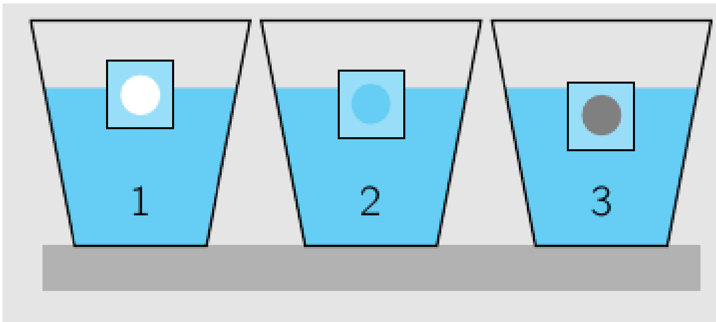
German Physics Olympiad

2nd Round Finals, 2020

Translated By: **Ahmed Saad Sabit**
Edited By: **-**

Problem 1. Three ice cubes are floating in each glass full of water. The ice cube in glass 1 has an air bubble in it. The ice cube in glass 2 has a cavity inside and the third ice cube floats in glass 3 with an aluminum core. **What can be said about the water level in the glasses directly?**



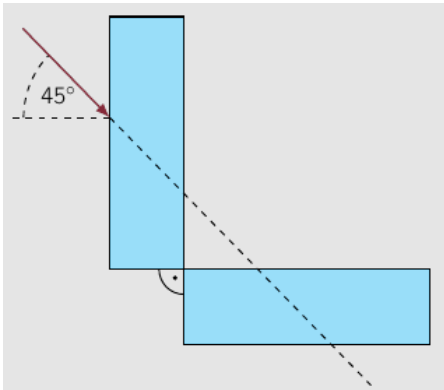
(A) The water in glass 1 has risen, the other glasses are unchanged.

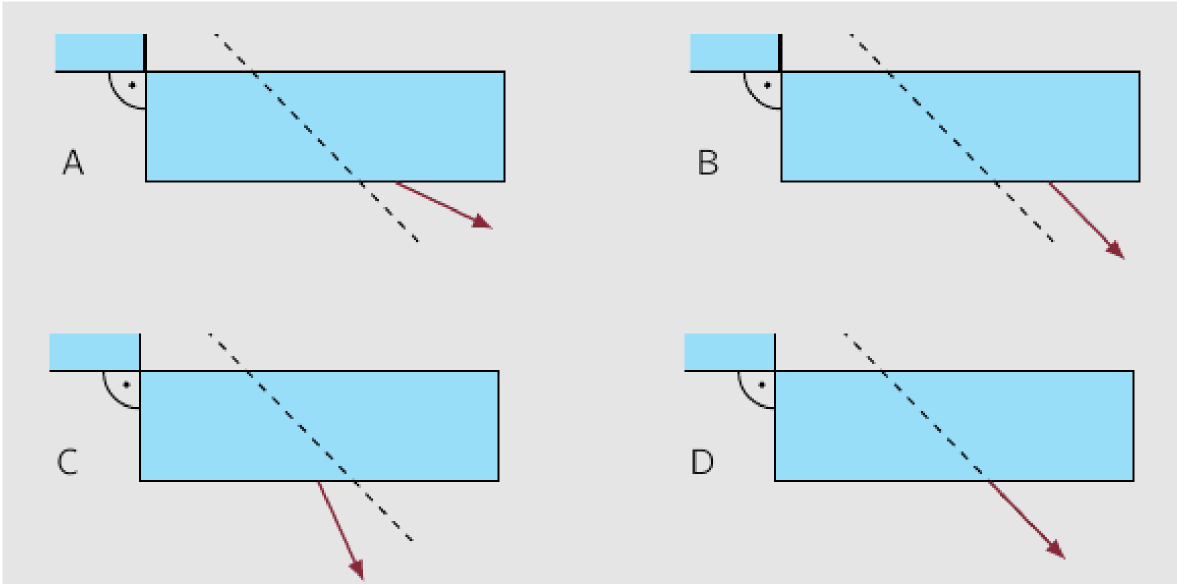
(B) The water level in glass 3 has got down, the other glasses are unchanged.

(C) The water level in glass 1 and 3 has risen, that in glass 2 is unchanged.

