INTERDISCIPLINARY IN TEACHING PHYSICS AND TECHNICAL SCIENCES USING DIFFERENTIAL EQUATIONS AS A CONNECTION

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Abstract
The article demonstrates the significant role of differential equations in teaching physics, electrical engineering, and electronics, while also providing scientific insights into the laws of switching when connecting and disconnecting an electrical circuit from a source. According to the authors, interdisciplinary connections play an important role in solving problems in the teaching of physics and technical sciences.

Keywords: Commutation, electrical circuit, differential equation, fundamental laws of dynamics, Kirchhoff's law, interdisciplinary connection, charge quantity.

Introduction

Information technologies, designed for teaching, are an integral part of the technical means of training. Today, it is impossible to live without information technology. These include computers, video projectors, interactive whiteboards, and codoscopes. In the process of teaching, it is necessary to always remember that what is seen is assimilated several times faster than what is heard, and is remembered for a long time. The use of ICT by teachers in their lessons plays an important role in improving the quality of education. Today, every teacher should conduct classes using ICT in their subject using presentations, visual aids, multimedia tools, and electronic textbooks.

RESEARCH MATERIALS AND METHODOLOGY

The development of physics, electrical engineering, electronics, and radio engineering is the main basis for the development of information and communication technologies. The role of physical and technical sciences in the high-quality and unchanged transmission of information over long distances is invaluable. Einstein, known as the genius of the ages, wrote, "Mathematical differential equations entered physics as a slave and, over time, became its mistress." Indeed, there is no field of mathematics where differential equations have not

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penetrated. Electrical and magnetic phenomena, which a person sees, hears, smells (doesn't feel, doesn't know), are also brought to the boundaries of human cognition and thinking using differential equations. As proof of this, let's start by analyzing the current flow process in several electrical circuits.

Let us derive the formula for the time dependence of the transient phenomenon in the electrical circuit of current *i* (t), if R and C consist of a series-connected active resistance and a capacitor capacitor (diagram 1). If switch K is closed, a closed loop is formed, and current begins to flow throughout the entire circuit. The voltages of R and C connected in series are directly proportional to the electromotive force ε, and according to Kirchhoff's second law:

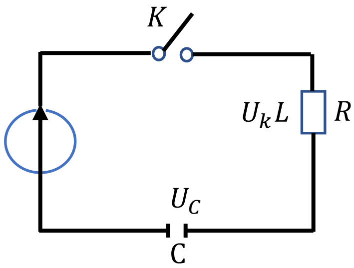

Diagram 1.
Electrical circuit

$$U_R + U_C = \varepsilon \qquad (1)$$

the sum of the voltages in the circuit is equal to the sum of the electromotive forces (EMF) in this electrical circuit. In turn, using the fact that the elements of the electrical circuit are differentiable or integrable, we obtain the differential equation of the given electrical circuit (diagram 1).

$$U_R = R_i = R \cdot C \cdot \frac{dU_C}{dt} = \tau \frac{dU_C}{dt} \qquad (2)$$

In this formula, i is the current, which is a function of time (A), R is the electrical resistance (Ω), C is the electrical capacitance (Φ), U_R, U_C are the voltages at the ends of the resistance and capacitor (V), τ is the relaxation time constant (seconds).

It is often required to prove that τ = R · C in formula (2) is time, $q = C \cdot U$ q is the amount of charge (C), $\tau = R \cdot \frac{q}{U} = \frac{q}{\frac{U}{n}} = \frac{Jt}{j} = [t]$ therefore, since $R \cdot C$ is a constant value expressing time, then

$$\tau \frac{dU_C}{dt} + U_C = \varepsilon \qquad (3)$$

is formed. A first-order differential equation is obtained. In this case, ε, τ are constant values and are solved using the methods of differential equations with alternating variables (U_C, t).

$$\frac{dU_C}{dt} = \frac{\varepsilon - U_C}{\tau}, \quad \frac{dU_C}{\varepsilon - U_C} = \frac{dt}{t} \qquad (4)$$

Integrating both sides of differential equation (4), U_C and $i(t)$ we'll find: $-\int \frac{d(\varepsilon - U_C)}{\varepsilon - U_C} = \frac{1}{\tau}\int dt$ we use the table integral. $-\ln[\varepsilon - U_C] = \frac{t}{\tau} - \ln C$ where C is the integral constant, $\ln[\varepsilon - U_C] = -\frac{t}{\tau} + \ln C = \ln e^{\frac{-t}{\tau}} + \ln C = \ln Ce^{\frac{-t}{\tau}}$ we use the properties of the logarithm,

$$\varepsilon - U_C = Ce^{\frac{-t}{\tau}} \qquad (5)$$

Substituting the boundary conditions into the last formula, it is clear that U_C=ε at t=0.

