Space, rocket and aerospace technologies in science and programming.

Author, MSc: Adrian Szklarski: 10.2023

Subject: How to solve Physics assignments..

Temat: Jak rozwiązywać zadania z Fizyki..

Introduction: Algorithm for solving tasks in General Physics based on a simple example of a bullet for a black powder weapon. Solution using Python, C and Matlab.

Fig. 1: A black powder weapon, kal. 375 (.36) [1]

Wstęp: Algorytm rozwiązywania zadań z Fizyki ogólnej w oparciu o prosty przykład kuli do broni czarno prochowej. Rozwiązanie przy zastosowaniu Python, C i Matlab.

Programming language:
Python

Contact me:

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Analysis of the physical content of the task:

1. Careful reading of the task content
2. Mental reconstruction of the course associated with the physical phenomenon under study
3. Determination of the course of the solution
4. If possible, drawing out the task in order to better understand it and guide the correct course of reasoning

Analiza treści fizycznej zadania:

1. Wnikliwe przeczytanie treści zadania
2. Myślowe odtworzenie przebiegu związanego z badanym zjawiskiem fizycznym
3. Ustalenie przebiegu rozwiązania
4. Jeżeli to możliwe, rozrysowanie zadania w celu lepszego jego zrozumienia i naprowadzania na właściwy tok rozumowania

Preparation of the solution:

1. Statement of the given quantities and their expressions in the system of units. Prerequisite Necessary to be able to substitute values into formulas. For the SI system, it is necessary to express these data in the main units of this system, not in multiples or sub-multiples. It is useful to indicate these values in the figure.
2. Statement of the quantities sought in the order in which they will be determined in the course of solving the task
3. Statement of formulas in basic form. Write down the basic formulas that are the mathematical form of the laws governing the phenomena and choose from them those that relate the quantities sought to the given quantities

Przygotowanie rozwiązania:

1. Zestawienie danych wielkości i ich wyrażenia w układzie jednostek. Warunek Konieczny aby móc podstawiać wartości do wzorów. Dla układu SI należy te dane wyrazić w jednostkach głównych tego układu, a nie w wielokrotnych czy pod wielokrotnych. Warto te wartości zaznaczyć na rysunku
2. Zestawienie wielkości szukanych w takiej kolejności jak będą wyznaczane w trakcie rozwiązywania zadania
3. Zestawienie wzorów w postaci zasadniczej. Zapis podstawowych wzorów stanowiących matematyczną postać praw rządzących tymi zjawiskami i wybranie z nich tych które wiążą wielkości szukane z wielkościami danymi

Solving tasks:

1. Transformation of physical formulas that allow you to read the final result by direct substitution of data

We start with the formula containing the quantity sought and successively eliminate those quantities that are not given in the body of the task and will not be determined either.
As a result of the transformation, we get one or more equations where the left side is the values sought, and the right side is the data or previously determined.

Rozwiązywanie zadań:

1. Przekształcenie wzorów fizycznych umożliwiające odczytanie wyniku końcowego przez bezpośrednie podstawianie danych

Zaczynamy od wzoru zawierającego wielkość szukaną i kolejno eliminujemy te wielkości, które nie są podane w treści zadania i nie będą również wyznaczane.
W wyniku przekształcenia otrzymujemy jedno lub kilka równań gdzie lewa strona to wartości szukane, a prawa dane albo wcześniej wyznaczone.

2. Substitute numerical values in agreed and expressed in the same system of units

3. Perform numerical operations according to the rules of arithmetic
4. Compile the results in the appropriate units, give the symbols of physical quantities with the numerical value with the specified accuracy and the dimension of the unit

2. Podstawiamy wartości liczbowe w uzgodnionych i wyrażonych w tym samym układzie jednostek
3. Wykonanie działań liczbowych według zasad arytmetyki
4. Zestawienie wyników w odpowiednich jednostkach, podajemy symbole wielkości fizycznych z wartością liczbową z określoną dokładnością oraz wymiar jednostki

Checking the results of the activity:

1. checking the correctness of reasoning in the accepted description of phenomena and laws
2. correctness of algebraic transformations, numerical operations, operations on units

Sprawdzanie wyników działania:

1. Kontrola prawidłowości rozumowania w przyjętym opisie zjawisk i praw
2. Poprawność przekształceń algebraicznych, działań liczbowych, działań na jednostkach

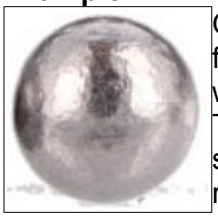
The purpose of this item, to answer the question "Does the value of the result make sense and does the dimension of its unit correspond to the determined physical quantity".

