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APPLICATION OF DIFFERENTIAL EQUATIONS TO PHYSICAL EXAMPLES IN THE STUDY OF FORCED VIBRATIONS WITHOUT TAKING INTO ACCOUNT THE RESISTANCE OF THE MEDIUM.

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Eshboltayev Iqbol Mamirjonovich
PhD. Associate Professor of Kokand State Pedagogical Institute
Erkinova Mokhlaroyim Mukhtarjon kizi
02/22 student of physics and astronomy group
Eshboltayev Ikromjon Iqbol ogli
Student of 01/23-mathematics-informatics group

Annotation

Ignoring the mass of the spring and the resistance of the medium, we find the law of motion of the load. Taking into account the differential equation of motion, since the tension force of the spring is balanced by the force of gravity in the state of inertia, the differential equation is simplified, and this equation is the free oscillation of the load . represents It is called the equation of a harmonic oscillator and we clarify the physical meaning of e chim .

Key word

resistance of environment, differential equation of motion, harmonic oscillation, free oscillation, second-order linear homogeneous differential equation , Newton's second law , Hooke's law .

vibration without taking into account the resistance of the medium by means of differential equations, we have to work the following physical example: PA weighted load $l$is suspended from a vertical spring of the same length as the load. The load $Q\sin pt$is affected by the periodic force, where $Q$and $p$are constants. Find the law of motion of the load, ignoring the mass of the spring and the resistance of the medium.

Solving, we form the differential equation of motion :

$$m\frac{d^2x}{dt^2} = -cx + Q\sin pt$$

In addition, we $k^2 = c/m$introduce the $q = Q/m$the equation as

$$\frac{d^2x}{dt^2} + k^2x = q\sin pt\#(1)$$

we can rewrite it in the form. It consists of a second-order non-homogeneous linear equation with constant coefficients and a homogeneous equation ( )

corresponding to ($\frac{d^2x}{dt^2} + k^2x = 01$). Therefore $X = A\sin(kt + \alpha)$; $\bar{x}$remains to be found . If $p \neq k$we assume that the $\bar{x}$particular solution $\bar{x} = M\cos pt + N\sin pt$should be sought in the form , where $M$and $N$are the coefficients to be found. so that

$$k^2 \left| \begin{aligned} \bar{x} &= M\cos pt + N\sin pt \\ \overline{x'} &= -Mp\sin pt + Np\cos pt \\ \overline{x''} &= -Mp^2\cos pt - Np^2\sin pt \end{aligned} \right.$$

By doing the calculations, we get the following:

$$-Mp^2 + Mk^2 = 0, \ -Np^2 + Nk^2 = q$$

from here $M = 0$and $N = q/(k^2 - p^2)$, thus generated

$$\bar{x} = \frac{q}{k^2 - p^2}\sin pt\#(2)$$

a particular solution $Qsin\,pt$determines the oscillations, called forced oscillations, that generate the driving force. Forced oscillations have a period with an excitation force $k > p$that is the same in phase with it (that is, has the same initial phase), or $k < p$differs from , that is, $N < 0$if π.

The law of motion is expressed by the following general solution:

$$x = \frac{q}{k^2 - p^2}\sin pt + A\sin(kt + \alpha)\#(3)$$

It consists of the sum of specific forced vibrations (2) determined by the external self-restraint force and completely internal reasons: specific vibrations ( ) depending on the stiffness of the spring and the mass of the load .$x = A\sin(kt + \alpha)$

If initial conditions: $x(0) = x_0$and $x'(0) = \vartheta_0$are given, then arbitrary $A$and αinvariant can be defined. For this, we differentiate the function (3):

$$\frac{dx}{dt} = \frac{qp}{k^2 - p^2}\cos pt + Ak\cos(kt + \alpha)$$

and $x$and $\frac{dx}{dt}$of the argument to the expression of$t = 0$ we put faith ; as a result A, we form a system of equations with respect to and :α

$$x_0 = A\sin\alpha$$

$$v_0 = \frac{qp}{k^2 - p^2} + Ak\cos\alpha$$

change it to :

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$$x_0 = A\sin\alpha$$

$$\frac{1}{k}\left(\vartheta_0 - \frac{qp}{k^2 - p^2}\right) = A\cos\alpha$$

we square and add both parts of these equations. In that case

$$A = \sqrt{x_0^2 + \frac{1}{k^2}\left(\vartheta_0 - \frac{qp}{k^2 - p^2}\right)^2}$$