$$U_C = \varepsilon - Ce^{\frac{-t}{\tau}} = \varepsilon(1 - e^{\frac{-t}{\tau}}) \qquad (6)$$

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if the capacitor voltage changes according to formula (6), by substituting its value into formula (1), after some simplification, we obtain the value of i (t). $U_R + \varepsilon - \varepsilon e^{\frac{-t}{\tau}} = \varepsilon; \quad U_R = \varepsilon e^{\frac{-t}{\tau}}$
Using Ohm's Law

$$i(t) = \frac{U_R}{R} = \frac{\varepsilon}{R} e^{\frac{-t}{\tau}} \qquad (7)$$

the resulting formula is obtained.

Formula (7) represents the dependence characterizing the process of time transition of the electric current we are looking for in a closed circuit R and C connected in series
(Fig. 1).

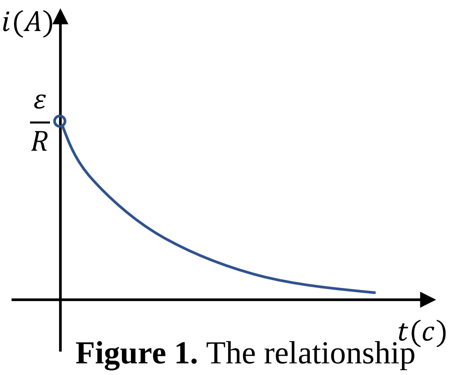

Figure 1. The relationship between electric current and time.

If, in Scheme 1, instead of a capacitor in an electrical circuit, a coil is connected, an electromagnetic field is created in the coil, creating an electric starter for starting cars and military and combat equipment. Field voltages of this electrical device

$$iR + L\frac{di}{dt} = \varepsilon \qquad (8)$$

is characterized by the equation $\tau = \frac{L}{R}$ In this formula, L is the inductance of the coil (H), and τ is the commutation time constant (s). By dividing the differential equation (8) by L and equating the right side to zero, we find the solution to the homogeneous differential equation. This state corresponds to the commutation state when the electrical circuit is disconnected from the source $t(t) = Ce^{\frac{-t}{\tau}}$ we obtain the formula.

Consisting of conclusions expressing the resulting formula, giving an electrotechnical meaning, which are interpreted as follows:

when R and C are connected in series to the electrical circuit during switching, i.e., when disconnected from the source, there is current in the electrical circuit, which does not change abruptly but gradually decreases continuously according to the law exp $(-\frac{t}{\tau})$. Since there is a charge on the capacitor even when the electrical equipment is disconnected from the source, in the electrical circuit, up to the time $\tau = R \cdot C$, $i(t) = \frac{\varepsilon}{n} exp\,(-\frac{t}{\tau})$ is current and warns of danger.

DISCUSSION

Differential equations of mathematics today are inextricably linked with all sciences. In turn, physics, theoretical mechanics, in short, military-technical sciences serve as the main basis for solving problems of varying degrees of difficulty. Dynamics is one of the constituent branches of the science of theoretical mechanics, which can answer the question of why a body moves [4]. The fundamental law of dynamics is Newton's second law, which is the section on the generating forces of motion. Force is a vector quantity, and the force F acting on a body is equal to the product of the mass of this body and the acceleration it acquires under the action of this force. In the Cartesian coordinate system, if the resultant force of several forces acting on a body causes the system to move, then the differential equation of Newton's Second Law is projected along all axes:

$$F_x = ma_x = mx_t''$$
$$F_y = ma_y = my_t'' \quad (9)$$
$$F_z = ma_z = mz_t''$$

This differential is calculated by a system of equations. If the resultant value of the acting forces is equal to zero, the dynamic problem takes on a static form. Usually, several forces can act on a body, and by selecting their magnitude and direction, using the scalar expression of the force, and knowing that the first-order time derivative of the equation of motion is velocity, and the first-order derivative of velocity or the second-order derivative of the equation of motion is acceleration, we obtain the differential equation:

$$m \cdot \frac{d^2x}{dt^2} = m \cdot \frac{dv}{dt} = \sum_{i=1}^{n} F_i \quad (10)$$

in this formula, the natural numbers denoting the forces acting on the body, i - from one to n. As proof of the above, we will try to solve several problems of the dynamics section using the first physical method (we will find the differential operation on the graph). We will solve the remaining two problems using the laws of differential equations and compare their methodological convenience.

