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ENGINEERING APPLICATIONS IN THE TEACHING OF MATHEMATICS II ⊗

MÉRNÖKI ALKALMAZÁSOK A MATEMATIKA II. TANTÁRGY OKTATÁSÁBAN

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Abstract: *It has been four years now, that our course book, the title of which is "Mathematical tools in engineering applications, Volume I" was published. Since then it has been an essential study aid for the subject Mathematics I. The book follows a new "engineer friendly" approach as it uses problems typically occurring in the fields of engineering and economics for the demonstration of the use of mathematical concepts and tools. Our teaching experiences and also the results of students' opinion polls proved that we are on the right track, thus we decided to write the second volume of the book for Mathematics II. By know the majority of the applications in Volume II are ready and we present the more important ones here.*

Keywords: *teaching mathematics, engineering applications*

Kivonat: *Idén négy éve annak, hogy a „Matematikai eszközök mérnöki alkalmazásokban" című jegyzetünk első kötete megjelent. Ez a mű, amely a mérnöki és közgazdasági tudományokban tipikusan előforduló problémákon keresztül mutatja be a különböző matematikai eszközök, módszerek alkalmazását, azóta a „Matematika I" tárgy oktatásának nélkülözhetetlen kelléke lett. Az oktatási tapasztalataink, valamint a hallgatók körében elvégzett közvélemény kutatások egyaránt azt igazolják, hogy helyes úton járunk, így belefogtunk a „Matematika II" tárgyhoz tartozó második kötet megírásába. Mostanra az alkalmazások jelentős része elkészült, néhányat a fontosabbak közül példaképpen itt ismertetünk.*

Kulcsszavak: *matematikaoktatás, műszaki példák*

1. INTRODUCTION

At the technical colleges and universities of Hungary the methodology of teaching mathematics still follows the traditional way in the elaboration of the different topics and also in the conveyance of knowledge. But at the applied level of abstraction less and less students can receive the necessary knowledge. In 2009 the authors took the first step to give an answer to the problem, and published the course book "Mathematical tools in engineering applications, Volume I" [1]. In this book – which is a study aid for the compulsory subject Mathematics I – the exercises are related to real technical problems. This way the students can realize that learning mathematics is useful, because they can see the extended application of mathematics in several engineering fields. (For example in chapters dealing with geometry, the objects are parts of buildings, engineering structures or machines.)

Our approach emphasizes why it is so important to learn mathematical methods and concepts, and where and how they can be applied. With this new teaching method, and applying our course book, the connection between mathematics and the special engineering subjects, will be clearer for the students.

The new method has already been applied in four semesters; the experiences are promising [2,3] proving that we are on the right track. Thus we decided to write the second volume of the book for Mathematics II. By know the majority of the applications in Volume II are ready, we present the more

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important ones here. Most of the applications are real technical and scientific problems from different fields of engineering and physics (e.g. Technical Mechanics, Thermodynamics, Electrotechnics and Optics). The others are simple mathematical exercises related to technical problems and created by the authors.

2. ENGINEERING APPLICATIONS

The structure of the course book "Mathematical Tools in Engineering Applications, Volume II" is the same as the one of Volume I. Thus it is divided into chapters and groups of exercises in them. Each group of exercises starts with a theoretical summary, which provides a brief, but concise and professionally adequate description of the given engineering field. This is followed by a sample exercise with its solution and a series of similar exercises.

In the following we present four exercises as examples from four different groups of exercises. All the chapters and the exercise groups in them are under construction. The titles of these chapters and groups are: Differential and extreme value calculus (Exercise group: "Kinematics of a particle."), Differential and extreme value calculus (Exercise group: "Maxwell speed distribution of ideal gases"), Integral calculus (Exercise group: "Maxwell speed distribution of ideal gases"), Integral calculus (Exercise group: "The resultant of a distributed force system").

Example 1

An electric drive car starts from rest. Its position-time function is $s(t) = A \cdot \left[\ln\left(1+e^{B(t+C)}\right) + \ln\left(1+e^{-B(t+C)}\right) - D \cdot t\right] + E$. The position and time are measured in meter and second respectively.

