Ministry of Higher Education and Scientific Research

Al-Mustaqbal University

Department of Chemical Engineering and petroleum Industrials

Week: 4,5

Mathematics II

2nd Stage

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2023-2024

Triple integral

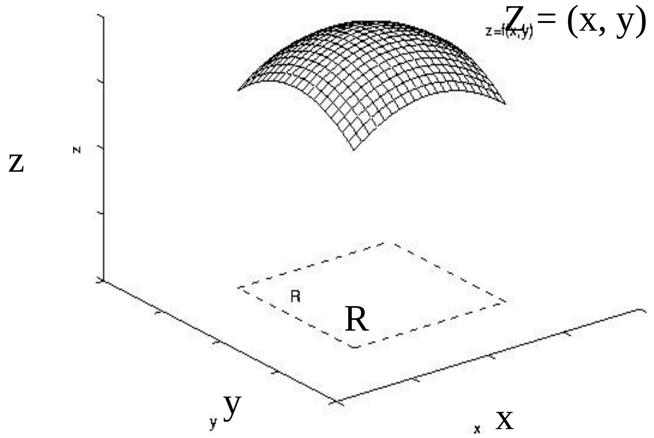
If f(x, y, z) is a function defined on a closed bounded region D in space, such as the regionoccupied by a solid ball or a lump of clay, then the integral of f over D may be defined inthe following way.

$$V = \iiint_D dV = \int_{x=a}^{x=b} \int_{y=g_1(x)}^{y=g_2(x)} \int_{z=f_1(x,y)}^{z=f_2(x,y)} F(x,y,z)\, dz\, dy\, dx$$

a- **Surface area**

Let f (x, y) be a differentiable function. As we have seen, z=f(x, y) defines a surfacein x y z-space. In some applications, it necessary to know the surface area of the surface above some region R in the xy-plane. See the figure 1.

$$S = \iint_R \sqrt{1 + \left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}\, dydx$$

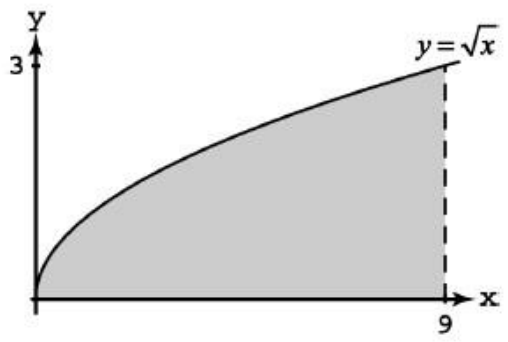


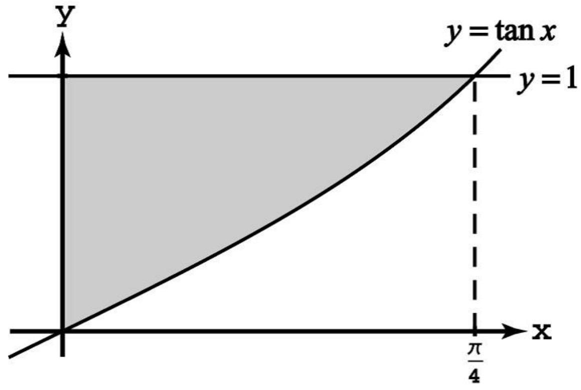
Examples

1. **Double integral**

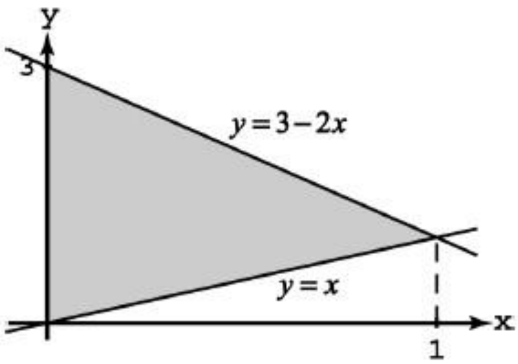
a- **Cartesian form**

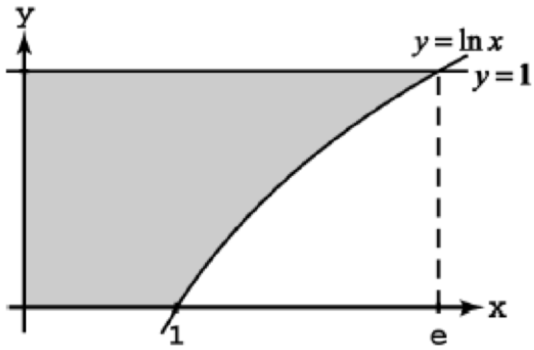
1- Find the limits of the following integral



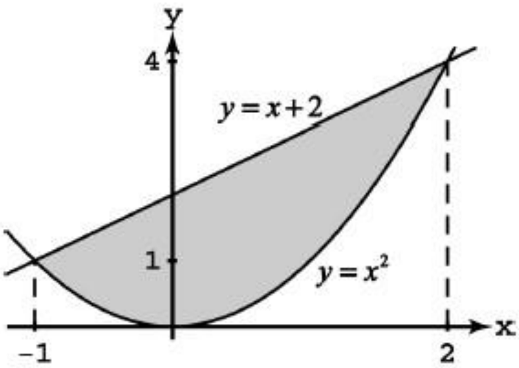


(a) (b)





(c) (d)



(e)

$\boxed{d}$ $$\int_0^1 \int_0^1 dy\,dx + \int_1^e \int_{\ln x}^1 dy\,dx$$

3 $$\int_0^1 \int_0^{e^y} dx\,dy$$

$\boxed{e}$ $$\int_{-1}^2 \int_{x^2}^{x+2} dy\,dx$$

$$\int_0^1 \int_{-\sqrt{y}}^{\sqrt{y}} dx\,dy + \int_1^3 \int_{y-2}^{\sqrt{y}} dx\,dy$$