RESEARCH RESULTS

Problem 1. Let the velocity graph be as shown in the figure when lifting the shaft cage. Determine the tension forces T_1, T_2 and T_3 of the rope from which the cell is suspended for three time intervals, if the mass of the cell is 480 kg. If time 1) $\Delta t_1 = 2\ c$; 2) $\Delta t_2 = 6\ c$; 3) $\Delta t_3 = 2$ varies in intervals (Fig. 2) [1].

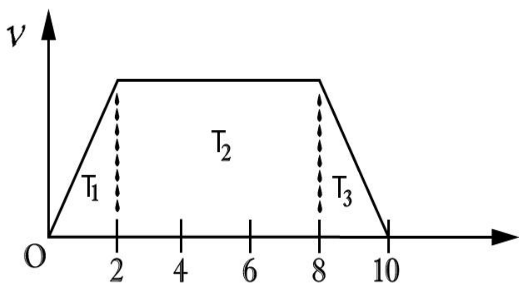

Figure 2. Speed graph

Solution: From the fundamental law of dynamics, it is known that three forces act on a cell. These are the force of gravity R, the tension of the rope T1, and the resultant force of the system ma. In the first section, the acceleration is positive, i.e., $a = \frac{v-v_0}{t-t_0} = \frac{\Delta v}{\Delta t} = \frac{5}{2}\ m/s^2$, Let's find the time derivative of velocity from the graph, then according to formula (2):

$$ma = T_1 - mg \quad (3)$$

we obtain the formula and, substituting the values in the problem statement,

$$T_1 = m(a+g) = 480 \cdot (2{,}5 + 9{,}8) = 5904\ \text{N}$$

we find the tension force, similarly from the equation α=0 in section T_2 $T_2 = mg$ that is $T_2 = 480 \cdot 9{,}8 = 4704\ N$ and in the third part of T_3 from the fact that a<0 P> T_3, $ma = P - T_3$, $T_3 = m(g-a) = 480(9{,}8 - 2{,}5) = 3504\ N$ is equal to.

Answers: $T_1 = 5904$ N, $T_2 = 4704$ N, $T_3 = 3504$ N

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Problem 2. Internal combustion engine piston $x(t) = r(\cos\omega t + \frac{r}{4l}\cos 2\omega t)$ cm, according to the law, it oscillates horizontally, where r is the length of the crank, *l* is the length of the connecting rod, and ω is the constant angular velocity of the shaft.
Determine the maximum force acting on the piston, if its mass is M. (Fig. 3) [3].
Solution: From the equation of motion of the piston of an internal combustion engine, i.e., taking twice the time derivative of x and substituting it into the differential equation $F_x = Mx_t''$ we use the maximum positive value of the cosine.

$$v = x_t' = -r(\sin\omega t - -\frac{2r}{4l}\sin 2\omega t) \quad \text{(cm/s)};$$

$$a = x_t'' = v_t' = -r\omega^2(\cos\omega t + \frac{r}{l}\cos 2\omega t) \quad (\text{cm/s}^2)$$

from this $F_x = Mr\omega^2\left(1+\frac{r}{l}\right)$ the greatest horizontal force, ωt=0 in cosωt=1 reaches a maximum. **Answer:** $F_x = Mr\omega^2\left(1+\frac{r}{l}\right)$.

Problem 3. Equation of oscillations of a body with a mass of 2.04 kg along the horizontal axis $x(t) = 10\sin\frac{\pi t}{2}$ (m) oscillates according to the law. Find the force acting on the body along the horizontal axis and its maximum value [2].
Solution: We use the differential equation of the fundamental law of dynamics. $F_x = mx_t''$ From this it is clear that we must take twice the derivative of the equation of motion with respect to time.

$$v_x = x_t' = 10\cdot\frac{\pi}{2}\cdot\cos\frac{\pi}{2}t, \;\; a_x = x_t'' = -10\cdot\frac{\pi^2}{4}\cdot\sin\frac{\pi}{2}t = -\frac{\pi^2}{4}x;$$

$$F_x = mx_t'' = -2{,}04\frac{\pi^2}{4}x = -5{,}033x, \;\; F_{max} = -m\cdot\frac{\pi^2}{4}\cdot 10\cdot\sin\frac{\pi}{2}t = 2{,}04\cdot\frac{\pi^2}{4}\cdot 10 = 50{,}3 \text{ N}$$

Answer: $F_x = -5{,}033x$, $F_{max} = 50{,}3$ N

CONCLUSION

In conclusion, it is not difficult to be convinced that the use of differential equations as an innovative connection in the teaching of physics and technical sciences is very important for specialists in the field of physics and astronomy. In the process of solving the above problems, we became convinced that simple classical formulas alone are not enough for solving physics and technical problems.

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