NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 8, ISSUE 4, Apr. -2022

USING THE METHODS OF "MATRYOSHKA" AND "CONSECUTIVE CONTRACTION" TO EXPLAIN THE THEORY OF MOTION OF A MATERIAL POINT

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ANNOTATION:

The paper presents methods of using the methods of "matryeshka" and "consecutive grinding" to increase the level of students' mastery of complex topics of theoretical mechanics. It also explains how to use these methods to calculate the derivatives of complex functions and to express the angular momentum of a point in various coordinate systems.

Keywords: derivative, function, angular momentum, material point, cylindrical coordinate system, matryoshka, successive grinding, method.

INTRODUCTION:

As you know, to improve the performance in physics, one has to turn to interactive and mathematical methods. This is due to the fact that there are a number of difficulties that students face when mastering physics.

In particular, there are a number of difficulties in mastering theoretical mechanics by students in the course of theoretical physics. This is due to the fact that prior to this course, students have only worked with 1D or 2D spaces. In addition, when forming the concepts of theoretical mechanics, it is necessary to refer to the concepts of courses in higher mathematics, vector algebra, and methods of differential calculus.

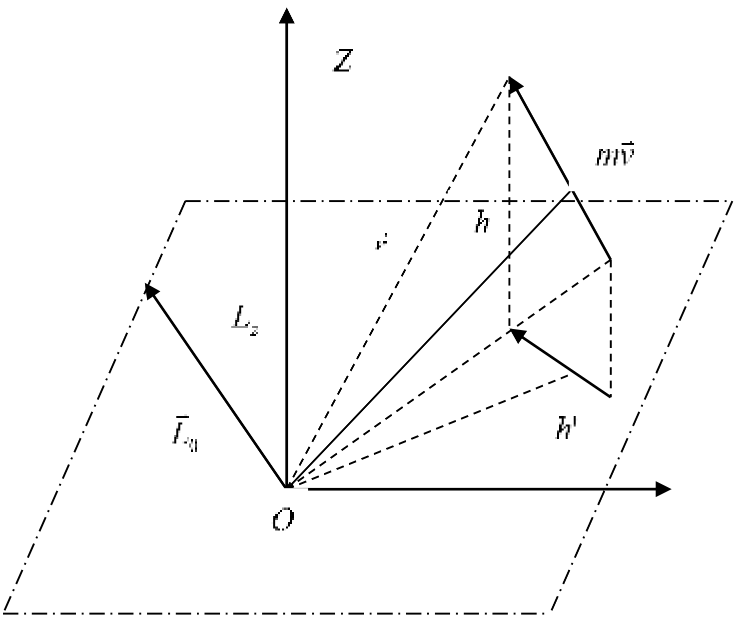
The use of interactive methods to solve such problems gives effective results. Methods such as Fish Skeleton, BBB and Find a Partner can be used to improve students' understanding of theoretical mechanics. However, there are such processes and quantities that it is advisable to use the "matryoshka" and "successive reduction" methods, which give even better results than these methods, for expressing them in different coordinate systems. One of these quantities is the angular momentum of a point about the center.

In order to have a complete understanding of this value, the student must have fully formed elements of vector algebra, actions on determinants. The angular momentum of a point about the center is a vector perpendicular to the plane on which the center of the coordinate system and the momentum vector lie. The direction of the angular momentum can be determined by the direction of movement of the gimlet. The angular momentum vector and its modulus with respect to a point can be written as follows

$$\vec{M} = [\vec{r}, m\vec{v}] \qquad (1)$$

Representing the momentum vector relative to a point in a Cartesian coordinate system is not difficult for students.

However, when representing the momentum vector relative to a point in a cylindrical coordinate system, the student will need knowledge of algebraic operations on vectors and determinants, as well as differentiation of functions. This is due to the fact that in order to express the angular momentum simultaneously along three axes, it is necessary to apply the algebra of vectors, function differentials and operations on determinants.



Rice. 1. The angular momentum vector relative to the point.

There are processes in which it is necessary to express the projections of the angular momentum in cylindrical coordinates by the expression in formula (1). In this case, we mean the following relationship between a cylindrical coordinate system and a Cartesian coordinate system. Cartesian (x, y, z) and cylindrical (r, φ, z) coordinates are related as follows:

$x = r\cos\varphi,\quad y = r\sin\varphi,\ z = z$ (2)

Then we expand the expression (1,1) in the form of a determinant

$$\vec{M} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ x & y & z \\ mv_x & mv_y & mv_z \end{vmatrix} \qquad (3)$$

We use the method of "successive reduction" to calculate the determinant, we express the projections of the moments, respectively, of the orts.

$$\vec{M} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ x & y & z \\ mv_x & mv_y & mv_z \end{vmatrix} = \vec{i}\begin{vmatrix} y & z \\ mv_y & mv_z \end{vmatrix} - \vec{j}\begin{vmatrix} x & z \\ mv_x & mv_z \end{vmatrix} + \vec{k}\begin{vmatrix} x & y \\ mv_x & mv_y \end{vmatrix} \quad (4)$$

To solve the determinant, we need to have:

$v_x = \dot{x},\ v_y = \dot{y},\ v_z = \dot{z}$ (5)

$$M_x = \begin{vmatrix} y & z \\ mv_y & mv_z \end{vmatrix} = y \times mv_z - z \times mv_y \qquad (6)$$

Taking into account (5), expression (6) has the following form

$M_x = m(y\dot{z} - z\dot{y})$ (7)

Using the connection in expression (2), we obtain:

$M_x = m(r\sin\varphi\,\dot{z} - z(r\sin\varphi)^{\boldsymbol{\cdot}})$ (8)

To calculate the derivative, we use the "matryoshka" method. In the "matryoshka" method, an individual nesting doll is an argument (as a child) for the previous one and a function (as a parent) for the next one. This method looks like this: If we take the derivative of the complex function F(q(k(r(x, y, z)))) with respect to x. Opening each shell (function), we take the derivative with respect to the next shell (argument). The total derivative is obtained by multiplying all the individual derivatives obtained.

