ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN

ARCH 331

DR. ANNE NICHOLS

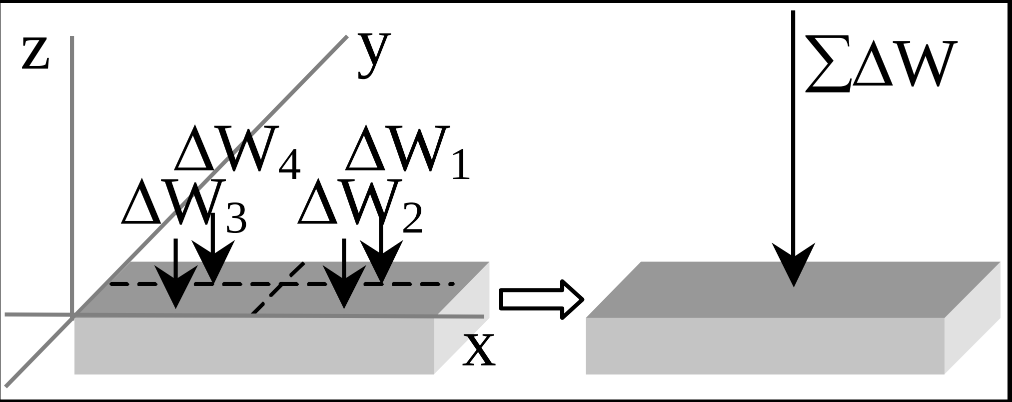
FALL 2013

lecture
nine

beam sections - geometric properties

Center of Gravity

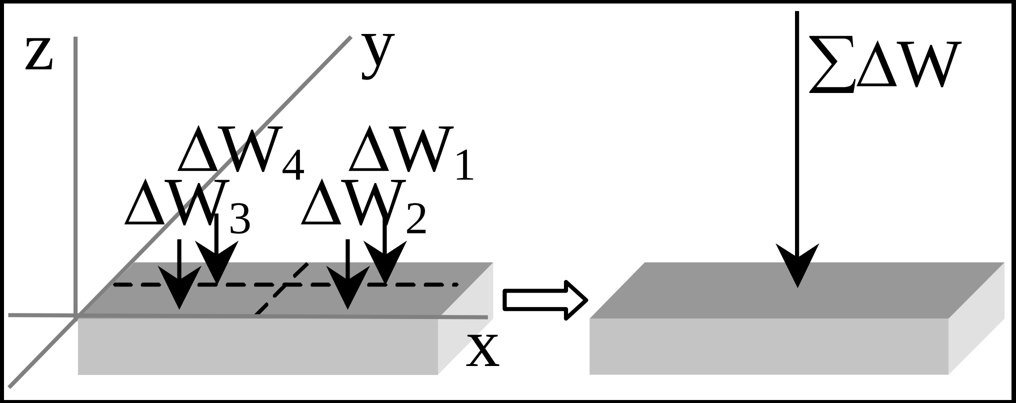
- *location of equivalent weight*
- *determined with calculus*



- *sum element weights* $W = \int dW$

Center of Gravity

- *"average" x & y from moment*



$$\sum M_y = \sum_{i=1}^{n} x_i \Delta W_i = \bar{x}W \Rightarrow \quad \bar{x} = \frac{\sum (x\Delta W)}{W}$$

"bar" means average

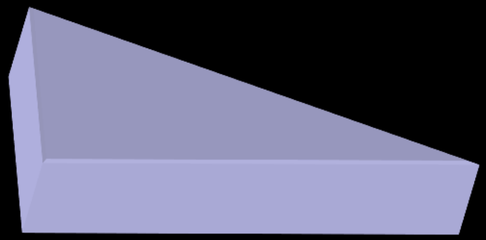
$$\sum M_x = \sum_{i=1}^{n} y_i \Delta W_i = \bar{y}W \Rightarrow \quad \bar{y} = \frac{\sum (y\Delta W)}{W}$$

