LPR Cup

9.s05.e05

Hint 2

IMPORTANT! The next task is both a hint and an alternative to the main task. Three important points:

1. You can continue to send the solution to the main problem.
2. At any moment before the final deadline you can start to solve the Alternative problem. If you do so, at the beginning of the solution write: *I am doing the Alternative problem!* In this case a penalty coefficient for the Alternative problem is

$$0{,}7 \cdot \sum_i \frac{k_i \cdot p_i}{10},$$

   where p_i is a point for the problem item, and k_i is a penalty coefficient for the corresponding problem's item at the moment of moving to the Alternative problem. In other words, maximal points for the alternative problem equals to the maximal points you can gain at the moment of moving to the alternative one multiplied by 0,7. Also, we remind you that a penalty coefficient can't be less than 0,1. Solutions of the main problems from that moment will not be checked. Be careful!
3. The task consists of several items. The penalty multiplier earned **before** is applied to all points. In the future, each item is evaluated as a separate task. If you send a solution without any item, this item's solution is considered as Incorrect. For more information about scoring points for composite tasks, see the rules of the Cup. **Since switching to an alternative selection, there is no opportunity to return to solving the main task.** Also, after switching to an alternative task **the points for the main task are reset**.

Introduction

There were drafts next to the folder, from which an attentive Observer could find out how Hans came to certain results of his main work.

Alternative task

Part 1. Why do nuclei reactions matter?

The correct dice was rolled 3 times and the sum of the results turned out to be 6.

1. *(0 points)* What are the possible sequences of dice roll results?
2. *(0 points)* What is the most likely sequence?
3. *(2 point)* Which result set is the most likely?

Part 2. Collisions. Threshold

1. *(1 points)* The oxygen atom ^{16}O collides with the caesium atom ^{133}Cs. It is known that the ionization energy of the caesium atom is $E_1 = 3.9$ eV. What is the minimum kinetic energy of an oxygen atom at which ionization of a caesium atom will occur? Consider the blow as the central one.

Part 3. Off-center strike

Consider two material points with masses m_1 and m_2, which move at speeds $\vec{v}_1$ and $\vec{v}_2$, respectively.

1. *(0 points)* Find the velocity of the center of mass of such a system?
2. *(0 points)* Show that the momentum of a material point in the reference frame of the center of mass is $\mu\vec{v}_{\text{rel}}$, where $\mu = m_1 m_2/(m_1 + m_2)$ is the reduced mass, and $\vec{v}_{\text{rel}}$ – the relative velocity of these two points.
3. *(0 points)* Prove that the kinetic energy of the system of material points in the reference frame of the center of mass is equal to $\mu v_{\text{rel}}^2/2$
4. *(0 points)* Using the results of the previous paragraphs, show that if these two material points elastically collide, then the momentum modulus of each of them will not change in the reference frame of the center of mass.
5. *(0 points)* Show that in the case of a central impact in the initial reference frame (laboratory), the velocities of material points after a collision are $2\vec{v}_{\text{cm}} - \vec{v}_1$ and $2\vec{v}_{\text{cm}} - \vec{v}_2$.

Let a particle of mass M collide with a resting particle of mass $m < M$. The impact is elastic and off-center.

6. *(0 points)* Draw in one figure the velocity of the particle M in the initial reference frame, the velocity of the center of mass and the velocity of the particle in the reference frame of the center of mass.
7. *(0 points)* Draw the geometric location of the points, the end of the velocity vector of the particle of mass M after impact.
8. *(2 points)* Find the maximum deviation angle of the velocity vector of a heavy particle after a collision.
9. *(1 point)* What is the angle between the velocity vectors of the particles after impact.
10. *(0 points)* How will the task pattern change if the impact is inelastic?

Part 3. Autonomous discharge.

Let's consider qualitatively the process of the emergence of an independent gas discharge. The space between two flat conductive electrodes (cathode and anode) located at a distance of d from each other is filled with gas, and the electrodes themselves are connected to a DC voltage source.

The process of forming a gas discharge consists of two parts. The first is the formation by electrons in the process of ionization of a current of electrons and ions in a medium filling the space between the electrodes. The second part is the knocking out of new secondary electrons by ions from the cathode. To simplify the task, we will replace the process of knocking out electrons from the cathode with a similar one: we will assume that every electron that reaches the anode is captured by some element that provokes the birth of electrons in the cathode region and at the same time all the ions in our system will not affect anything.

Let's look at each of these processes in more detail. Suppose an electron was formed between the electrodes for some reason. Under the influence of an electric field, it begins to accelerate and move from the cathode to the anode and in the process collide with gas molecules, ionizing them. The new electrons formed will also move towards the anode. At the same time, they will form more and more electron-ion pairs, and ions will not do this (because their speed, which is one of the determining parameters in this process, will be significantly less than the speed of electrons). And then, when reaching the anode, a special element will provoke the birth of new electrons in the cathode region in proportion (with a coefficient of η) to the electrons that have come to the anode.

We will call the total ionization coefficient α the number of electrons at the end (in the anode region) of the avalanche generated from one electron that began its path in the cathode region. We will call external ionization a certain process that creates primary electrons. These can be a variety of processes: ultraviolet or gamma radiation passing through a gas, an additional conductor creating a small current of electrons, and so on. In our consideration, we will assume that this process is localized in the cathode region.

1. *(1 point)* It is known that the electron current in the cathode region is equal to I_{ek}, which includes the current of an external ionizer and the current of secondary electrons generated by a special element. The total ionization coefficient α is known. Find the electronic current in the anode area.

2. *(1 point)* Determine what is the current generated by a special element in the cathode area I_{xk}.

3. *(1 point)* Express the electron currents of the cathode and anode I_{ek} and I_{ea} through the ionization current I_i.

A breakdown is a situation when the electronic current I_{ea} increases infinitely at an arbitrarily small ionization current. If, after the breakdown occurs , the external ionizer is removed and the current does not stop, then the discharge is called independent: ionization is supported by processes in the discharge itself. (In our simplified case, processes in a discharge and a special element)

4. *(1 point)* Determine under what condition a breakdown will occur on α, η and d and the discharge will become independent?