles collide elastically with each other and with the wall of the container;
- the molecules interact with each other only during collisions.)

b) *Explaining the origin of the pressure of the gas:*

1+1+1 point

(Maximum point is due if following characteristics are all mentioned:
- the particles collide with the examined surface;
- the collisions are frequent;
- thus, pressure is initiated.)

c) *The connection between the random motion of the particles and the temperature:*

2 points

At higher temperature the random motion of the particles is more intensive.
(Stating the exact formula is not required.)

d) *Setting up the equation of state:*

3 points

(Stating one form, the appropriate formula is enough)

e) *Setting up the combined gas law:*

2 points

f) *Deriving, Charles' law, the pressure law and Boyle's law, from the combined gas law:*

1+1+1 point

(The candidate should state which quantity is kept constant in a certain process, and how the combined gas law can be simplified. Formula or verbal reasoning can be accepted.)

Total **18 points**

Topic 3.

a) *Describing how the emission spectrum can be produced:*

Describing how the emission of light is induced:

2 points

A substance emits light, if its atoms are excited e.g.: it should be heated.

Describing the dispersion of light:

2 points

The emitted light can be separated e.g. by a prism or a diffraction grating.

b) *Describing the difference between the spectrum of glowing gases or vapours and that of glowing liquids and solids:*

2 points

The spectrum of gaseous atoms is a line spectrum, the spectrum of liquids and solids is continuous.

(It can be accepted without reasoning.)

c) *Explaining the absorption and emission of light according to the Bohr model of the atom:*

6 points

(The 6 points are only due if the following facts are mentioned:

- There are only certain allowed atomic orbitals;
- only discrete energies can be associated to these orbitals;
- the difference between the energies of the different states is the same as the energy of the emitted or absorbed photon
- while an electron moves from one orbit to another.

Sketch, or verbal reasoning or a sketch with verbal reasoning can all be accepted.)

d) *Explaining the line spectrum of glowing gases and vapours:*

3 points

(The 3 points are only due if the following facts are mentioned:

- the energy of the emitted photon determines its frequency;
- discrete frequencies can be related to discrete energy levels;
- in the spectrum of light, dispersed by a prism, separate lines can be observed, according to the discrete frequencies of the emitted light.

It is enough to explain the emission spectrum.)

e) *Describing an example for the spectrum analysis:*

3 points

E.g.: analytic investigations, analysis of stars, proof of the big-bang theory.
(The 3 points are due if the description contains what kind of information can be gained from the explained investigation.)

Total 18 points

Assessing the presentation according to the description of the exam.

Grammar:

0-1-2 points

- The essay is clear, understandable and contains grammatically correct sentences.
- There are no spelling mistakes in the scientific terms, names and notations.

Coherence of text:

0-1-2-3 points

- The essay is complete and can be understood as a whole;
- The composition is coherent, the set of ideas described by the candidate is consistent, and clear.

If the candidate wrote less than 100 words, no points can be rewarded for the presentation.

If the chosen topic is not clear, evaluate the one, which was written last.

PART THREE

Problem 1.

Data: $U = 17$ kV, $m = 9.1 \cdot 10^{-31}$ kg, $q = 1.6 \cdot 10^{-19}$ C, $h = 6.6 \cdot 10^{-34}$ J·s.

Finding the work done by the electric field:

$W = qU$

1 point

$W = 1.6 \cdot 10^{-19}\,\text{C} \cdot 17 \cdot 10^{3}\,\text{V} = 2.72 \cdot 10^{-15}\,\text{J}$

1 point

Applying the work-energy theorem for the motion of the electron:

$\frac{1}{2} m v^2 = W$

2 points

Calculating the speed of the accelerated electron:

$v = \sqrt{\frac{2W}{m}}$

1 point

$v = \sqrt{\frac{2 \cdot 2.72 \cdot 10^{-15}\,\text{J}}{9.1 \cdot 10^{-31}\,\text{kg}}} = 7.73 \cdot 10^{7}\ \frac{\text{m}}{\text{s}}$

1 point

Calculating the de Broglie wavelength of the electron:

