

# Formulas-3

Fubini's Theorem

$$V = \iint_R f(x, y) dA = \int_c^d \int_a^b f(x, y) dx dy = \int_a^b \int_c^d f(x, y) dy dx$$

if  $R$  is defined by  $a \leq x \leq b$  and  $g_1(x) \leq y \leq g_2(x)$  then,

$$V = \int_a^b \int_{g_1(x)}^{g_2(x)} f(x, y) dy dx$$

Notice: The functions  $g_n(x)$  are evaluated first.

## Properties

$$\begin{aligned} \iint_R c f(x, y) dA &= c \iint_R f(x, y) dA \\ \iint_R f(x, y) \pm g(x, y) dA &= \iint_R f(x, y) dA \pm \iint_R g(x, y) dA \\ \iint_R f(x, y) dA &\geq 0 \text{ if } f(x, y) \geq 0 \text{ on } R \\ \iint_R f(x, y) dA &\geq \iint_R g(x, y) dA \text{ if } f(x, y) \geq g(x, y) \text{ on } R \end{aligned}$$

If  $R_1$  and  $R_2$  are non-overlapping regions,

$$\iint_R f(x, y) dA = \iint_{R_1} f(x, y) dA + \iint_{R_2} f(x, y) dA$$

$$A = \iint_R dA = \int_{x_1}^{x_2} \int_{y_1}^{y_2} dy dx = \int_{\theta_1}^{\theta_2} \int_{r_1}^{r_2} r dr d\theta$$

$$V = \iint_R f(x, y) dA$$

$$\text{Average Value} = \frac{1}{\text{Area of } R} \iint_R f dA \quad \text{OR} \quad \frac{1}{\text{Volume of } D} \iiint_D F dV$$

$$\begin{aligned} V &= \iiint_D dV \\ &= \int_{x_1}^{x_2} \int_{y_1}^{y_2} \int_{z_1}^{z_2} dz dy dx \\ &= \int_{\theta_1}^{\theta_2} \int_{r_1}^{r_2} \int_{z_1}^{z_2} r dz dr d\theta \\ &= \int_{\rho_1}^{\rho_2} \int_{\phi_1}^{\phi_2} \int_{\theta_1}^{\theta_2} \rho^2 \sin(\phi) d\theta d\phi d\rho \end{aligned}$$

# Mass and First Moments

## 3D Solids

$\delta$  is the density function.

$$\text{Mass: } M = \iiint_D \delta \, dV$$

$$\text{First Moments: } M_{yz} = \iiint_D x\delta \, dV, M_{xz} = \iiint_D y\delta \, dV, M_{xy} = \iiint_D z\delta \, dV$$

$$\text{Center of mass: } \bar{x} = \frac{M_{yz}}{M}, \bar{y} = \frac{M_{xz}}{M}, \bar{z} = \frac{M_{xy}}{M}$$

## 2D Plates

$$\text{Mass: } M = \iint_R \delta \, dA$$

$$\text{First Moments: } M_y = \iint_R x\delta \, dA, M_x = \iint_R y\delta \, dA$$

$$\text{Center of mass: } \bar{x} = \frac{M_y}{M}, \bar{y} = \frac{M_x}{M}$$

# Moments of Inertia

## 3D Solids

$$\text{About x-axis: } I_x = \iiint_D (y^2 + z^2)\delta \, dV$$

$$\text{About y-axis: } I_y = \iiint_D (x^2 + z^2)\delta \, dV$$

$$\text{About z-axis: } I_z = \iiint_D (x^2 + y^2)\delta \, dV$$

$$\text{About a line L: } I_L = \iiint_D r^2(x, y, z)\delta \, dV$$

## 2D Plates

$$\text{About x-axis: } I_x = \iint_R y^2\delta \, dA$$

$$\text{About y-axis: } I_y = \iint_R x^2\delta \, dA$$

$$\text{About a line L: } I_L = \iint_R r^2(x, y)\delta \, dA$$

$$\text{About the origin: } I_O = \iint_R (x^2 + y^2)\delta \, dA = I_x + I_y$$

# Joint probability density function

## Conditions

$$\begin{aligned}f(x, y) &\geq 0 \\ \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) dx dy &= 1 \\ P((X, Y) \in R) &= \iint_R f(x, y) dx dy\end{aligned}$$

## Mean and expected value

$$\begin{aligned}\mu_X &= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x f(x, y) dx dy \\ \mu_Y &= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} y f(x, y) dx dy\end{aligned}$$

## Cylindrical Coordinates $(r, \theta, z)$

$$\begin{aligned}x &= r \cos \theta \\ y &= r \sin \theta \\ z &= z \\ r^2 &= x^2 + y^2 \\ \tan \theta &= \frac{y}{x} \\ \iiint_T dV &= \iiint r \, dr d\theta dz\end{aligned}$$

## Spherical Coordinates $(\rho, \phi, \theta)$

$$\begin{aligned}r &= \rho \sin(\phi) \\ x &= r \cos(\theta) = \rho \sin(\phi) \cos(\theta) \\ y &= r \sin(\theta) = \rho \sin(\phi) \sin(\theta) \\ z &= \rho \cos(\phi) \\ \rho &= \sqrt{x^2 + y^2 + z^2} = \sqrt{r^2 + z^2} \\ \iiint_T dV &= \iiint \rho^2 \sin \phi \, d\rho d\phi d\theta\end{aligned}$$

## Jacobian

$$\begin{aligned}J(u, v) &= \begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial x}{\partial v} \\ \frac{\partial y}{\partial u} & \frac{\partial y}{\partial v} \end{vmatrix} = \frac{\partial(x, y)}{\partial(u, v)} \\ \iint_R f(x, y) dx dy &= \iint_G f(g(u, v), h(u, v)) \left| \frac{\partial(x, y)}{\partial(u, v)} \right| du dv \\ J(u, v, w) &= \begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial x}{\partial v} & \frac{\partial x}{\partial w} \\ \frac{\partial y}{\partial u} & \frac{\partial y}{\partial v} & \frac{\partial y}{\partial w} \\ \frac{\partial z}{\partial u} & \frac{\partial z}{\partial v} & \frac{\partial z}{\partial w} \end{vmatrix} = \frac{\partial(x, y, z)}{\partial(u, v, w)}\end{aligned}$$

$$\iiint_D f(x,y,z)dx dy dz = \iiint_B f(g(u,v,w),h(u,v,w),k(u,v,w)) \left|\frac{\partial(x,y,z)}{\partial(u,v,w)}\right|du dv dw$$