Cel tego punktu, odpowiedź na pytanie: „Czy wartość wyniku jest sensowna i czy wymiar jego jednostki odpowiada wyznaczonej wielkości fizycznej”

The results can be generalized: that is, to answer the question: to what quantities and factors and how does the search quantity depend?

Wyniki można uogólnić: tzn. odpowiedzieć na pytanie: do jakich wielkości i czynników i w jaki sposób zależy wielkość szukana?

Example:



Over-caliber 80 grain (**5.2 grams**) bullet from ACP-Sport in 375 caliber (9.52 mm) for black-rifle weapons. They are made of the highest quality lead, produced without lead-bearing secondary materials.
The bullets have been subjected to a dressing process, so they do not have lint, seams. Designed for use with black-rifle revolvers - Remington, Colt, pistols and rifles in .36 caliber

To determine the diameter of a lead sphere, it was weighed on a balance, obtaining the result **5.2 grmas**. Calculate the diameter of the sphere and the relative errors of the direct measurement of its weight and the measurement of the composite diameter.

1. **Analysis of the physical content of the task:**

The purpose of the task: to determine the diameter of a lead sphere - a body with a well-defined geometric shape.

Using a scale, the weight was measured $m[g]$
The formula directly relating mass and diameter of a sphere is not known, however, the relationship determining density through mass and volume and the formula for the volume of a sphere is known.

The relative error of a mass measurement can be determined because we know the magnitude of the measured mass and the absolute error as the sensitivity of the measuring instrument.

To determine the relative error of the diameter measurement should be calculated diameter, the row of the last significant digit in the final result will be a measure of the absolute measurement of the composite diameter.

2. **Preparation of the solution:**

Data units, SI system:

Absolute error as the sensitivity of the measuring instrument	$e_a = 0.01[g] = 0.01 \cdot 10^{-3}[kg]$
Mass	$m = 5.2\,g = 5.2 \cdot 10^{-3}[kg]$
Density of lead	$\rho = 11300[\frac{kg}{m^3}]$

Search values:

Diameter	Φ
Relative mass error	e_m
Relative error of diameter measurement	e_Φ

Overview of the basic formulas:

$$\rho = \frac{m}{V} \quad , \quad V = \frac{4 \cdot \pi}{3} \cdot r^3 \quad , \quad r = \frac{\Phi}{2} \quad , \quad error = \frac{e}{l}$$

3. **Solving tasks**:

$$V = \frac{4 \cdot \pi}{3} \cdot r^3 \rightarrow \frac{4 \cdot \pi}{3} \cdot \left(\frac{\Phi}{2}\right)^3$$

$$\rho = \frac{m}{V} \rightarrow \frac{m}{\frac{4 \cdot \pi}{3} \cdot \left(\frac{\Phi}{2}\right)^3} \rightarrow \frac{6 \cdot m}{\pi \cdot \Phi^3} \rightarrow$$

$\Phi = \sqrt[3]{\frac{6 \cdot m}{\pi \rho}}$, $e_m = \frac{e_a}{m}$, $e_\Phi = \frac{e_{a2}}{\Phi}$, where $e_{a2} = 0.1$ - The adopted order of calculation accuracy

$$e_m = \frac{e_a}{m} \cdot 100[\%] \quad , \quad e_\Phi = \frac{e_{a2}}{\Phi} \cdot 100[\%]$$

4. **Checking the results of the activity**:
Based on the results, it can be concluded that:
- measuring the diameter of a sphere is possible by weighing it, if we know the density of the material from which it is made
- the accuracy depends on the accuracy of the mass measurement, but also on the accuracy with which the density of the material is given (in the example to two significant digits, so the accuracy of the diameter measurement is smaller, that is, a larger relative error than the accuracy of the mass measurement
- the accuracy of a composite measurement is determined by the component measurement made with the lowest accuracy

Python Version

```python
'''
To determine the diameter of a lead sphere, it was weighed on a balance,
obtaining the result 5.2 grmas. Calculate the diameter of the sphere and the
relative errors of the direct measurement of its weight and the measurement
of the composite diameter.

Created by @AdrianSzklarski, 10.2023
'''

import numpy as np


class Bullet:
    def __init__(self):
        # Absolute error as the sensitivity of the measuring instrument[kg]
        self.e_a = 0.01 * 1e-3
        self.e_a2 = 0.1

        # Mass[kg]
        self.m = 5.2 * 1e-3

        # Density of lead[kg / m ^ 3]
        self.ro = 11300

        self.get_calculation()

    def get_calculation(self):
        x = (6 * self.m) / (np.pi * self.ro)
        Fi = round(np.cbrt(x) * 1000, 2)
        re = round(self.e_a / self.m, 7)
        re_p = round(re * 100, 2)
        ed = round(self.e_a2 / Fi, 6)
        ed_p = round(ed * 100, 2)
        return Fi, re, re_p, ed, ed_p

    def __str__(self):
        return f'Diameter Fi              [mm]: {self.get_calculation()[0]}\n' \
               f'Relative error                : {self.get_calculation()[1]}\n' \
               f'Relative error             [%]: {self.get_calculation()[2]}\n' \
               f'Error diameter measurement    : {self.get_calculation()[3]}\n' \
               f'Error diameter measurement [%]: {self.get_calculation()[4]}'


if __name__ == '__main__':
    bullet = Bullet()
    print(bullet)
```