$\lambda = \frac{h}{p}$

1 point

$p = mv$

1 point

$\lambda = \frac{h}{mv}$

1 point

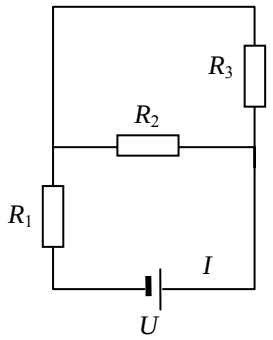
$\lambda = \frac{6.6 \cdot 10^{-34}\,\text{J} \cdot \text{s}}{9.1 \cdot 10^{-31}\,\text{kg} \cdot 7.73 \cdot 10^{7}\,\frac{\text{m}}{\text{s}}} = 9.4 \cdot 10^{-12}\ \text{m}$

1 point

Total **10 points**

Problem 2

Data: R_1= 80 ohm, R_2 = 300 ohm, U = 10 V, I = 0.05 A.



a)
Calculating the equivalent resistance, using the e.m.f. of the battery and the current in the main branch:

1 point

$$R_e = \frac{U}{I}$$

$$R_e = \frac{10\,\text{V}}{0.05\,\text{A}} = 200\,\Omega$$

Finding the equivalent resistance (R_{23}) of the resistors R_2 and R_3, connected in parallel,

$$R_e = R_1 + R_{23}$$

1 point

$$R_{23} = R_e - R_1 = 200\,\Omega - 80\,\Omega = 120\,\Omega$$

1 point

Calculating R_3:

$$\frac{1}{R_{23}} = \frac{1}{R_2} + \frac{1}{R_3}$$

1 point

$$R_3 = \frac{R_2 R_{23}}{R_2 - R_{23}} = \frac{300\,\Omega \cdot 120\,\Omega}{300\,\Omega - 120\,\Omega} = 200\,\Omega$$

1 point

b)
Determining the voltage across R_2:

$$U_2 = U_{23}$$

1 point

$$U_{23} = R_{23} I$$

1 point

$$U_2 = 120\,\Omega \cdot 0.05\,A = 6\,\text{V}$$

1 point

Calculating the power dissipated at R_2:

$$P_2 = \frac{U_2^2}{R_2}$$

1 point

$$P_2 = \frac{(6\,\mathrm{V})^2}{300\,\Omega} = 0.12\ \mathrm{W}$$

1 point

Total **10 points**

Problem 3.

Data: $v_o = 3$ m/s, $D = 400$ N/m, $m = 0.25$ kg.

Solution I.

a)

Calculating the maximum compression of the spring, using the conservation of energy:

$$\frac{1}{2}mv_0^2 = \frac{1}{2}D\Delta l^2$$

2 points

$$\Delta l = \sqrt{\frac{mv_0^2}{D}}$$

1 point

$$\Delta l = \sqrt{\frac{0.25\,\text{kg}\cdot(3\frac{\text{m}}{\text{s}})^2}{400\frac{\text{N}}{\text{m}}}} = 0.075\ \text{m} = 7.5\ \text{cm}$$

1 point

b)

Finding the greatest acceleration of the car applying Newton's 2nd law:

$$F_{\max} = D\Delta l$$

1 point

$$F_{\max} = 30\ \text{N}$$

1 point

$$a_{\max} = \frac{F_{\max}}{m}$$

1 point

$$a_{\max} = \frac{30\ \text{N}}{0.25\ \text{kg}} = 120\ \frac{\text{m}}{\text{s}^2}$$

1 point

c)

Calculating the period:

$$T = 2\pi\sqrt{\frac{m}{D}}$$

2 points

$$T = 6.28 \cdot \sqrt{\frac{0.25\,\text{kg}}{400\,\frac{\text{N}}{\text{m}}}} = 0.16\,\text{s}$$

1 point

Determining the time questioned:

2 points

$$t = \frac{T}{2} = 0.08\,\text{s}$$

Total **13 points**

Solution II.

Determining the period:

$$T = 2\pi\sqrt{\frac{m}{D}}$$

2 points

$$T = 6.28 \cdot \sqrt{\frac{0.25\,\text{kg}}{400\,\frac{\text{N}}{\text{m}}}} = 0.16\,\text{s}$$

1 point

Determining the time questioned:

2 points

$$t = \frac{T}{2} = 0.08\,\text{s}$$

Calculating the angular frequency:

$$\omega = \frac{2\pi}{T} = \frac{2 \cdot 3.14}{0.157\,\text{s}} = 40\,\frac{1}{\text{s}}$$

1 point

Finding the maximum compression (the amplitude of the oscillation) from the speed of the cart (the greatest speed of the oscillation):

$\Delta l = A$

1 point

$v_0 = v_{\max}$

1 point

$v_0 = \Delta l \omega$

1 point

$$\Delta l = \frac{v_0}{\omega} = \frac{3\ \frac{\text{m}}{\text{s}}}{40\ \frac{\text{N}}{\text{m}}} = 0.075\ \text{m} = 7.5\ \text{cm}$$