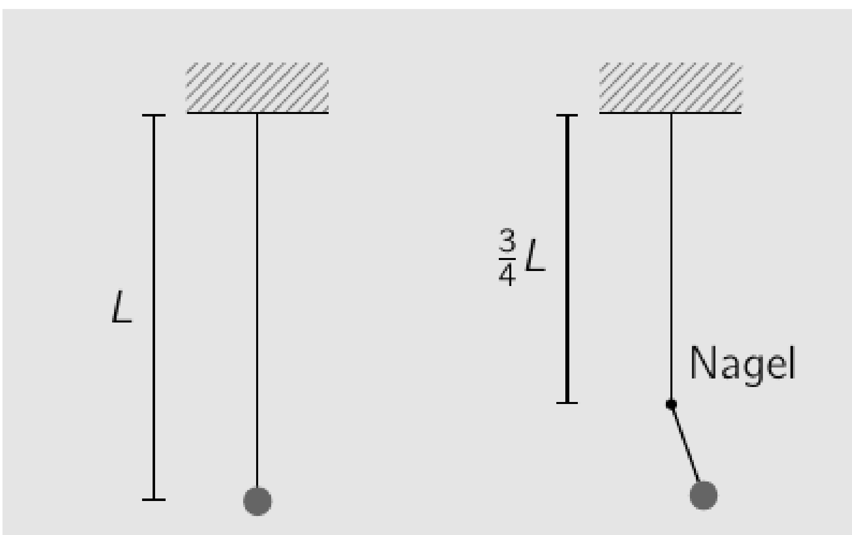
(D) The water level in all glass is unchanged.

Problem 2. Two glass slabs are kept in a position as shown in the figure. A beam of light hits the left slab at an angle of 45°. The path the light beam would have taken if there was no glass is shown by the dotted line.
The refractive index of the glass is 1.5 and the surrounding is air. **Which of the following sections of the option shows the course of the refracted light beam after the exit from the second cuboid?**

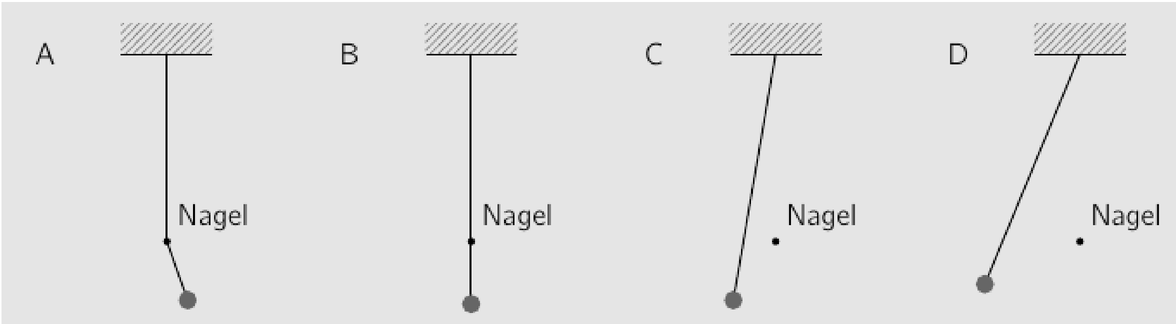




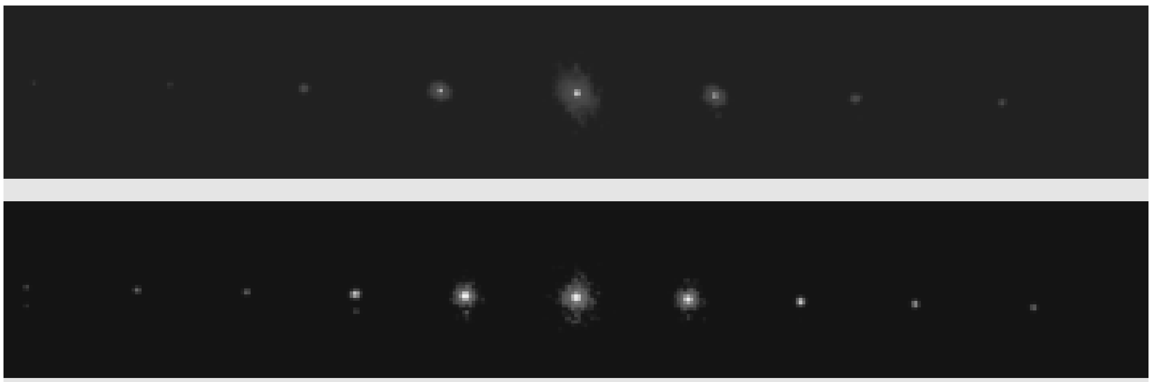
Problem 3. A small metal ball hangs from a pivot, with the string length L. The period of oscillation about this pivot is $T = 1.0$
Now, a nail at a distance $\frac{3}{4}L$ from the pivot is hammered down. When swinging to the right the pendulum hits the nail, it's path of motion is hindered by it.