C Version

```c
/*
To determine the diameter of a lead sphere, it was weighed on a balance,
obtaining the result 5.2 grmas. Calculate the diameter of the sphere and the
relative errors of the direct measurement of its weight and the measurement
of the composite diameter.

Created by @AdrianSzklarski, 10.2023
*/

#include <stdio.h>
#include <math.h>
#define M_PI 3.14159265358979323846

float calculate(float m, int ro, float e_a, float e_a2)
{
    float x, power, Fi, e_m, e_mp, e_fi, e_fip;

    x = (6*m)/(M_PI*ro);
    power = (float) 1/3;
    Fi = pow(x, power)*1000;

    // Determination of the relative error of mass measurement and diameter measurement

    e_m = e_a / m;
    e_mp = e_m * 100;
    e_fi = e_a2 / Fi;
    e_fip = e_fi * 100;

    printf("Diameter Fi [mm]              : %.2lf\n", Fi);
    printf("Relative error                : %.7lf\n", e_m);
    printf("Relative error [P]            : %.2lf\n", e_mp);
    printf("Error diameter measurement    : %.6lf\n", e_fi);
    printf("Error diameter measurement [P]: %.2lf\n", e_fip);
}

int main()
{
    float e_a, e_a2, fi, m, power;
    int ro;
    // Absolute error as the sensitivity of the measuring instrument [kg]
    e_a = 0.01 * 1e-3;
    e_a2 = 0.1;

    // Mass [kg]
    m = 5.2*1e-3;

    // Density of lead [kg/m^3]
    ro =11300;

    calculate(m, ro, e_a, e_a2);

    return 0;
}
```

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Matlab Version

```
% To determine the diameter of a lead sphere, it was weighed on a balance,
% obtaining the result 5.2 grmas. Calculate the diameter of the sphere and the
% relative errors of the direct measurement of its weight and the measurement
% of the composite diameter.

% Created by @AdrianSzklarski, 10.2023

% clc;
% clear all;
% close all;

% Absolute error as the sensitivity of the measuring instrument [kg]
e_a = 0.01 * 1e-3;
e_a2 = 0.1;

% Mass [kg]
m = 5.2 * 1e-3;

% Density of lead [kg/m^3]
ro =11300;

% Calculation

x = (6*m)/(pi*ro);
Fi = round(nthroot(x,3)*1000*100)/100;

% Results:
res_Fi = ['Diameter Fi [mm]              : ', num2str(Fi)];

% Determination of the relative error of mass measurement and
%diameter measurement

e_m = ['Relative error                : ', num2str(e_a / m)];
e_m100 = round((e_a / m)*100*100)/100;
e_mp = ['Relative error [%]           : ', num2str(e_m100)];


e_fi = ['Error diameter measurement    : ', num2str(e_a2 / (Fi))];
e_fi100 = round((e_a2/(Fi))*100*100)/100;
e_fip = ['Error diameter measurement [%]: ', num2str(e_fi100)];

% Results
disp(res_Fi)
disp(e_m)
disp(e_mp)
disp(e_fi)
disp(e_fip)
```

Results:

Python 3

```
Diameter Fi                [mm]: 9.58
Relative error                 : 0.0019231
Relative error              [%]: 0.19
Error diameter measurement     : 0.010438
Error diameter measurement [%]: 1.04
```

C

```
Diameter Fi [mm]               : 9.58
Relative error                 : 0.0019231
Relative error [P]             : 0.19
Error diameter measurement     : 0.010440
Error diameter measurement [P]: 1.04
```

Matlab

```
Diameter Fi [mm]               : 9.58
Relative error                 : 0.0019231
Relative error [%]             : 0.19
Error diameter measurement     : 0.010438
Error diameter measurement [%]: 1.04
```

Original caliber (9.52 mm), caliber obtained from results (9.58 mm)

[1] https://military-zone.sklep.pl/p4931,rewolwer-czarnoprochowy-uberti-navy-1861-kal-36.html