Centroid

- "average" x & y of an area
- for a volume of constant thickness
  - $\Delta W = \gamma t \Delta A$ where γ is weight/volume
  - center of gravity = centroid of area

$$\bar{x} = \frac{\sum(x\Delta A)}{A}$$

$$\bar{y} = \frac{\sum(y\Delta A)}{A}$$

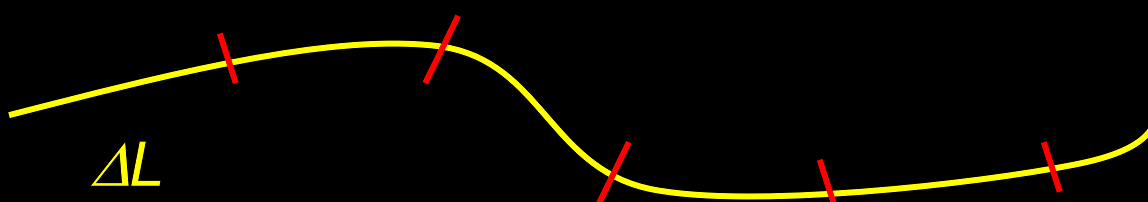


Centroid

- *for a line, sum up length*

$$\bar{x} = \frac{\sum(x\Delta L)}{\boldsymbol{L}}$$

$$\bar{y} = \frac{\sum(y\Delta L)}{\boldsymbol{L}}$$

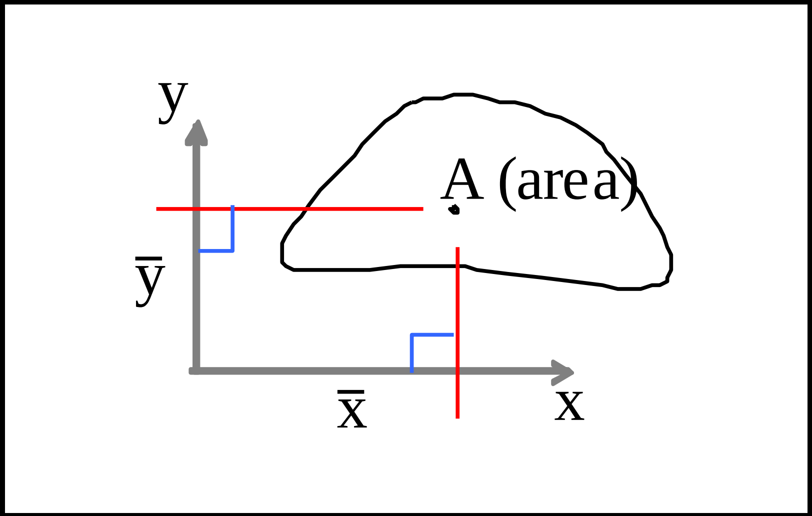


1^{st} Moment Area

- *math concept*
- *the moment of an area about an axis*

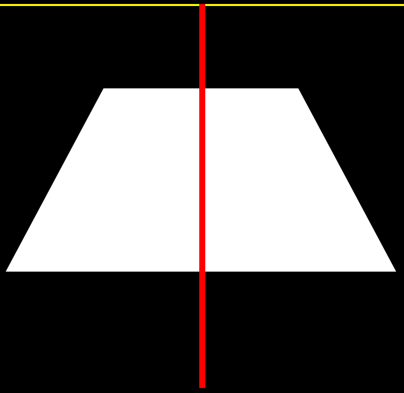
$$Q_x = \bar{y}A$$

$$Q_y = \bar{x}A$$