The ball will now take a motion like the 2nd figure. **Which of the following figures shows the position of the ball after $t = 1.5$ seconds of letting go?**

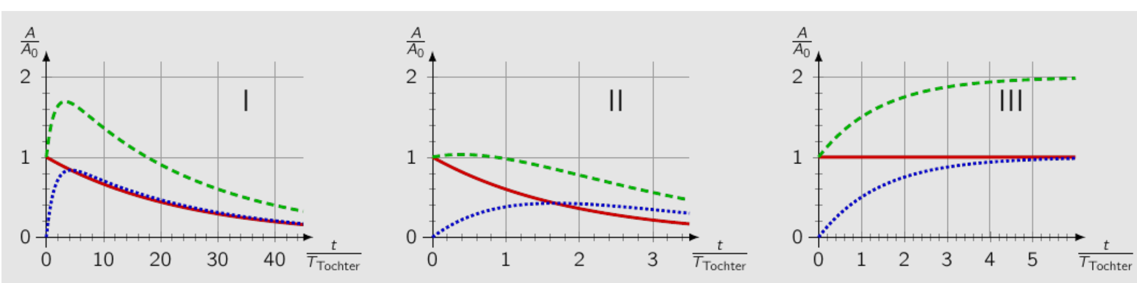


Problem 4. In one experiment, monochromatic laser light falls perpendicularly onto an optical grating with 300 lines each mm. The interference pattern is observed on a screen behind the grating. The distance of the screen to the grating is very large compared to the extent of the interference pattern.



The adjacent Grayscale images demonstrate when using two lasers with different wavelengths but otherwise the same Experimental set-up, arising from the screen Interference pattern.
The wavelength of from the first laser emitted Light is 650 nm.
How big is the wavelength of the laser light emitted by the second laser?

Problem 5. Three radioactive preparations are considered below. Initially, at time t = 0, they consist of 100% of a single radioactive isotope, the respective parent nuclide. The initial activity of the preparations is designated A_0 in each case. The direct products of decay, the daughter nuclides, are also radioactive again and decay. Further subsequent decays are no longer considered. The mother and daughter nuclides of the three preparations are:



$$\text{Preparation 1: } {}^{226}Ra\ (T_{mother} = 1600\ a) \rightarrow {}^{222}Rn\ (T_{daughter} = 3.8d)$$

$$\text{Preparation 2: } {}^{211}Pb\ (T_{mother} = 36.1\ min) \rightarrow {}^{211}Bi\ (T_{daughter} = 2.14\ min)$$

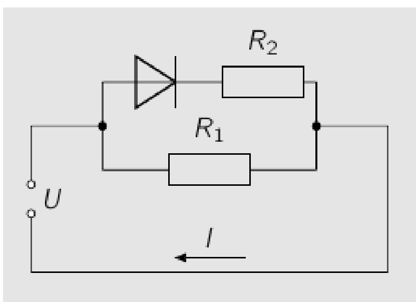
$$\text{Preparation 3: } {}^{214}Pb\ (T_{mother} = 26.8\ min) \rightarrow {}^{214}Bi\ (T_{daughter} = 19.9\ min)$$

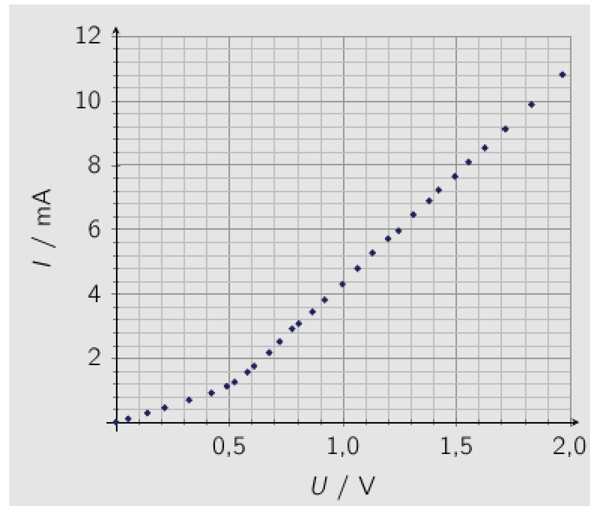
With T_{mother} or T_{daughter} the half-lives of the respective nuclides are indicated. The following graphs show the time courses of the activities A of both the mother nuclide and of the daughter nuclide and the total activity for the three preparations.

