EXPERIMENTAL PHYSIC

EXERCISE 1

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Problem 1: Error calculation $\mathbf{3+1+1+1}$ **Points**

Part 1:

In the table below a (made up) set of data representing the temperatures at which some experiment was conducted is presented:

T_1	T_2	T_3	T_4	T_5
130K	130.24K	129.123K	127.1K	131.7K

T_6	T_7	T_8	T_9	T_{10}
130.11K	130.90K	129.4K	130.21K	128.978K

Calculate the mean, variance and standard deviation of this set.

Part 2:

Calculate the following values using the temperature mean and deviation, i.e., calculate the values and error propagation for:

a. $E = \frac{3}{2} k_B T$, Average kinetic energy of a monoatomic ideal gas where k_B is the Boltzmann constant

b. $c_V = 234R\left(\frac{T}{433K}\right)^3$, Specific heat capacity of aluminum where R is universal gas constant

c. $W = e^{-\frac{m \cdot g \cdot h}{k_B T}}$, Distribution of a gas molecule, use for $m = 22.4 \cdot 10^{-27}\mathrm{kg}$ and $h = 1\mathrm{m}$

Hint, error propagation: if some value x with error u is used to calculate a value $y(x \pm u)$, then the propagated error u_{prop} is calculated according to

$$u_{\mathrm{prop}} = \sqrt{\left(\frac{\partial y(x)}{\partial x} \cdot u\right)^2}$$

Problem 2: Vectors $\mathbf{2+2+2}$ Points

Calculate the following vectors:

a. $c = \begin{pmatrix} 2x \\ 1 \\ -2 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ x \\ 0 \end{pmatrix}$ and $\vec{c} = \begin{pmatrix} 2x \\ 1 \\ -2 \end{pmatrix} \times \begin{pmatrix} 1 \\ x \\ 0 \end{pmatrix}$

Derive for the vectors $\vec{a}$ and $\vec{b}$ the vector product $\vec{a} \times \vec{b}$.

b. $\vec{a} = \begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix} = a_x \hat{e}_x + a_y \hat{e}_y + a_z \hat{e}_z$ and $\vec{b} = \begin{pmatrix} b_x \\ b_y \\ b_z \end{pmatrix} = b_x \hat{e}_x + b_y \hat{e}_y + b_z \hat{e}_z$

Calculate the angle between the two vectors $\vec{a}$ and $\vec{b}$ first using the scalar product and then the vector product:

c. $\vec{a} = \begin{pmatrix} 2 \\ 3 \\ -7 \end{pmatrix}$ $\vec{b} = \begin{pmatrix} 2 \\ -5 \\ 1 \end{pmatrix}$

Problem 3: Unit Conversion $\mathbf{12 \cdot 0.5}$ Points

Perform the following unit conversions:
Example: 1m in [mm] → 1000 mm

a. 0°C in [K]
b. $3 \cdot 10^8$ m/s in [km/h]
c. 9.81 m/s^2 in [N/kg]
d. 9.8067 Pa in [bar]
e. 17 cm^2 in [m^2]
f. 28.3 l in [mm^3]
g. 2200 kcal in [kJ]
h. $9.21 \cdot 10^6$ J in [kWh]
i. 2928 Ω in [cm^2 g h^{-3} A^{-2}]
j. 1.5 C in [mA h]
k. 0,511 MeV/Particle in [J/mol]

Task to think about

Assume that a singular particle is trapped at point $x = 0$ in a tube i.e. its possibility to move is confined to one dimension. There are no explicit forces acting on this confined particle however, by *thermal fluctuation* the particle is able to move either to the right or to the left in a random fashion.

The graphs below show the probability to find this particle at the point $x = 0$ after some time t ($t_1 < t_2 < t_3$).

a) Observing the graphs, what qualitative statement can you make about the probability to find the particle at its exact starting point $x = 0$ after some time t? Will the particle ever find back to its starting point?
b) Assuming that the particle is no longer confined to one dimensional movement but to two dimensional and eventually three dimensional movement. How would the probability distribution describing the particle position change?