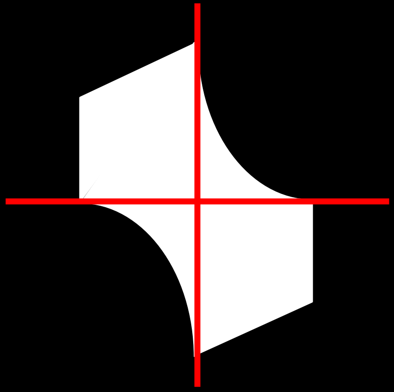


Symmetric Areas

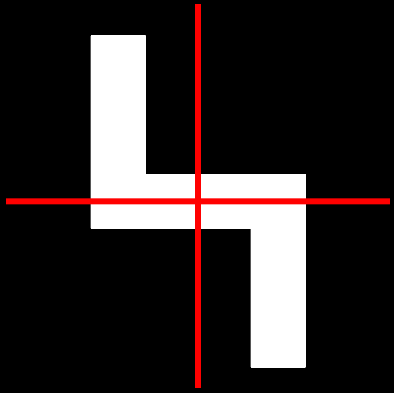
- *symmetric about an axis*



- *symmetric about a center point*

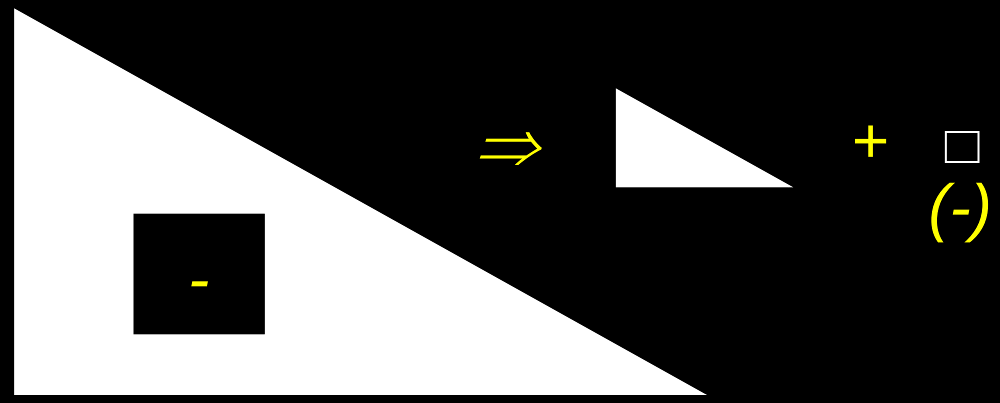


- *mirrored symmetry*



Composite Areas

- *made up of basic shapes*
- *areas can be <u>negative</u>*
- *(centroids can be negative for any area)*



Basic Procedure

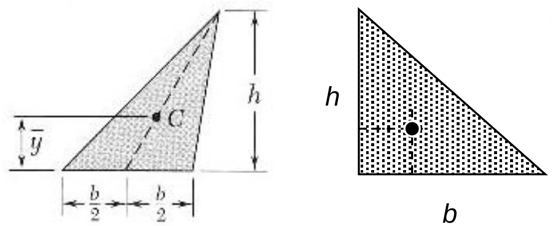
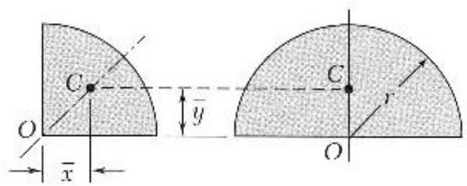
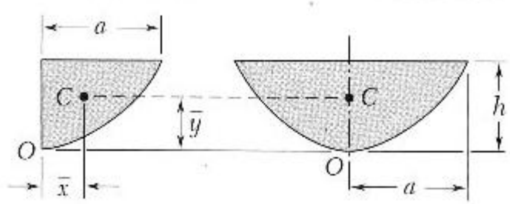
1. Draw reference origin (if not given)
2. Divide into basic shapes (+/-)
3. Label shapes
4. Draw table
5. Fill in table
6. Sum necessary columns
7. Calculate $\hat{x}$ and $\hat{y}$