(a) $\int_0^9 \int_0^{\sqrt{x}} dy\,dx$

$\int_0^3 \int_{y^2}^9 dx\,dy$

b $\int_0^{\pi/4} \int_{\tan x}^1 dy\,dx$

$\int_0^1 \int_0^{\tan^{-1} y} dx\,dy$

c $\int_0^1 \int_x^{3-2x} dy\,dx$

$\int_0^1 \int_0^y dx\,dy + \int_1^3 \int_0^{(3-y)/2} dx\,dy$

2- Evaluate the following

a $\int_0^3 \int_1^2 1 + 8xy \; dy\, dx$ b $\int_0^1 \int_0^1 \left(1 - \frac{x^2+y^2}{2}\right) dx\, dy$

c $\int_0^3 \int_{-2}^0 (x^2y - 2xy)\, dy\, dx$ d $\int_\pi^{2\pi} \int_0^\pi (\sin x + \cos y)\, dx\, dy$

e $\iint_S (\sin x + \cos y)\, dA$ bounded by the area in fig.1

f $\iint_R xy^2\, dA$ bounded by the area in fig.2

g- $\iint_T (x - 3y)\, dA$ in fig.3

h- $\iint_R dA.$ bounded by the area in fig.4

i- $\iint_R dA.$ bounded by the area in fig.5

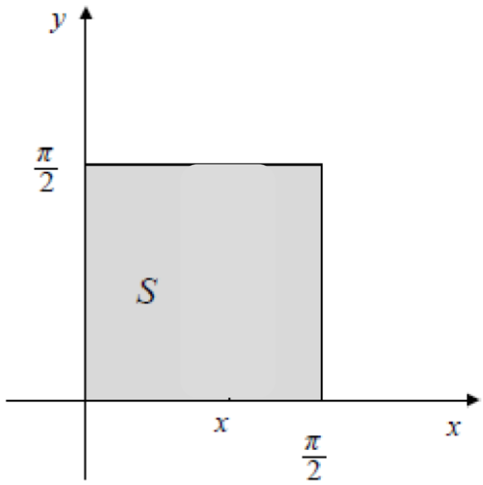


Figure 1

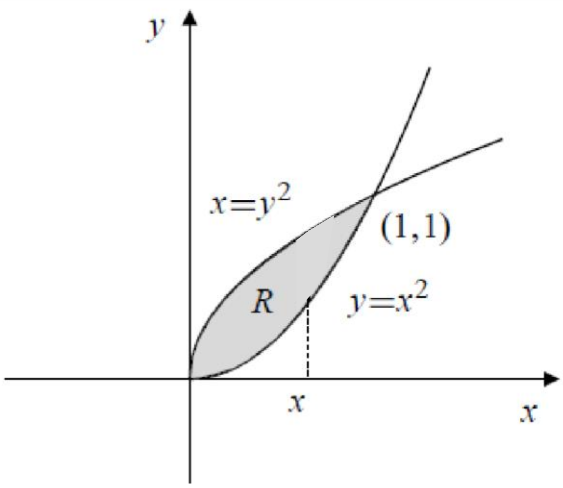


Figure 2

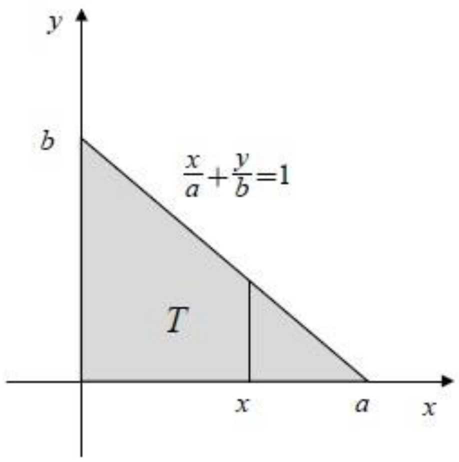


Figure 3

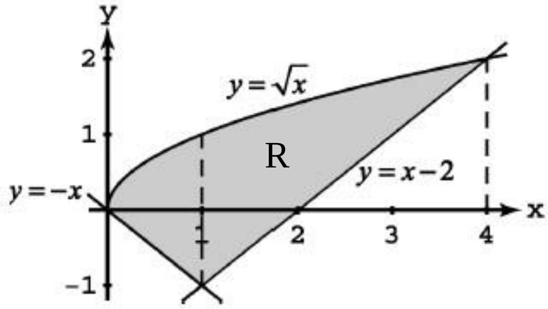


figure4

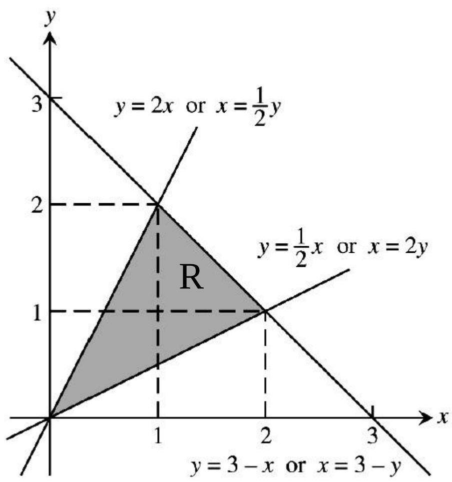


Figure 5

a $\int_0^3\int_1^2 (1+8xy)\,dy\,dx = \int_0^3 \left(y+8x\frac{y^2}{2}\right)\Big|_1^2 dx$

$$= \int_0^3 \{1+12x\}\,dx$$

$$= \left(x+12\frac{x^2}{2}\right)\Big|_0^3$$

$$= (3+6(9)) - (0) = (3+54) = \mathbf{57}$$

b $\int_0^1 \int_0^1 \left(1-\frac{x^2+y^2}{2}\right) dx\,dy = \int_0^1 \left[x-\frac{x^3}{6}-\frac{x\,y^2}{2}\right]_0^1 dy$