Data: $A = 250\left[\frac{m}{s}\right]$, $B = 0{,}145\left[\frac{1}{s}\right]$, $C = 6{,}494[s]$, $D = 0{,}064\left[\frac{1}{s}\right]$, $E = -400[m]$.

a, Calculate the velocity- and acceleration-time function of the car.

b, Calculate the value of position, velocity and acceleration at $10[s]$ after the starting.

c, Calculate the top speed of the car. (The top speed is calculated as: $v_{\max} = \lim_{t \to \infty} v(t)$)

d, Calculate the value of acceleration if $t \to \infty$.

Example 2

A research group of ATOMKI in Debrecen studies semiconductor materials. The materials are analysed under high vacuum condition in a special vacuum chamber. During the analysis there are only $N = 10^{12}$ nitrogen molecules in the chamber. Other parameters of the residual nitrogen gas are listed below:

$$m_0 = 4{,}652 \cdot 10^{-26}\, kg\,,\ T = 273{,}15K\,,\ k = 1{,}38 \cdot 10^{-23}\,\frac{J}{K}$$ (m_0 is the mass of a molecule).

a, Derive the $n(v)$ speed distribution function of the gas and calculate the first and second derivative functions of it.

($n(v) = Av^2 e^{-Bv^2}$, where: $A = N\sqrt{\frac{2}{\pi}\left(\frac{m_0}{kT}\right)^3}$, $B = \frac{m_0}{2kT}$).

b, Calculate the v^* speed at which the molecules move with the highest probability at a given moment. ($n(v^*)$ is the absolute maximum of the $n(v)$ function .)

c, Perform the analysis of the $n(v)$ function then plot it.

Example 3

Answer the questions below regarding Example 2.

a, Calculate the number of molecules the speed of which is in the $[100{,}200]\left[\frac{m}{s}\right]$ range (see Figure 1.)

b, Calculate the number of molecules the speed of which exceeds $700\left[\frac{m}{s}\right]$.

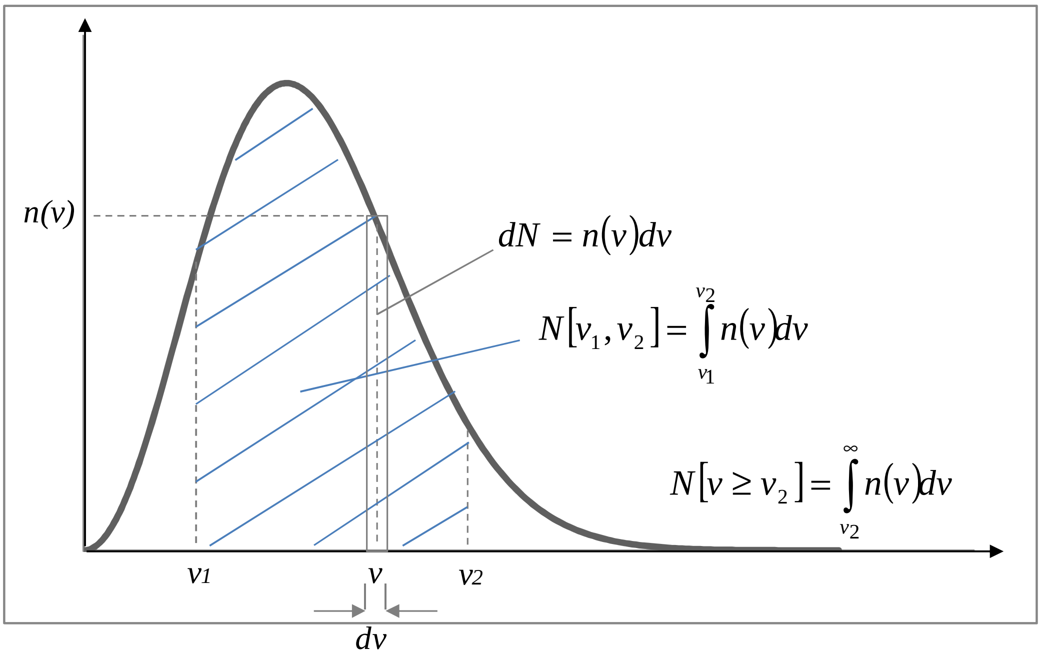

Figure 1: Maxwell speed distribution of ideal gases

Example 4

Figure 2 shows a scale which is balanced. In the scale pan there is a prism made of steel.