Component	Area	$\bar{x}$	$\bar{x}A$	$\bar{y}$	$\bar{y}A$
Σ					

Area Centroids

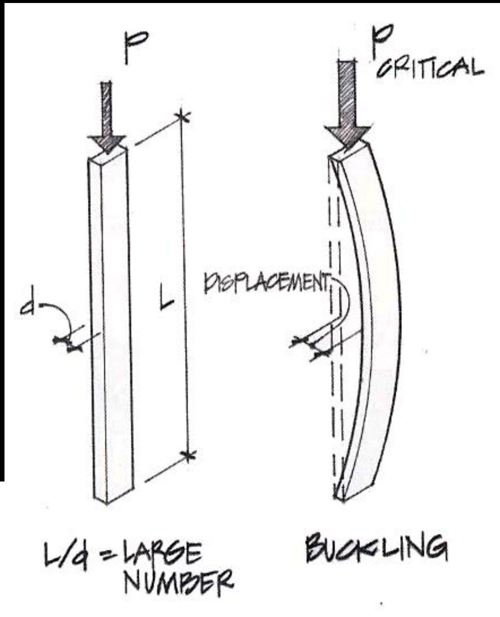
- *Table 7.1 – pg. 242*

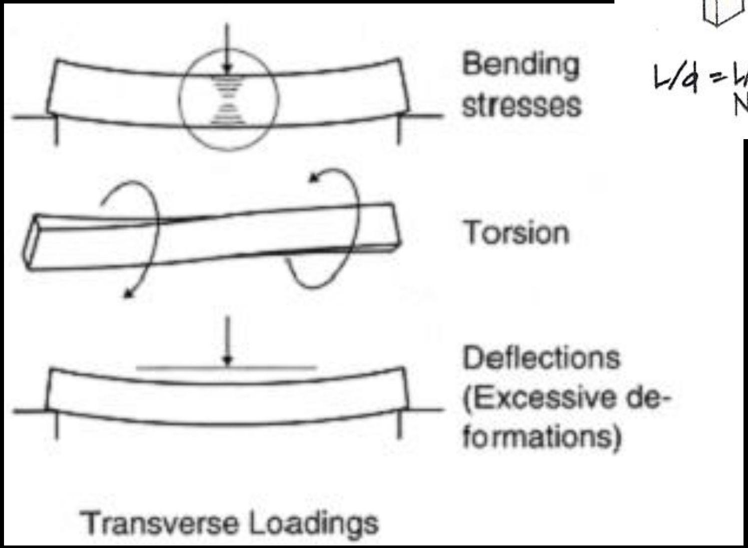
Centroids of Common Shapes of Areas and Lines

Shape		$\bar{x}$	$\bar{y}$
Triangular area		$\frac{b}{3}$ *right triangle only*	$\frac{h}{3}$
Quarter-circular area		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$
Semicircular area		0	$\frac{4r}{3\pi}$
Semiparabolic area		$\frac{3a}{8}$	$\frac{3h}{5}$
Parabolic area		0	$\frac{3h}{5}$

Moments of Inertia

- 2^{nd} moment area
  - math concept
  - area x $(distance)^2$
- need for behavior of
  - beams
  - columns