Solution

$$= \int_0^1 \left(\frac{5}{6} - \frac{y^2}{2}\right) dy = \left[\frac{5}{6}y - \frac{y^3}{6}\right]_0^1 = \frac{2}{3}$$

c $\displaystyle\int_0^3 \int_{-2}^0 (x^2y - 2xy)\, dy\, dx = \int_0^3 \left[\frac{x^2y^2}{2} - xy^2\right]_{-2}^0 dx = \int_0^3 (4x - 2x^2)\, dx$

$$= \left[2x^2 - \frac{2x^3}{3}\right]_0^3 = 0$$

d $\displaystyle\int_\pi^{2\pi} \int_0^\pi (\sin x + \cos y)\, dx\, dy = \int_\pi^{2\pi} [-\cos x + x\cos y]_0^\pi\, dy$

$$= \int_\pi^{2\pi} (2 + \pi\cos y)\, dy = [2y + \pi\sin y]_\pi^{2\pi} = 2\pi$$

e $\displaystyle\iint_S (\sin x + \cos y)\, dA$

$$= \int_0^{\pi/2} \int_0^{\pi/2} (\sin x + \cos y)\, dy\, dx$$

$$= \int_0^{\pi/2} dx \left(y\sin x + \sin y\right)\Big|_{y=0}^{y=\pi/2}$$

$$= \int_0^{\pi/2} \left(\frac{\pi}{2}\sin x + 1\right) dx$$

$$= \left(-\frac{\pi}{2}\cos x + x\right)\Big|_0^{\pi/2} = \frac{\pi}{2} + \frac{\pi}{2} = \pi.$$

f $\displaystyle\iint_R xy^2\, dA = \int_0^1 x\, dx \int_{x^2}^{\sqrt{x}} y^2\, dy$

$$= \int_0^1 x\, dx \left(\frac{1}{3}y^3\right)\Big|_{y=x^2}^{y=\sqrt{x}}$$

$$= \frac{1}{3}\int_0^1 \left(x^{5/2} - x^7\right) dx$$

$$= \frac{1}{3}\left(\frac{2}{7}x^{7/2} - \frac{x^8}{8}\right)\Big|_0^1$$

$$= \frac{1}{3}\left(\frac{2}{7} - \frac{1}{8}\right) = \frac{3}{56}.$$

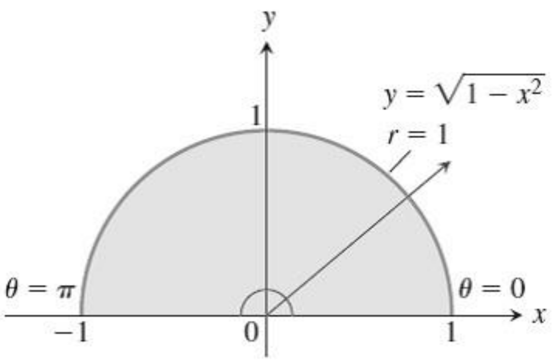
g
$$\iint_T (x-3y)\,dA = \int_0^a dx \int_0^{b(1-(x/a))} (x-3y)\,dy$$
$$= \int_0^a dx \left(xy - \frac{3}{2}y^2\right)\Bigg|_{y=0}^{y=b(1-(x/a))}$$
$$= \int_0^a \left[b\left(x-\frac{x^2}{a}\right) - \frac{3}{2}b^2\left(1-\frac{2x}{a}+\frac{x^2}{a^2}\right)\right] dx$$
$$= \left(b\frac{x^2}{2} - \frac{b}{a}\frac{x^3}{3} - \frac{3}{2}b^2x + \frac{3}{2}\frac{b^2x^2}{a} - \frac{1}{2}\frac{b^2x^3}{a^2}\right)\Bigg|_0^a$$
$$= \frac{a^2b}{6} - \frac{ab^2}{2}.$$

h
$$\int_0^1 \int_{x/2}^{2x} 1\,dy\,dx + \int_1^2 \int_{x/2}^{3-x} 1\,dy\,dx$$
$$= \int_0^1 [y]_{x/2}^{2x} dx + \int_1^2 [y]_{x/2}^{3-x} dx$$
$$= \int_0^1 \left(\tfrac{3}{2}x\right) dx + \int_1^2 \left(3-\tfrac{3}{2}x\right) dx$$
$$= \left[\tfrac{3}{4}x^2\right]_0^1 + \left[3x - \tfrac{3}{4}x^2\right]_1^2 = \tfrac{3}{2}$$

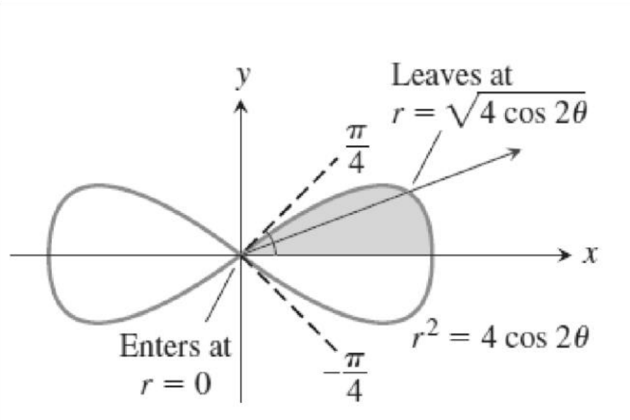
i
$$\int_0^1 \int_{-x}^{\sqrt{x}} 1\,dy\,dx + \int_1^4 \int_{x-2}^{\sqrt{x}} 1\,dy\,dx$$
$$= \int_0^1 [y]_{-x}^{\sqrt{x}} dx + \int_1^4 [y]_{x-2}^{\sqrt{x}} dx$$
$$= \int_0^1 (\sqrt{x}+x)\,dx + \int_1^4 (\sqrt{x}-x+2)\,dx$$
$$= \left[\tfrac{2}{3}x^{3/2} + \tfrac{1}{2}x^2\right]_0^1 + \left[\tfrac{2}{3}x^{3/2} - \tfrac{1}{2}x^2 + 2x\right]_1^4 = \tfrac{13}{3}$$

b- <u>Poalr form</u>

1- Find the limits of the following integral



(a)