As you can see, the derivative of complex functions resembles the separation of a Russian nesting doll (Fig. 2). Nesting dolls can be numbered from the smallest. The derivative is taken as follows: the derivative of the 5th doll (function) is taken from the 4th doll (argument), the derivative of the 4th (function) is taken from the 3rd (argument), the derivative of the 3rd (function) is taken from 2-u (argument), and the derivative of the 2nd (function) is taken over the 1st (argument). This is similar to the derivative of the above complex function.

Rice. 2. Russian nesting dolls with open shells.

Using this method, we get:

$M_x = m(r\sin\varphi\,\dot{z} - z\dot{r}\sin\varphi - zr\cos\varphi\,\dot{\varphi})$
(9)

Let's simplify the expression

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$M_x = m\sin\varphi\,(r\dot{z} - z\dot{r}) - mzr\cos\varphi\,\dot{\varphi})$
(10)

(10) the formula is the projection of the angular momentum vector on the X axis for cylindrical coordinates

To find the value along the Y-axis in the same way, we will use the "successive reduction" method:

$M_y = -\begin{vmatrix} x & z \\ mv_x & mv_z \end{vmatrix} = -(x \times mv_z - z \times mv_x)$
(11)

Taking into account (5), the expression looks like:

$M_y = m(z\dot{x} - x\dot{z})$ (12)

Using the connection in expression (2), we obtain:

$M_y = m(z(r\dot{\cos}\,\varphi) - r\dot{z}\cos\varphi)$ (13)

We use the "matryoshka" method to calculate the derivative

$M_y = m(z\dot{r}\cos\varphi - zr\sin\varphi\dot{\varphi} - r\dot{z}\cos\varphi)$ (14)

If we simplify the expression

$M_y = m\cos\varphi(z\dot{r} - r\dot{z}) - mzr\sin\varphi\dot{\varphi}$ (15)

(15) is the projection of the angular momentum vector on the Y axis for cylindrical coordinates.

In the same way, to find the value along the Z axis, we use the "successive reduction" method

$M_z = \begin{vmatrix} x & y \\ mv_x & mv_y \end{vmatrix} = x \times mv_y - y \times mv_x$
(16)

Taking into account (5), the expression has the following form:

$M_z = m(x\dot{y} - y\dot{x})$ (17)

Using the connection in expression (2), we obtain:

$M_z = m(r\cos\varphi\,(r\dot{\sin}\,\varphi) - r\sin\varphi(r\dot{\cos}\,\varphi))$
(18)

We use the "matryoshka" method to calculate the derivative

$M_z = m[r\cos\varphi\,(\dot{r}\sin\varphi + r\dot{\varphi}\cos\varphi) - r\sin\varphi(\dot{r}\cos\varphi + r\varphi\sin\varphi]$ (19)

$M_z = mr^2\dot{\varphi}$ (20)

(20) is a representation of the projection of the angular momentum vector on the Z-axis for cylindrical coordinates.

The general expression of the angular momentum vector with respect to a point in cylindrical coordinates is as follows:

$\vec{M} = \left(m\sin\varphi\,(r\dot{z} - z\dot{r}) - mzr\cos\varphi\,\dot{\varphi}\right)\vec{\imath} + (m\cos\varphi(z\dot{r} - r\dot{z}) - mzr\sin\varphi\dot{\varphi})\vec{\jmath} + +mr^2\dot{\varphi}\vec{k}$
(21)

From expression (20), the following relationship can be derived. If we write an expression for the Lagrange function of a point in a cylindrical system, we get:

$L = \frac{m}{2}(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) - U(x, y, z)$
(22)

Using expression (2), we obtain:

$L = \frac{m}{2}\left((r\dot{\cos}\,\varphi)^2 + (r\dot{\sin}\,\varphi)^2 + \dot{z}^2\right) - U(r, \varphi, z)$
(23)

(23) Using the rules of the derivative, we bring the expression to the following form:

$L = (\dot{r}\cos\varphi - r\sin\varphi\dot{\varphi})^2 + (\dot{r}\sin\varphi + r\cos\varphi\dot{\varphi})^2 + \dot{z}^2) - U(r, \varphi, z)$ (24)

Simplifying the expressions, we get:

$L = \frac{m}{2}(\dot{r}^2 + r^2\dot{\varphi}^2 + \dot{z}^2) - U(r, \varphi, z)$
(25)

Comparing expression (25) with expression (20) found above, we get:

$M_z = \frac{\partial L}{\partial \dot{\varphi}} = mr^2\dot{\varphi}$ (26)

From this we can conclude that the generalized momentum (Pφ) corresponding to the generalized coordinate (φ) is equal to .

In a course in theoretical physics, using methods such as "sequential contraction" and "matryoshka dolls" to derive similar patterns can help improve academic performance.

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