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The Use of Computer Mathematics Maple in the Educational Process

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Abstract: The article shows how the system of computer mathematics Maple can be used in the study of topics «Integral calculus of functions of several variables». Examples illustrating the process of calculating and disclosing the triple integral applied nature of the material.

Keywords: double and triple integral; applications of multiple integrals geometry system; of computer mathematics Maple.

The topic "Integral calculus of functions of several variables" occupies an important place in the educational process in higher education. It is of great importance both in mathematics itself and is widely used in solving applied problems. At the same time, in order to make the process of mathematical modeling of the studied practical problems more visual and understandable, various packages of computer mathematics systems are useful, in particular, the Maple system can be used.

Research objective. To consider the capabilities of the Maple computer mathematics system for calculating multiple integrals and solving applied problems.

As you can see, this approach is not very successful. Therefore, for clarity of illustration, we will use different scales along the coordinate axes:

Research material. Let us consider several examples related to the calculation of multiple integrals or their applications in geometry, and show the possibilities of solving these tasks in the Maple system.

Example 1. Calculate the volume of a straight beam, limited from above by a paraboloid $z = 4 - x^2 - y^2$ and having a square base, limited in the plane Oxy by straight lines $x = \pm 1,\ y = \pm 1$

Solution. First of all, we make a drawing using the Maple system:

```
> restart:
> with(plots):
> with(student):
> A1:=plot3d([(u),(v),(4-u^2-v^2)],u=-1..1,v=-1..1,axes=normal):
A2:=plot3d([(u),(v),(0)],u=-1..1,v=-1..1,axes=normal):
A3:=plot3d([(1),(u),(v)],u=-1..1,v=0..3-u^2,axes=normal):
A4:=plot3d([(-1),(u),(v)],u=-1..1,v=0..3-u^2,axes=normal):
A5:=plot3d([(u),(1),(v)],u=-1..1,v=0..3-u^2,axes=normal):
A6:=plot3d([(u),(-1),(v)],u=-1..1,v=0..3-u^2,axes=normal):
> display({A1,A2,A3,A4,A5,A6},labels=[x,y,z],scaling=constrained,
view=[-1.5 ..1.5,-1.5 ..1.5,0 ..4.5]);
```

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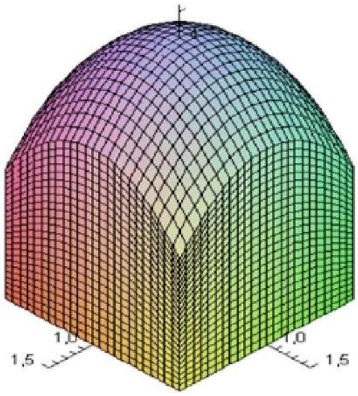

$$\iiint_{(V)} (xz)^2\, dxdydz = \int_0^2 dx \int_0^{2x} dy \int_0^{xy} (xz)^2\, dz = \int_0^2 dx \int_0^{2x} x^2 \left(\frac{z^3}{3}\Big|_0^{xy} \right) dy = \frac{1}{3}\int_0^2 x^5 dx \int_0^{2x} y^3 dy =$$

$$= \frac{1}{3} \int_0^2 x^5 dx \left(\frac{y^4}{4}\Big|_0^{2x} \right) dx = \frac{4}{3} \int_0^2 x^9 dx =$$

Since the base of the beam is a square with sides parallel to the coordinate axes *Ox* and *Oy*, the integration limits for both variables are constant.

Using the formula

$$V = \int_{(V)} f(x, y)\, dxdy,$$

we get:

$$V = \int_{-1}^{1} dx \int_{-1}^{1} (4 - x^2 - y^2)\, dy = \int_{-1}^{1} \left[4y - x^2 - \frac{y^2}{3} \right]\Bigg|_{-1}^{1} =$$

$$= \int_{-1}^{1} \left(8 - 2x^2 - \frac{2}{3} \right) dx = \left[\frac{22}{3} x - \frac{2}{3} x^3 \right]\Bigg|_{-1}^{1} = \frac{44}{3} - \frac{4}{3} 13\frac{1}{3}.$$

The calculation of the integral in Maple looks like this:

```
> restart:
> with(student):
> Doubleint(4-x^2-y^2,y=-1..1,x=-1..1);
```

$$\int_{-1}^{1}\int_{-1}^{1} 4 - x^2 - y^2 \, dy\, dx \qquad (1.)$$

```
> value(%);
```

$$\frac{40}{3}$$

Let us construct the surface cut out by the cylinder:

Example 2. Calculate the area of the part of the surface $2z = x^2 + y^2$ cut out by the cylinder $\left(x^2 + y^2\right)^2 = x^2 - y^2$.