(b)

a $\displaystyle\int_0^{\pi}\int_0^{1} e^{r^2}\, r\, dr\, d\theta$

b $\displaystyle\int_0^{\pi/4}\int_0^{\sqrt{4\cos 2\theta}} r\, dr\, d\theta$

2- Evaluate the following

a $\displaystyle\int_{\pi/4}^{\pi/2}\int_{0}^{6\csc\theta} r^2 \cos\theta \, dr\, d\theta$

b $\displaystyle\int_{0}^{\pi/4}\int_{0}^{2\sec\theta} r^2 \sin\theta \, dr\, d\theta$

c $\displaystyle\int_{\pi/6}^{\pi/4}\int_{\csc\theta}^{\sqrt{3}\sec\theta} r \, dr\, d\theta$

d $\displaystyle\int_{0}^{\pi/4}\int_{\sec\theta}^{2\cos\theta} \frac{1}{r^4}\, r \, dr\, d\theta$

e $\displaystyle\iint_S x\, dA$ bounded by area shown in fig.6

f $\displaystyle\iint_C y\, dA$ bounded by area shown in fig.7

g $\boldsymbol{dA}$-bounded by area shown in fig.8

$\boldsymbol{A}$

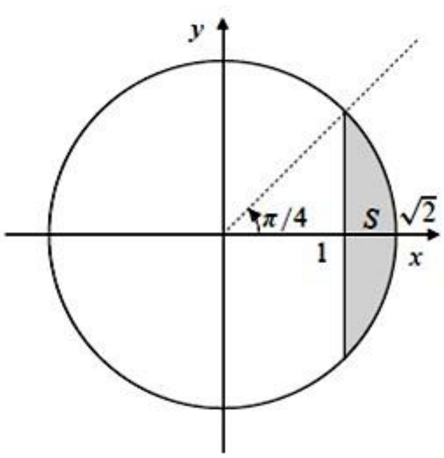


Figure 6

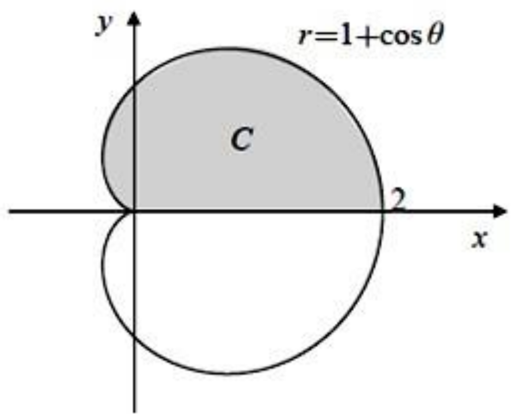


figure7

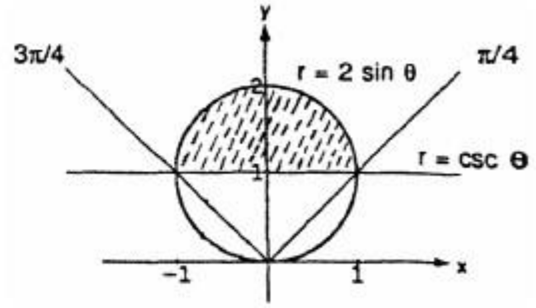


Figure 8

Solution

$\boxed{\text{a}}$ $$\int_{\pi/4}^{\pi/2}\int_{0}^{6\csc\theta} \mathrm{r}^2\cos\theta\,\mathrm{dr}\,\mathrm{d}\theta = 72\int_{\pi/4}^{\pi/2}\cot\theta\csc^2\theta\,\mathrm{d}\theta$$

$$= -36\left[\cot^2\theta\right]_{\pi/4}^{\pi/2} = 36$$

$\boxed{\text{b}}$ $$\int_{0}^{\pi/4}\int_{0}^{2\sec\theta} \mathrm{r}^2\sin\theta\,\mathrm{dr}\,\mathrm{d}\theta = \tfrac{8}{3}\int_{0}^{\pi/4}\tan\theta\sec^2\theta\,\mathrm{d}\theta = \tfrac{4}{3}$$

$\boxed{\text{c}}$ $$\int_{\pi/6}^{\pi/4}\int_{\csc\theta}^{\sqrt{3}\sec\theta} \mathrm{r}\,\mathrm{dr}\,\mathrm{d}\theta = \int_{\pi/6}^{\pi/4}\left(\tfrac{3}{2}\sec^2\theta - \tfrac{1}{2}\csc^2\theta\right)\mathrm{d}\theta$$

$$= \left[\tfrac{3}{2}\tan\theta + \tfrac{1}{2}\cot\theta\right]_{\pi/6}^{\pi/4} = 2-\sqrt{3}$$

$\boxed{\text{d}}$ $$\int_{0}^{\pi/4}\int_{\sec\theta}^{2\cos\theta} \tfrac{1}{\mathrm{r}^4}\,\mathrm{r}\,\mathrm{dr}\,\mathrm{d}\theta = \int_{0}^{\pi/4}\left[-\tfrac{1}{2\mathrm{r}^2}\right]_{\sec\theta}^{2\cos\theta}\mathrm{d}\theta = \int_{0}^{\pi/4}\left(\tfrac{1}{2}\cos^2\theta - \tfrac{1}{8}\sec^2\theta\right)\mathrm{d}\theta\ \ \mathrm{d}\theta$$

$$= \left[\tfrac{1}{4}\theta + \tfrac{1}{8}\sin 2\theta - \tfrac{1}{8}\tan\theta\right]_{0}^{\pi/4} = \tfrac{\pi}{16}$$