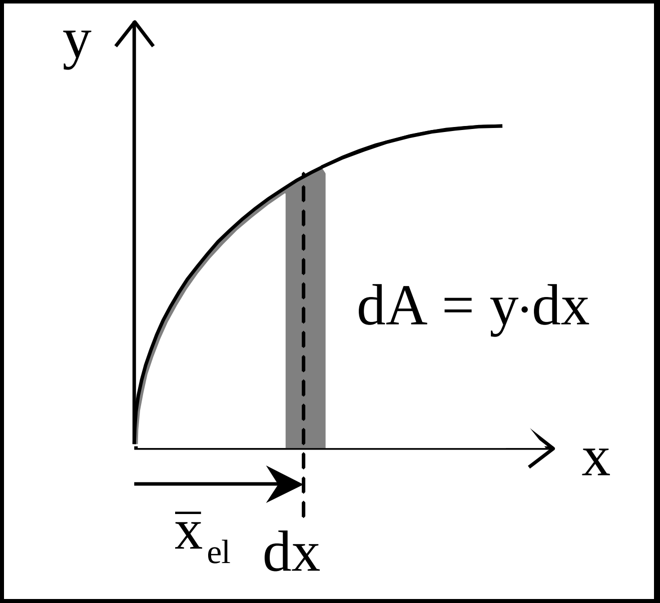


Moment of Inertia

- *about any reference <u>axis</u>*
- *can be <u>negative</u>*

$$I_y = \int x^2 dA$$

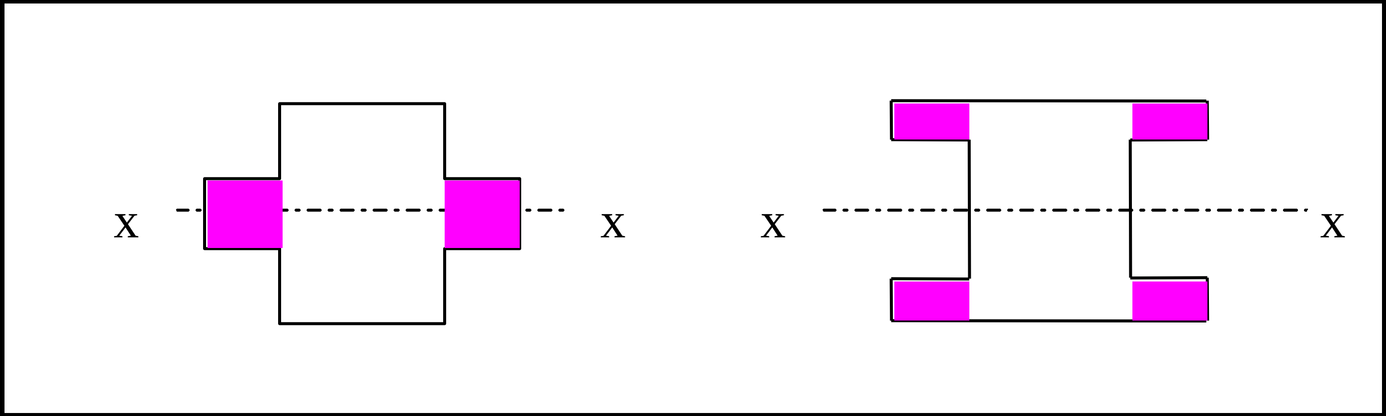
$$I_x = \int y^2 dA$$



- *resistance to bending and buckling*

Moment of Inertia

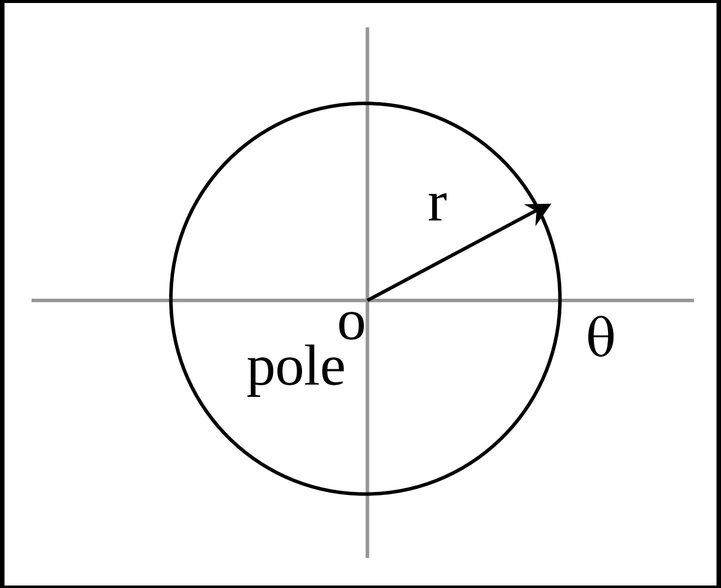
- same area moved away a distance
  - larger I