Solution. The contour of the projection of the cut out part onto the plane *Oxy* is the lemniscate $\rho = \sqrt{\cos 2\varphi}$.

```
> restart:
> with(plots):
> with(student):
> A1:=plot3d([(u),(v),((u^2+v^2)/2)], u=-4..4,v=-4..4,axes=normal):
A2:=plot3d([(u),((1/2)*sqrt(-2-4*u^2+2*sqrt(8*u^2+1))),(v)],u=-1..1,v=-1..1, axes=normal):
A3:=plot3d([(u),(-(1/2)*sqrt(-2-4*u^2+2*sqrt(8*u^2+1))),(v)],u=-1..1,
v=-1..1,axes=normal):
>display({A1,A2,A3,A4,A5},labels=[x,y,z], scaling=constrained,view=[-1.5 ..1.5,-1.5 .. 1.5,0 ..1]);
```

Let's construct a surface cut out by a cylinder:

> **solve((x^2+y^2)^2=x^2-y^2,y);**

$$\frac{\sqrt{-2-4x^2+2\sqrt{8x^2+1}}}{2},\ -\frac{\sqrt{-2-4x^2+2\sqrt{8x^2+1}}}{2},\ \frac{\sqrt{-2-4x^2-2\sqrt{8x^2+1}}}{2},$$
$$-\frac{\sqrt{-2-4x^2-2\sqrt{8x^2+1}}}{2}$$

```
>A4:=plot3d([(u),(v),((u^2+v^2)/2)],u=-1..1,v=-(1/2)*sqrt(-2-4*u^2+2*sqrt(8*u^2+1))..(1/2)*sqrt(-2-4*u^2+2*sqrt(8*u^2+1)),axes=normal):
> display({A4},labels=[x,y,z],scaling=constrained,view=[-1.1..1.1,-.1..1.1,0..1.1]);
```

The cylinder cuts out two equal pieces of surface from the paraboloid. From the equation of the paraboloid we obtain the integrand function for which

$$z'_x = x,\ \ z'_y = y;$$

$$\sqrt{1+(z'_x)^2+(z'_x)^2} = \sqrt{1+x^2+y^2}.$$

Therefore,

$$S = \iint\limits_{(D)} \sqrt{1+x^2+y^2}.$$

We transform the integral to polar coordinates .

The integrand will be written as

$$\sqrt{1+x^2+y^2} = \sqrt{1+\rho},$$

and the equation of the lemniscate is in the form

$$(\rho\cos^2\varphi + \rho\sin^2\varphi)^2 = \rho\cos^2\varphi - \rho\sin^2\varphi,$$

or $\rho = \sqrt{\cos 2\varphi}$. Since the paraboloid and the cylinder are symmetrical with respect to the planes *Oxz, Oyz*, it is sufficient to calculate the integral over one quarter of the lemniscate located in the first quarter of the plane *Oxz*:

$$\frac{1}{4}S = \int_0^{\frac{\pi}{4}} d\varphi \int_0^{\sqrt{\cos 2\varphi}} \sqrt{1+\rho^2}\,\rho\,d\rho = \frac{5}{9} - \frac{\pi}{12},$$

where

$$S = 4 \cdot \left(\frac{5}{9} - \frac{\pi}{12}\right) = \frac{20}{9} - \frac{\pi}{3}.$$

Calculating an integral in Maple:

> restart:

> with(student):

> Doubleint(4*rho*sqrt(1+rho^2),rho=0..sqrt(cos(2*phi)),phi=0..Pi/4);

$$\int_0^{\frac{\pi}{4}} \int_0^{\sqrt{\cos(2\phi)}} 4\rho\sqrt{1+\rho^2}\,d\rho\,d\phi$$

> value(%);

$$-\frac{\pi}{3} + \frac{20}{9}$$

Conclusion

The use of not only "manual" but also computer calculations in the educational process makes the process of mathematical modeling of a situation more visual and representable for students (especially in the case of three-dimensional space); it allows to reduce the labor intensity of calculations (which is especially important when studying a course in higher mathematics in non-core areas of training) and to compare mathematical and computer methods for solving the same mathematical problem (which is useful for students at a core level of training).

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