$\boxed{\text{e}}$ $$\int_{\sec\theta}^{\sqrt{2}} r\cos\theta\, r\, dr\, d\theta$$

$$\iint_S x\,dA = 2\int_0^{\pi/4} d\theta \int_{\sec\theta}^{\sqrt{2}} r\cos\theta\, r\,dr$$

$$= \frac{2}{3}\int_0^{\pi/4}\cos\theta\left(2\sqrt{2}-\sec^3\theta\right)d\theta$$

$$= \frac{4\sqrt{2}}{3}\sin\theta\Big|_0^{\pi/4} - \frac{2}{3}\tan\theta\Big|_0^{\pi/4}$$

$$= \frac{4}{3}-\frac{2}{3}=\frac{2}{3}$$

f $$\iint_C y\,dA = \int_0^{\pi}\int_0^{1+\cos\theta} r\sin\theta r\,dr\,d\theta$$
$$= \frac{1}{3}\int_0^{\pi} \sin\theta(1+\cos\theta)^3\,d\theta \quad \text{Let } u = 1+\cos\theta$$
$$du = -\sin\theta\,d\theta$$
$$= \frac{1}{3}\int_0^{2} u^3\,du = \left.\frac{u^4}{12}\right|_0^2 = \frac{4}{3}$$

g $$\int_{\pi/4}^{3\pi/4}\int_{\csc\theta}^{2\sin\theta} \mathrm{r}\,\mathrm{dr}\,\mathrm{d}\theta = \frac{1}{2}\int_{\pi/4}^{3\pi/4}(4\sin^2\theta - \csc^2\theta)\,\mathrm{d}\theta$$
$$= \frac{1}{2}\left[2\theta - \sin 2\theta + \cot\theta\right]_{\pi/4}^{3\pi/4} = \frac{\pi}{2}$$

c- <u>Change of variables</u>

Evaluate the following integrals in polar form

a $$\int_0^2\int_0^{\sqrt{4-y^2}} (x^2+y^2)\,dx\,dy$$

b $$\int_0^2\int_0^{x} y\,dy\,dx$$

c $$\int_{\sqrt{2}}^2\int_{\sqrt{4-y^2}}^{y} dx\,dy$$

d $$\int_{-1}^1\int_{-\sqrt{1-x^2}}^{\sqrt{1-x^2}} \frac{2}{(1+x^2+y^2)^2}\,dy\,dx$$

e $$\int_0^1\int_x^{\sqrt{2-x^2}} (x+2y)\,dy\,dx$$

$\boxed{f}$ $\iint_S (x+y)\,dA$ where s is the area bounded in fig.10

$\boxed{h}$ $\iint_T (x^2+y^2)\,dA$

where T is the area bounded in fig.9

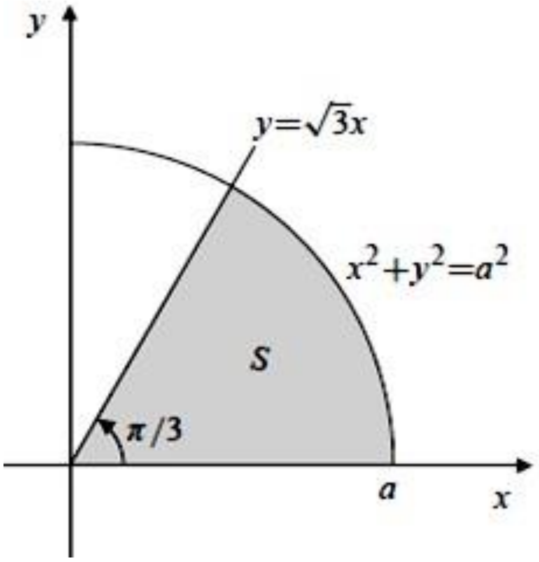


Figure 10

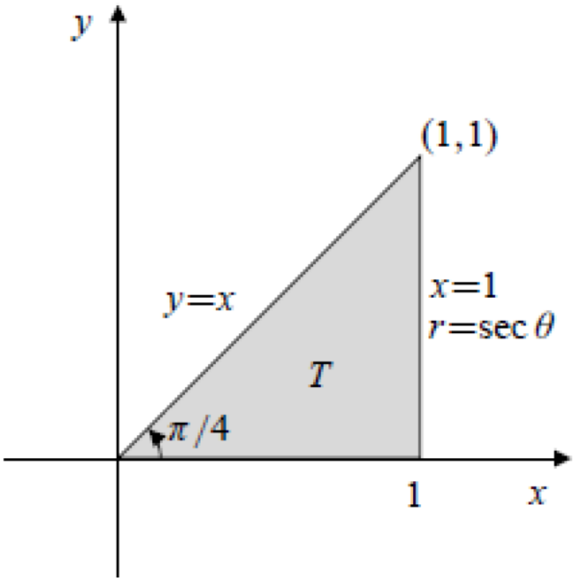
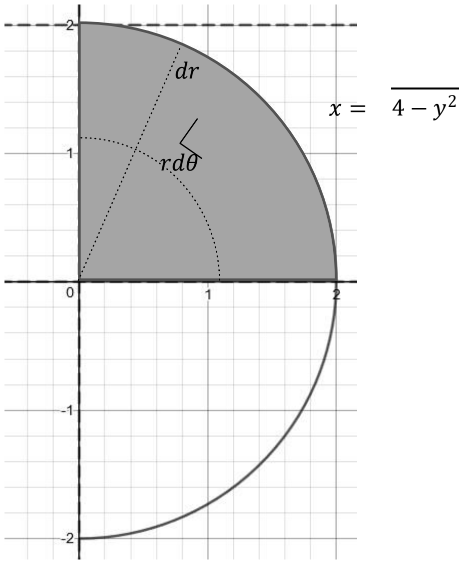