Polar Moment of Inertia

- *for roundish shapes*
- *uses polar coordinates (r and θ)*
- *resistance to twisting*

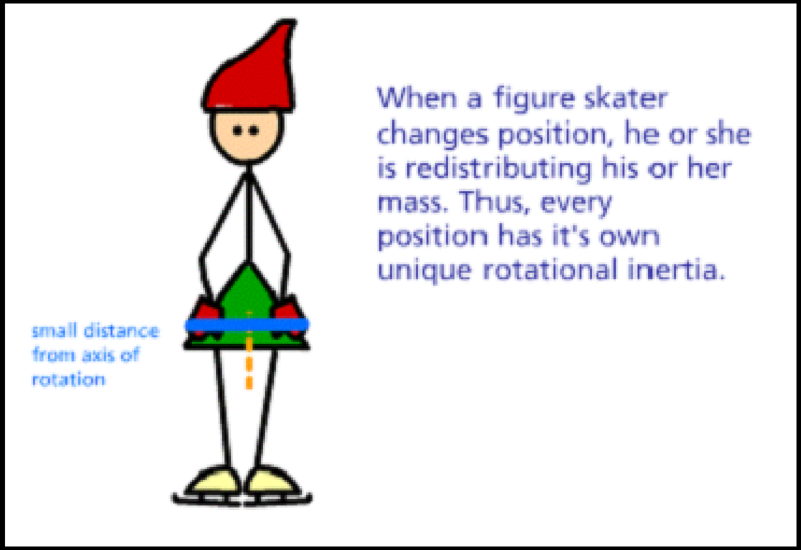
$$J_o = \int r^2 dA$$

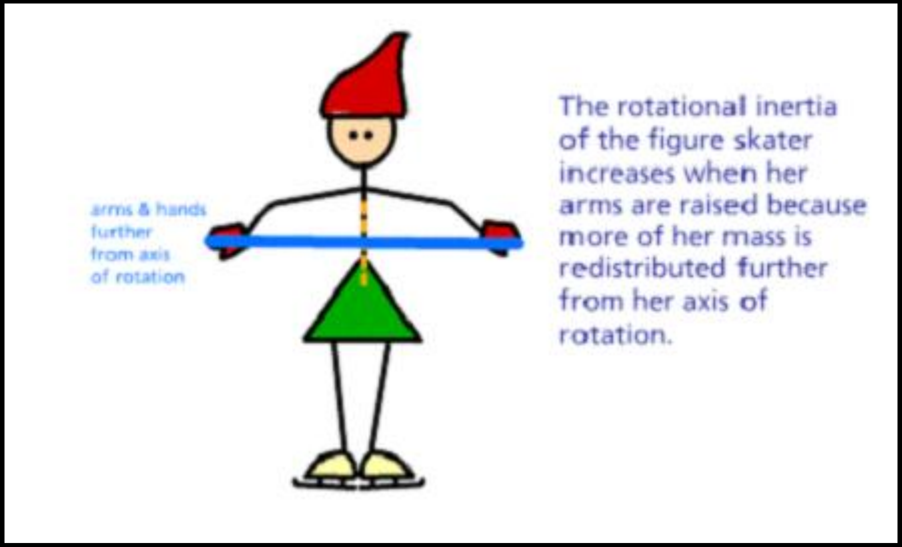


Radius of Gyration

- *measure of inertia with respect to area*

$$r_x = \sqrt{\frac{I_x}{A}}$$

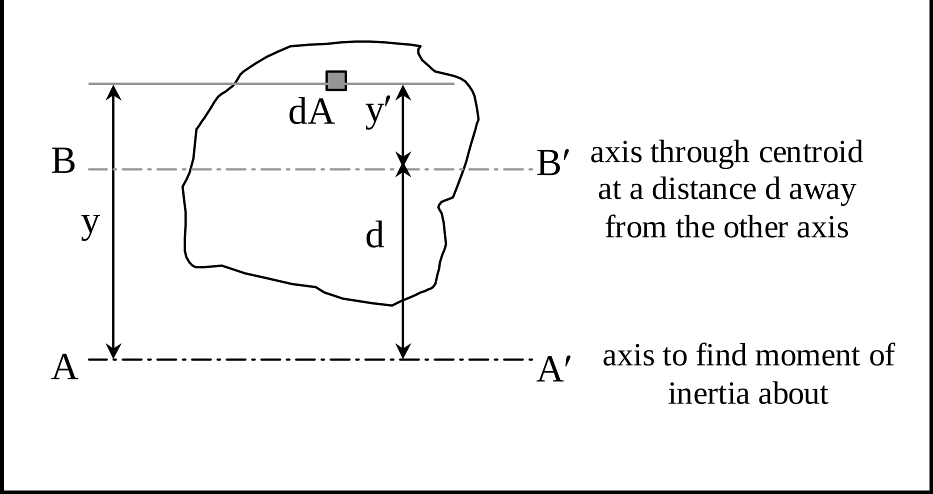




Parallel Axis Theorem

- *can find composite I once composite centroid is known (basic shapes)*

$$I_x = I_{cx} + Ad_y^{\,2}$$
$$= \bar{I}_x + Ad_y^{\,2}$$



$$I = \sum \bar{I} + \sum Ad^2$$

$$\boxed{\bar{I} = I - Ad^2}$$

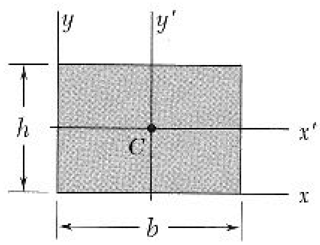
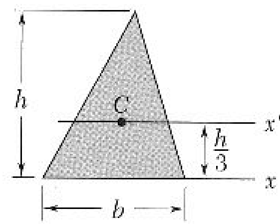
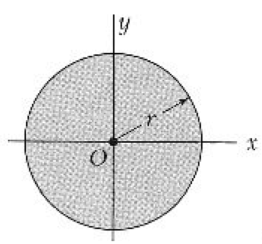
Basic Procedure

1. *Draw reference origin (if not given)*