Which of the three nuclide pairs belongs to which diagram?

	①	②	③
A	I	II	III
B	II	III	I
C	III	II	I
D	III	I	II

Problem 6. A diode is an electronic component which, in simplified form, has a completely isolating effect in one direction, the reverse direction. In the opposite direction, the diode hardly allows any current to pass up to a certain voltage. But after this voltage limit is crossed, however, it behaves approximately like an ideal conductor.





In the circuit shown below are a diode and two resistors installed with resistance values R_1 and R_2. In the adjacent graph are measured values of the current I in the circuit as a function of the applied voltage U shown.

Which resistance values best match the displayed measured values?

(A) $R_1 = 220\ \Omega$ and $R_2 = 670\ \Omega$

(B) $R_1 = 470\ \Omega$ and $R_2 = 220\ \Omega$

(C) $R_1 = 470\ \Omega$ and $R_2 = 150\ \Omega$

Problem 7. The ends of three round metal rods made of identical material are each held on constant temperature. The following data are known for the members:

(A) Rod I - diameter: 2.0 cm, length: 20 cm, temperatures of the rod ends: 50°C and 20°C

(B) Rod II - diameter: 3.0 cm, length: 50 cm, temperatures of the rod ends: 60°C and 30°C

(C) Rod III - diameter: 4.0 cm, length: 80 cm, temperatures of the rod ends: 70°C and 40°C

How do the thermal powers transferred through the rods due to thermal conduction behave P_I, P_{II} and P_{III} to each other (the services can all be accepted as positive)?

Problem 8. In the manufacturing of optical lenses, they are often provided with a very thin layer of transparent material in order of reduce the reflections made at certain wavelength ranges.
Consider a lens made from a material of refractive index 1.40. This should be given a thinnest possible layer of transparent material with index 1.24, to minimize reflections at normal incidence of light with a wavelength of 500 nm.

(A) **Determine how thick this layer should be in order to determine the intensity of the reflected light minimize.**

When light is perpendicular to a transition from a medium with a refractive index n_A to one with a refractive index n_B, a portion of the incident light intensity is reflected. Since the reflected components are very small under the present conditions, it is sufficient to only consider simple reflections.

The portion of light reflected,

$$R_{A \to B} = \left(\frac{n_B - n_A}{n_B + n_A}\right)^2$$

(B) **Compare the intensity of the on the coated lens at the specified wavelength total reflected light with the intensity of the light that passes through an uncoated Lens is reflected.** To do this, calculate the ratio of these intensities.

Despite the coating described, the intensity of the reflected light is low, however not zero.

(C) **State and explain how the coating would need to be changed to make it clear to achieve a better anti-reflection effect at the wavelength in question.**

Problem 9. The photo shows the test vehicle called Blackbird. The vehicle does not have its own Energy storage devices such as batteries or fuels, it is driven solely by the wind. In the vehicle there is only a transmission for the drive, which can transfer energy between the wheels and the propeller.
With the Blackbird, test drives were done on level ground with constant wind direction and constant wind speed - both along and against the wind. The speed of the vehicle is say $\vec{v}$.
The vehicle was in parallel the whole time or anti-parallel to the wind velocity $\vec{v}_w$. You can assume that during the test drives a constant speed was reached.
The Blackbird's designers claimed that when traveling in the direction of the wind, the vehicle speed was faster than the wind, i.e. with a constant speed $\vec{v}$, for which $\|\vec{v}\| > \|\vec{v}_w\|$. Some people criticized this as being unphysical and therefore impossible.
But is that it?