Figure 9

Solution

a- $\int_0^2 \int_0^{\sqrt{4-y^2}} (x^2 + y^2)\, dx\, dy$



$x_2 = \sqrt{4 - y^2}$, $x_1 = 0$

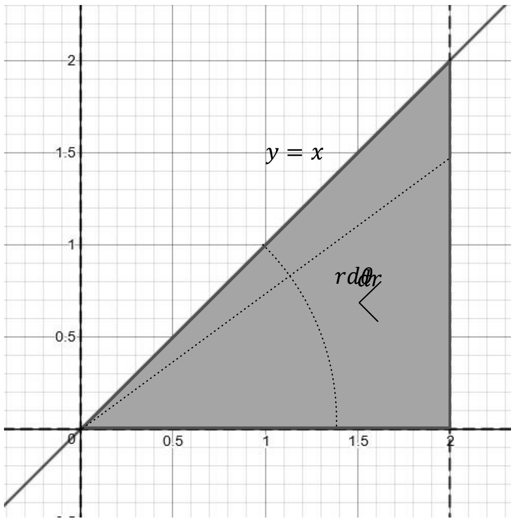
$y_2 = 2$, $y_1 = 0$

$f(x, y) = x^2 + y^2 = r^2$, $dxdy = rdrd\theta$

$$\int_0^2 \int_0^{\sqrt{4-y^2}} (x^2 + y^2)\, dx\, dy = \int_{\theta_1=0}^{\theta_2=\frac{\pi}{2}} \int_{r_1=0}^{r_2=2} r^2 \; rdrd\theta$$

$$= \int_{\theta_1=0}^{\theta_2=\frac{\pi}{2}} \int_{r_1=0}^{r_2=2} r^3\, drd\theta = \int_0^{\pi/2} \left[\frac{r^4}{4}\right]_0^2 drd\theta = 4\int_0^{\pi/2} d\theta = 2\pi$$

b- $\int_0^2 \int_0^x y\, dy\, dx$



$y_2 = x$, $y_1 = 0$

$x_2 = 2$, $x_1 = 0$

$f(x, y) = y = r \sin\theta$, $dxdy = rdrd\theta$

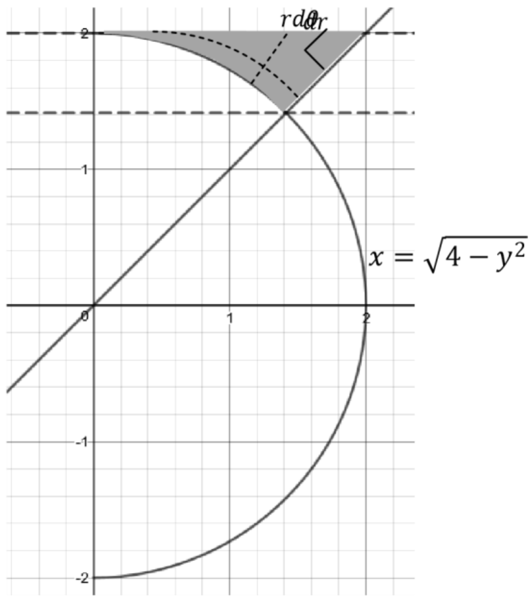
$$\int_0^2 \int_0^x \mathrm{y\, dy\, dx} = \int_0^{\pi/4} \int_0^{2\sec\theta} \mathrm{r}^2 \sin\theta\, \mathrm{dr\, d}\theta$$

$$= \frac{8}{3} \int_0^{\pi/4} \tan\theta \sec^2\theta\, \mathrm{d}\theta = \frac{4}{3}$$

c- $\displaystyle\int_{\sqrt{2}}^{2}\int_{\sqrt{4-y^2}}^{y} dx\,dy$

$x_2 = y \quad , \quad x_1 = \sqrt{4-y^2}$

$y_2 = 2 \quad , \quad y_1 = \sqrt{2}$



$f(x,y) = 1 \quad , \quad dxdy = rdrd\theta$

$$\int_{\sqrt{2}}^{2}\int_{\sqrt{4-y^2}}^{y} dy\,dx = \int_{\pi/4}^{\pi/2}\int_{2}^{2\csc\theta} r\,dr\,d\theta$$

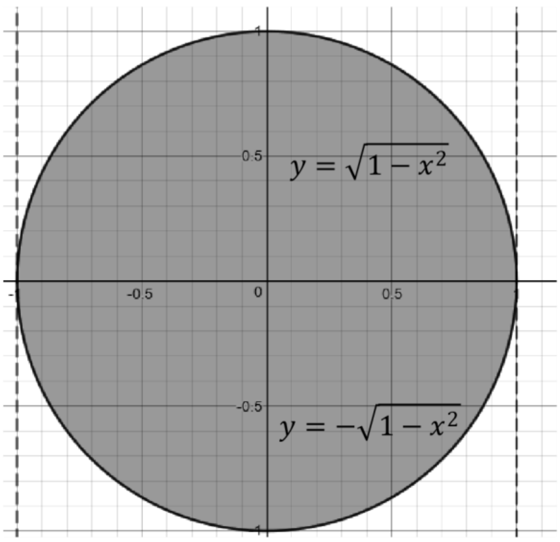
$$= \int_{\pi/6}^{\pi/4}(2\csc^2\theta - 2)\,d\theta = \left[-2\cot\theta - \tfrac{1}{2}\theta\right]_{\pi/4}^{\pi/2}$$

$$= 2 - \frac{\pi}{2}$$

d- $\displaystyle\int_{-1}^{1}\int_{-\sqrt{1-x^2}}^{\sqrt{1-x^2}} \frac{2}{(1+x^2+y^2)^2}\,dy\,dx$