2. *Divide into basic shapes (+/-)*
3. *Label shapes*
4. *Draw table with A, $\bar{x}$, $\bar{x}A$, $\bar{y}$, $\bar{y}A$, $\bar{I}$'s, d's, and Ad²'s*
5. *Fill in table and get $\hat{x}$ and $\hat{y}$ for composite*
6. *Sum necessary columns*
7. *Sum $\bar{I}$'s and Ad²'s*

$$(d_x = \hat{x} - \bar{x})$$
$$(d_y = \hat{y} - \bar{y})$$

Area Moments of Inertia

- Table 7.2 – pg. 252: (bars refer to centroid)
  - x, y
  - x', y'
  - C

Rectangle		$\bar{I}_{x'} = \frac{1}{12}bh^3$ $\bar{I}_{y'} = \frac{1}{12}b^3h$ $I_x = \frac{1}{3}bh^3$ $I_y = \frac{1}{3}b^3h$ $J_C = \frac{1}{12}bh(b^2 + h^2)$
Triangle		$\bar{I}_{x'} = \frac{1}{36}bh^3$ $I_x = \frac{1}{12}bh^3$
Circle		$\bar{I}_x = \bar{I}_y = \frac{1}{4}\pi r^4$ $J_O = \frac{1}{2}\pi r^4$