1 point

Calculating the maximum acceleration from the amplitude and the angular frequency:

$a_{\max} = \Delta l \omega^2$

2 points

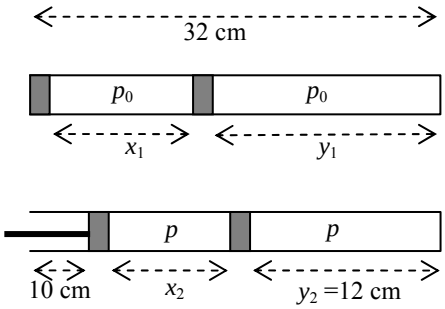
$$a_{\max} = 0.075\,\text{m} \cdot \left(40 \cdot \frac{1}{\text{s}}\right)^2 = 120 \frac{m}{s^2}$$

1 point

Total **13 points**

Problem 4.

Data: $p_o = 10^5$ Pa, $d = 2$ cm, $y_2 = 12$ cm .



a)

Calculating the lengths of the gas columns from the geometric conditions:

The total length of the two gas columns initially, and after the compression:

$L_1 = 32\text{ cm} - 2\text{ cm} = 30\text{ cm}$

$L_2 = 32\text{ cm} - 2\text{ cm} - 10\text{ cm} = 20\text{ cm}$

The length of the gas column on the left after compression:

$x_2 = L_2 - y_2 = 20\text{ cm} - 12\text{ cm} = 8\text{ cm}$

Setting up the parametric equation for the lengths of the two gas columns for the initial stage:

$x_1 + y_1 = L_1$ [1]

2 points

(partial credits can be given)

Applying Boyle's law for each gas:

setting up (using) the equation: $pV = \text{constant}$.

1 point

$p_0 A x_1 = pA x_2 \quad \Rightarrow \quad p_0 x_1 = p x_2$ [2]

1 point

$p_0 A y_1 = pA y_2 \quad \Rightarrow \quad p_0 y_1 = p y_2$ [3]

1 point

Solution of the equation system [1], [2], [3]:

E.g.: after adding equations [2] and [3]

$p_0(x_1 + y_1) = p(x_2 + y_2)$ is gained.

Using equation [1]

$$p = \frac{x_1 + y_1}{x_2 + y_2} p_0 = \frac{L_1}{L_2} p_0$$

$$p = \frac{30\text{ cm}}{20\text{ cm}} \cdot 10^5\text{ Pa} = 1.5 \cdot 10^5\text{ Pa}$$

3 points

(partial credits can be given)

Substituting the results to equation [2]:

$$x_1 = \frac{p}{p_0} x_2 = \frac{L_1}{L_2} x_2$$

$$x_1 = \frac{30\text{ cm}}{20\text{ cm}} \cdot 8\text{ cm} = 12\text{ cm}$$

2 points

(partial credits can be given)

(If the candidate considers the two gas columns as one and gains the result $p = \frac{L_1}{L_2} p_o$, then continuing this idea uses the proportionality of the lengths finds $x_1 = \frac{L_1}{L_2} x_2$, the maximum point can be awarded. In this case:

- the idea of unifying the gases – 2 points,
- determining L_1 and L_2 – 2 points,
- setting up Boyle's law – 1 point,
- calculating the final pressure (p) – 1 point,
- calculating x_2 – 1 point,
- setting up Boyle's law for the gas on the left – 2 points,
- calculating x_1 – 1 point.)

b)

Calculating the forces exerted on the system of the rod and the piston on the left:

The area of the piston: $A = \frac{d^2\pi}{4} = \frac{(0.02\text{ m})^2 \cdot 3.14}{4} = 3.14 \cdot 10^{-4}\text{ m}^2$

1 point

The force exerted by the air outside the tube: $F_k = p_k A = 10^5\text{ Pa} \cdot 3.14 \cdot 10^{-4}\text{ m}^2 = 31.4\text{ N}$

1 point

The force exerted by the air confined in the tube:
$F_b = pA = 1.5 \cdot 10^5\text{ Pa} \cdot 3.14 \cdot 10^{-4}\text{ m}^2 = 47.1\text{ N}$

1 point

The force exerted on the rod, according to the condition of the equilibrium: $F_{pálca} = F_b - F_k = 15.7\text{ N}$

1 point

Total **14 points**