$y_2 = \sqrt{1-x^2} \quad , \quad y_1 = -\sqrt{1-x^2}$

$x_2 = 1 \quad , \quad x_1 = -1$

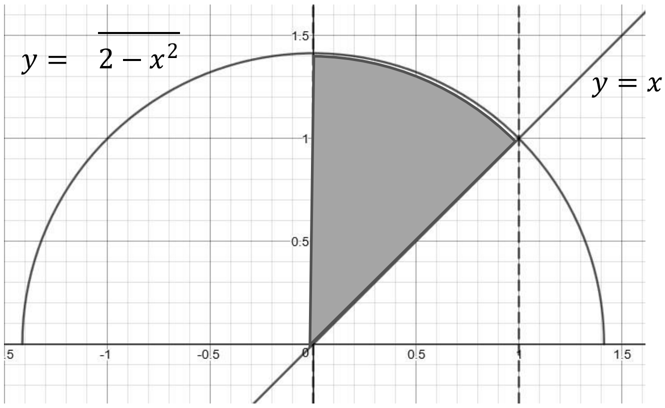


$$\frac{2}{(1+x^2+y^2)} = \frac{2}{(1+r^2)} \quad , \quad dxdy = rdrd\theta$$

$$= \int_{-1}^{1}\int_{-\sqrt{1-x^2}}^{\sqrt{1-x^2}} \frac{2}{(1+x^2+y^2)^2}\,dy\,dx$$

$$= 4\int_{0}^{\pi/2}\int_{0}^{1} \frac{2r}{(1+r^2)^2}\,dr\,d\theta = 4\int_{0}^{\pi/2}\left[-\frac{1}{1+r^2}\right]_{0}^{1} d\theta = 2\int_{0}^{\pi/2} d\theta = \pi$$

e- $$\int_0^1 \int_x^{\sqrt{2-x^2}} (x + 2y)\, dy\, dx$$



$(x + 2y) = r(\cos\theta + 2\sin\theta)$,

$dxdy = rdrd\theta$

$x_2 = 1$, $x_1 = 0$

$y_2 = \sqrt{2 - x^2}$, $y_1 = x$

$$\int_0^1 \int_x^{\sqrt{2-x^2}} (x + 2y)\, dy\, dx = \int_{\pi/4}^{\pi/2} \int_0^{\sqrt{2}} (r\cos\theta + 2r\sin\theta)\, r\, dr\, d\theta$$

$$= \int_{\pi/4}^{\pi/2} \left[\frac{r^3}{3}\cos\theta + \frac{2r^3}{3}\sin\theta\right]_0^{\sqrt{2}} d\theta = \int_{\pi/4}^{\pi/2} \left(\frac{2\sqrt{2}}{3}\cos\theta + \frac{4\sqrt{2}}{3}\sin\theta\right) d\theta$$

$$= \left[\frac{2\sqrt{2}}{3}\sin\theta - \frac{4\sqrt{2}}{3}\cos\theta\right]_{\pi/4}^{\pi/2} = \frac{2(1+\sqrt{2})}{3}$$

f- $$\iint_S (x + y)\, dA = \int_0^{\pi/3} d\theta \int_0^a (r\cos\theta + r\sin\theta) r\, dr$$

$$= \int_0^{\pi/3} (\cos\theta + \sin\theta)\, d\theta \int_0^a r^2\, dr$$

$$= \frac{a^3}{3}(\sin\theta - \cos\theta)\Big|_0^{\pi/3}$$

$$= \left[\left(\frac{\sqrt{3}}{2} - \frac{1}{2}\right) - (-1)\right]\frac{a^3}{3} = \frac{(\sqrt{3}+1)a^3}{6}$$

h- $$\iint_T (x^2+y^2)\,dA = \int_0^{\pi/4} d\theta \int_0^{\sec\theta} r^3\,dr$$

$$= \frac{1}{4}\int_0^{\pi/4} \sec^4\theta\,d\theta$$

$$= \frac{1}{4}\int_0^{\pi/4} (1+\tan^2\theta)\sec^2\theta\,d\theta \quad \text{Let } u=\tan\theta$$

$$du = \sec^2\theta\,d\theta$$

$$= \frac{1}{4}\int_0^1 (1+u^2)\,du$$

$$= \frac{1}{4}\left(u+\frac{u^3}{3}\right)\Big|_0^1 = \frac{1}{3}$$

d- <u>Triple integral</u>

Evaluate the following integrals:

a $$\int_0^1\int_0^1\int_0^1 (x^2+y^2+z^2)\,dz\,dy\,dx$$

b $$\int_0^{\sqrt{2}}\int_0^{3y}\int_{x^2+3y^2}^{8-x^2-y^2} dz\,dx\,dy$$

c $$\int_0^2\int_{-\sqrt{4-y^2}}^{\sqrt{4-y^2}}\int_0^{2x+y} dz\,dx\,dy$$

d $$\int_0^{\pi/6}\int_0^1\int_{-2}^3 y\sin z\,dx\,dy\,dz$$

e $$\int_0^1\int_0^{1-x^2}\int_3^{4-x^2-y} x\,dz\,dy\,dx$$

Solution

a- $$\int_0^1\int_0^1\int_0^1 (x^2+y^2+z^2)\,dz\,dy\,dx = \int_0^1\int_0^1 \left(x^2+y^2+\tfrac{1}{3}\right) dy\,dx$$
$$= \int_0^1 \left(x^2+\tfrac{2}{3}\right) dx = 1$$

