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Glossary of Formulas

Law of Sines:

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}$$

where a, b and c are the sides of a triangle and α, β and γ are the angles opposite to these sides.

Law of Cosines:

$$a^2 + b^2 - 2ab\cos\gamma = c^2$$

with Pythagoras's Theorem $a^2 + b^2 = c^2$ as special case when $\gamma = \pi / 2$

Cosine and Sine for Sum and Difference:

$$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$$
$$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$$

Special cases:

$$\cos(2\alpha) = \cos^2\alpha - \sin^2\alpha$$
$$\sin(2\alpha) = 2\sin\alpha\cos\alpha$$

Trigonometric Identity:

$$\cos^2\alpha + \sin^2\alpha = 1$$

Gradient of Scalar Field $\lambda(x, y)$:

$$\nabla \lambda = \left(\frac{\partial \lambda}{\partial x}, \frac{\partial \lambda}{\partial y} \right)$$

Divergence of Vector Field
$\phi = (\phi_1(x, y), \phi_2(x, y))$:

$$\nabla \cdot \phi = \frac{\partial \phi_1}{\partial x} + \frac{\partial \phi_2}{\partial y}$$

Dot product of vectors
$\phi = (\phi_1(x, y), \phi_2(x, y))$ and $\psi = (\psi_1(x, y), \psi_2(x, y))$:

$$\phi \cdot \psi = \phi_1 \psi_1 + \phi_2 \psi_2$$

Tangent and Normal
to parameterized curve $(x(t), y(t))$:

$$\mathbf{t} = (x'(t), y'(t))$$

$$\mathbf{n} = (y'(t), -x'(t))$$

The dot product of normal and tangent is zero:

$$\mathbf{t} \cdot \mathbf{n} = 0$$

Laplacian:

$$\nabla^2 \lambda = \nabla \cdot \nabla \lambda = \frac{\partial^2 \lambda}{\partial x^2} + \frac{\partial^2 \lambda}{\partial y^2}$$

Gauss's Integral Theorem:

$$\iint_R \nabla \cdot \phi dxdy = \oint_C \phi \cdot \mathbf{n} ds$$

Euler's Equation:

$$F_y - \frac{d}{dx} F_{y'} = 0$$

minimizes the integral

$$\int_a^b F(x, y, y')dx$$

with respect to the function $y(x), \quad a < x < b$

Special Case
when x is not included:

$$F - y' F_{y'} = c$$

Euler's Equation in 2D

$$F_u - \frac{\partial}{\partial x} F_p - \frac{\partial}{\partial y} F_q = 0$$

minimizes the integral

$$\iint_R F(x, y, u, p, q) dxdy$$

with respect to $u(x, y)$ on R where

$$p = \frac{\partial u}{\partial x} \quad \text{and} \quad q = \frac{\partial u}{\partial y}$$

Jacobian Determinant
for change of coordinates $x = f(u, v)$, $y = g(u, v)$:

$$dxdy = |J|dudv$$

with

$$J = \begin{vmatrix} f_u & f_v \\ g_u & g_v \end{vmatrix}$$

Special case for polar coordinates
$x = r\cos\theta$, $y = r\sin\theta$

$$dxdy = r\,drd\theta$$

Beckmann's Equations:

$$k\frac{\phi}{|\phi|} = \nabla\lambda$$

minimizes

$$\iint_R k|\phi|dxdy$$

subject to the constraint

$$\nabla\cdot\phi + z = 0$$

Market Area and Transportation Work:

$$A(P_n) = \iint_{P_n} dydx = nR^2\cos\frac{\pi}{n}\sin\frac{\pi}{n}$$

$$T(P_n) = \iint_{P_n}\sqrt{x^2+y^2}\,dydx = \frac{nR^3}{3}\left(\cos\frac{\pi}{n}\sin\frac{\pi}{n} + \cos^3\frac{\pi}{n}\ln\tan\left(\frac{\pi}{4}+\frac{\pi}{2n}\right)\right)$$

are the market area of a regular n-sided polygon with radius R. In the limiting case of a circle: $\lim_{n\to\infty} A(P_n) = \pi R^2$ and $\lim_{n\to\infty} T(P_n) = \frac{2}{3}\pi R^3$. Special cases:

$n = 3$	$A = \frac{\sqrt{3}}{4}R^2$	$T = \left(\frac{\sqrt{3}}{4} + \frac{\ln(2+\sqrt{3})}{8}\right)R^3$
$n = 4$	$A = \frac{2}{3}R^2$	$T = \left(\frac{2}{3} + \frac{\sqrt{2}\ln(1+\sqrt{2})}{3}\right)R^3$
$n = 6$	$A = \frac{\sqrt{3}}{2}R^2$	$T = \left(\frac{\sqrt{3}}{2} + \frac{3\sqrt{3}\ln(3)}{8}\right)R^3$

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