α To find , we divide both q terms of the first equation by the corresponding parts of the second equation; as a result

$$\mathrm{tg}\,\alpha = \frac{x_0 k}{\vartheta_0 - qp/(k^2 - p^2)},\ \text{бу ердан}\ \alpha = \mathrm{arctg}\frac{x_0 k}{\vartheta_0 - qp/(k^2 - p^2)}$$

in thissin $\alpha = \frac{x_0}{A}$, $\cos\alpha = \frac{1}{kA}\left(\vartheta_0 - \frac{qp}{k^2-p^2}\right)$

Thus, a particular solution is sought that satisfies the given initial conditions

$$x = \frac{q}{k^2 - p^2}\sin pt + A\sin kt\cos\alpha + A\cos kt\sin\alpha$$

or

$$x = \frac{q}{k^2 - p^2}\sin pt + \frac{1}{k}\left(\vartheta_0 - \frac{qp}{k^2 - p^2}\right)\sin kt + x_0\cos kt$$

consists of a function.

Characterizing special forced oscillations (2) was derived under the condition that it is a special solution $p \neq k$, that is, the frequency of the external force is not the same as the frequency of special vibrations . If so , things $p = k$will be completely different . Indeed , in such a case, the equation (1) can be written in the following form:

$$\frac{d^2x}{dt^2} + k^2x = q\sin kt \#(4)$$

The specific solution $\bar{x} = t(M\cos kt + N\sin kt)$should be sought in the form, where $M$and $N$are the coefficients to be determined. so that

$k^2 \mid \bar{x} = Mt\cos kt + Nt\sin kt,$

$0 \mid \overline{x'} = -Mkt\sin kt + Nkt\cos kt + M\cos kt + N\sin kt,$

$1 \mid \overline{x''} = -Mk^2t\cos kt - Nk^2\sin kt - 2Mk\sin kt + 2Nk\cos kt,$

where $-2Mk = q, 2Nk = 0$we find , and thus the private solution is of the form:

$$\bar{x} = -\frac{q}{2k}t\cos kt \#(5)$$

In this case, the general solution is:

$$x = -\frac{q}{2k}t\cos kt + A\sin(kt + \alpha)$$

$\frac{dx}{dt}$we find and $x$and $\frac{dx}{dt}$to the expression of$t = 0$ we put the faith :

$$\frac{dx}{dt} = -\frac{q}{2k}\cos kt + \frac{q}{2}t\sin kt + Ak\cos(kt + \alpha)$$

$$x_0 = A\sin\alpha$$

$$\vartheta_0 = -\frac{q}{2k} + Ak\cos\alpha \text{ ёки } \frac{1}{k}\left(\vartheta_0 + \frac{q}{2k}\right) = A\cos\alpha$$

From the following two equations:

$$A = \sqrt{x_0^2 + \frac{1}{k^2}\left(\vartheta_0 + \frac{q}{2k}\right)^2},\ \mathrm{tg}\,\alpha = \frac{x_0 k}{\vartheta_0 + q/2k}$$

from here

$$\alpha = \mathrm{arctg}\frac{x_0 k}{\vartheta_0 + q/2k};\ \sin\alpha = \frac{x_0}{A},\ \cos\alpha = \frac{1}{kA}\left(\vartheta_0 + \frac{q}{2k}\right)$$

We can rewrite the general solution as:

$$x = -\frac{q}{2k}t\cos kt + A\sin kt\cos\alpha + A\cos kt\sin\alpha$$

then the desired private solution satisfying the initial conditions is written in the following form:

$$x = -\frac{q}{2k}t\cos kt + \frac{1}{k}\left(\vartheta_0 + \frac{q}{2k}\right)\sin kt + x_0\cos kt$$

(5) the amplitude of forced oscillations $gt/(2k)$in this case can become infinitely large, even if h atto is not very large. qIn other words, sufficiently large amplitudes can be generated when the excitation forces are small. This phenomenon is called resonance. Thus , resonance occurs when the frequency of the excitation force becomes the same as the frequency of the natural oscillations .

However, it is not necessary that these frequencies actually have a specific value . The expression (2) derived for the forced vibration has an exact amplitude when the frequencies are $q/(k^2 - p^2)$close to each other $k$and $p$although b' is limited in frequency it can be very large .

The ability to generate large-amplitude oscillations is often used in various amplifiers, for example, in radio engineering. On the other hand, in many cases, the occurrence of large amplitudes is harmful, as it can lead to the destruction of structures (for example, bridges or roofs) .

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