b- $$\int_0^{\sqrt{2}}\int_0^{3y}\int_{x^2+3y^2}^{8-x^2-y^2} dz\,dx\,dy = \int_0^{\sqrt{2}}\int_0^{3y} (8-2x^2-4y^2)\,dx\,dy$$
$$= \int_0^{\sqrt{2}} \left[8x-\tfrac{2}{3}x^3-4xy^2\right]_0^{3y} dy = \int_0^{\sqrt{2}} (24y-18y^3-12y^3)\,dy$$
$$= \left[12y^2-\tfrac{15}{2}y^4\right]_0^{\sqrt{2}} = 24-30=-6$$

c- $$\int_0^2\int_{-\sqrt{4-y^2}}^{\sqrt{4-y^2}}\int_0^{2x+y} dz\,dx\,dy = \int_0^2\int_{-\sqrt{4-y^2}}^{\sqrt{4-y^2}} (2x+y)\,dx\,dy$$
$$= \int_0^2 \left[x^2+xy\right]_{-\sqrt{4-y^2}}^{\sqrt{4-y^2}} dy = \int_0^2 (4-y^2)^{1/2}(2y)\,dy$$
$$= \left[-\tfrac{2}{3}(4-y^2)^{3/2}\right]_0^2 = \tfrac{2}{3}(4)^{3/2} = \tfrac{16}{3}$$

d- $$\int_0^{\pi/6}\int_0^1\int_{-2}^3 y\sin z\,dx\,dy\,dz = \int_0^{\pi/6}\int_0^1 5y\sin z\,dy\,dz$$
$$= \tfrac{5}{2}\int_0^{\pi/6} \sin z\,dz = \frac{5\left(2-\sqrt{3}\right)}{4}$$

e- $$\int_0^1\int_0^{1-x^2}\int_3^{4-x^2-y} x\,dz\,dy\,dx = \int_0^1\int_0^{1-x^2} x(1-x^2-y)\,dy\,dx$$
$$= \int_0^1 x\left[(1-x^2)^2-\tfrac{1}{2}(1-x^2)\right] dx = \int_0^1 \tfrac{1}{2}x(1-x^2)^2\,dx$$
$$= \left[-\tfrac{1}{12}(1-x^2)^3\right]_0^1 = \tfrac{1}{12}$$

e- <u>Surface area</u>

Find the area of the following surfaces:

a- $Z=f(x,y)=6-3x-2y$lies in the region shown in fig. 11

b- $Z=x^2+y^2$ lies in the region shown in fig. 12

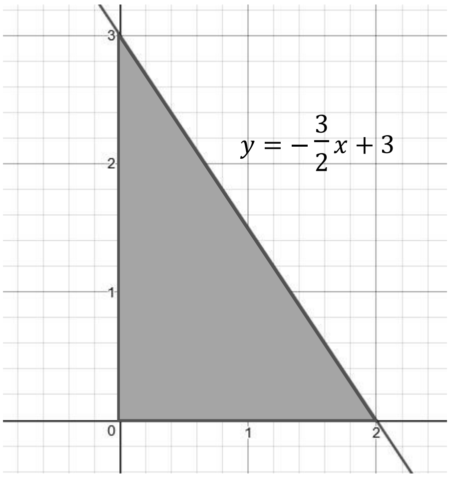


Figure 11

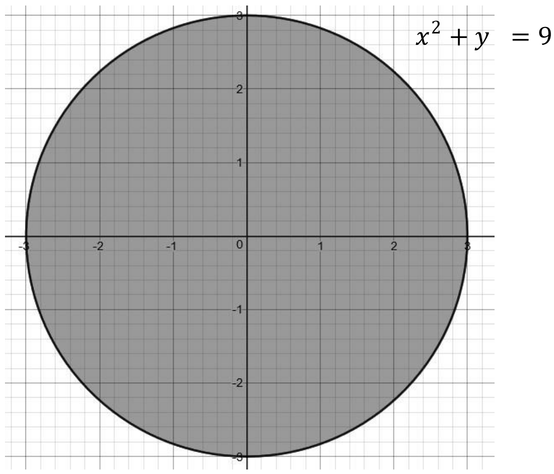


Figure 12

Solution

a- $Z=6-3x-2y$

$$\frac{\partial \mathrm{f}}{\partial \mathrm{x}} = -3 \quad , \quad \frac{\partial \mathrm{f}}{\partial \mathrm{y}} = -2 \quad , \quad 0 \le x \le 2 \quad , \quad 0 \le y \le -\frac{3}{2}\, x + 3$$

$$S = \iint\limits_R \sqrt{1 + \left(\frac{\partial \mathrm{f}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{f}}{\partial \mathrm{y}}\right)^2}\, dA$$

$$= \int_0^2 \int_0^{-\frac{3}{2}x+3} \sqrt{(-3)^2 + (-2)^2 + 1}\; dy\, dx = \sqrt{14} \int_0^2 \left(-\frac{3}{2}\, x + 3\right) dx$$

$$S = \sqrt{14}\left(-\frac{3}{4}x^2 + 3x\right)\Bigg|_0^2 = 3\sqrt{14}$$

b- $Z = x^2 + y^2$

$$\frac{\partial f}{\partial x} = 2x \quad , \quad \frac{\partial f}{\partial y} = 2y$$

$$S = \iint_R \sqrt{1 + \left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}\, dA$$

$$= \iint_R \sqrt{1 + 4x^2 + 4y^2}\, dA \qquad r^2 = x^2 + y^2$$

$$= \int_0^{2\pi} \int_0^{3} r\sqrt{1 + 4r^2}\, dr\, d\theta = \frac{2}{24}\int_0^{2\pi} [1 + 4r^2]^{\frac{3}{2}} \Big|_0^3 d\theta = 18 \int_0^{2\pi} d\theta = 36\pi$$