(A) **Explain why it is possible with constant wind speed v_w a constant speed $v > v_w$ in the direction of the wind. Indicate if energy is transferred from the propeller to the wheels or vice versa.**

To estimate the achievable speed, assume that when transmitting Energy between the surrounding air and the ground and vice versa, a proportion α of the available performance for further use is lost. So if, for example, energy from the surrounding air is transferred to the ground via the propeller, the gearbox and the wheels of the energy transmitted to the vehicle by the wind, only a portion $1 - \alpha$ for the drive be used.

(B) **Determine the speed v that the vehicle can reach when driving in the direction of the wind can.** Express your result in terms of v_w and α.

(C) **Determine the achievable speed for driving directly against the wind. Show this in terms of this by v_w and α and justify whether it is also possible in this case, faster to be than the wind.**

Problem 10. Controlled nuclear fusion could make an important contribution to energy supply in the future and is therefore intensively researched in plasma physics.
In the following, you should see the investigation of the fusion of the two hydrogen isotopes, Deuterium (^2H) and Tritium, (^3H), because of the fusion, a Helium Core is created.
^4He and a neutron ^1n. The response can be represented as,

$$^2H + ^3H \rightarrow ^4He + ^1n + E$$

E denotes the energy released during the fusion in the form of kinetic energy. the Rest masses of the particles and nuclei are:
Deuterium nucleus: $m_0 = 3,344\ 494 \cdot 10^{-27}\ kg$
Tritium core: $m_T = 5.008\ 268 \cdot 10^{-27}\ kg$
Helium core: $m_{He} = 6.646\ 477 \cdot 10^{-27}\ kg$
Neutron: $m_n = 1,674\ 927 \cdot 10^{-27}\ kg$

(A) **Calculate the energy E released during a single nuclear fusion by the above reaction.** Determine the proportions of energy attributable to the helium nucleus and the neutron E_{He} and E_n for the case that the initial kinetic energy of the hydrogen isotopes is negligible. Give your results in the unit MeV with $1MeV \approx 1.602\ 177 \cdot 10^{-13}\ J$ at.

For the fusion reaction ot take place, the hydrogen nuclei have to come close enough together. This can be achieved by putting an electrically neutral gas of isotopes to a very high temperature.

The gas then becomes completely ionized and becomes plasma.

(B) **Estimate how high the temperature of the plasma must be at least so that the hydrogen nuclei can come together at a distance of less than $10^{-14}\ m$ and thus one Fusion reaction becomes possible.** Assume that all the nuclei of an isotope correspond to move with the same amount of speed.

In fact, the amount of speed of the nucleus is not the same for all. As a result of that, some nuclei have more kinetic energy than others, the nuclear fusion can also initiate with lower temperatures. In the following, consider a plasma that is divided equally into deuterium and tritium nuclei with a particle density of $n = 1.0 \cdot 10^{20} m^{-3}$.

The temperature of the plasma is $T = 1.0 \cdot 10^8\ K$. In order to keep the plasma at these high temperatures and thus to maintain the nuclear fusion over a longer period of time, the energy losses of the plasma must be compensated.

The electrically neutral neutrons released during the fusion leave the plasma very quickly and its kinetic energy is no longer available to the plasma. In addition, there is a loss of energy through radiation and transport. The total resulting power loss P_V can be expressed with the help of the internal thermal energy of the plasma U and the so-called Express energy containment time τ by

$$P_V = \frac{U}{\tau}$$

You can assume that the plasma behaves in a good approximation like an ideal gas and for use the value $\tau = 1.0\ s$ for the energy containment time. The helium nuclei generated during the fusion, on the other hand, remain in the plasma and their kinetic energy heats the plasma. The heating power P_H is a function of the nuclear reaction rate density r, i.e. the mean number of fusion reactions per unit of time and volume, the plasma volume V and the kinetic energy E He of the helium nuclei and amounts to

$$P_H = rE_{He}V$$

(C) **Determine the mean nuclear reaction rate density r for the plasma at constant temperature.** Note that the plasma, which is electrically neutral as a whole, is not only ions but also contains electrons.

For the technical use of nuclear fusion, it is important to maintain the temperature. It is also necessary to spatially enclose the plasma for as long as possible. To compensate for the Plasma pressure and thus to contain the plasma, a magnetic field is applied. Of the The pressure generated by this field can be estimated in a simplified manner using the magnetic express the table flux density B and μ_0 (occurring numerical factors can be set to 1 will).

(D) **Estimate how large the magnetic flux density B has to be in order to produce the described plasma.**