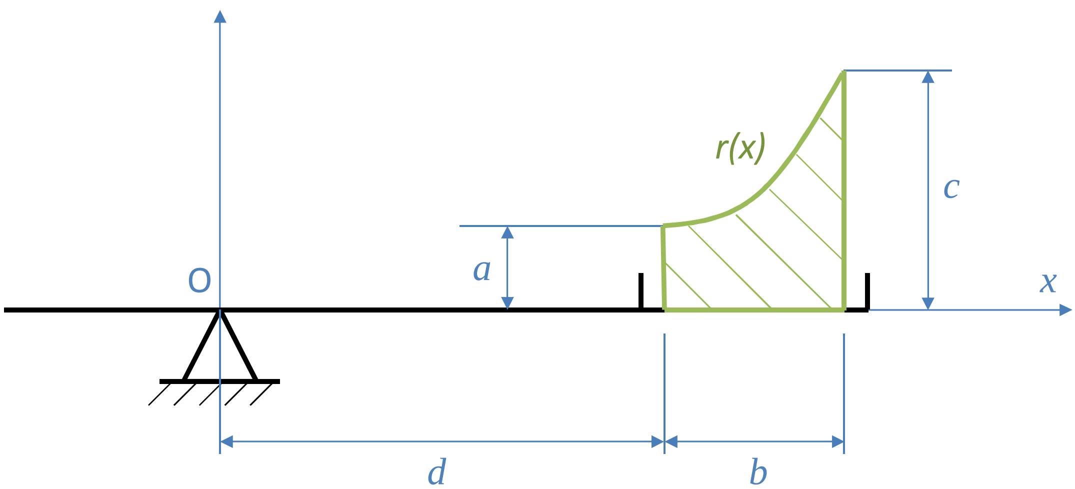

Figure 2

The longitudinal axis of the prism is normal to the plane of the figure, thus only the base of the prism can be seen. Apart from the geometric data which are marked in the figure the l length and ρ mass density of the prism are known. The cross section of the prism is characterised by the $r(x)$ function. The relationship between the $r(x)$ function and $f(x)$ intensity of the force (force density distribution) which the prism exerts on the pan is given below:

$$f(x) = l \cdot \rho \cdot g \cdot r(x)$$

Data: $a = 0{,}05[m]$, $b = 0{,}1[m]$, $c = 0{,}15[m]$, $l = 0{,}1[m]$, $d = 0{,}25[m]$, $\rho = 7800\left[\frac{kg}{m^3}\right]$, $g = 9{,}81\left[\frac{m}{s^2}\right]$.

a, Derive the $r(x)$ function if its graph is a parabola. The point with coordinates (d, a) is the peak of the parabola.

b, Calculate the magnitude of the force which the prism exerts on the pan. $\left(F = \int_d^{d+b} f(x)dx\right)$

c, Calculate the magnitude of the moment of force $\overline{F}$ relative to point O. $\left(M_O = \int_d^{d+b} f(x)xdx\right)$

d, Calculate the distance between the point of action of force $\overline{F}$ and point O. $\left(x_F = \frac{M_O}{F}\right)$

3. SUMMARY

The main motive of the authors for writing the course book "Mathematical Tools in Engineering Applications, Volume I and II" was to apply a new "engineer friendly" educational approach so to make the teaching of mathematics more effective. This kind of approach focuses on why the concepts and methods of mathematics should be learnt and where and how they can be applied. We hope that our course book makes the relationship between Mathematics and the different special engineering subjects clearer for the students.

4. REFERENCES

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