April 10, Week 12

Today: Chapter 9, Rotational Kinetic Energy

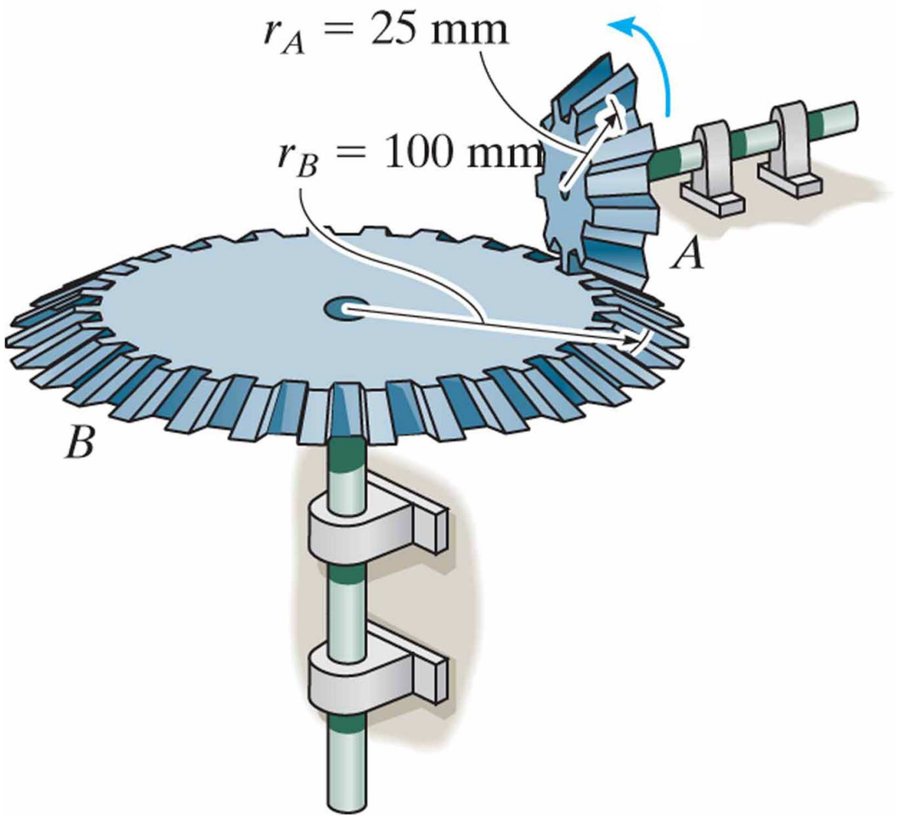
Homework Assignment #9 - Due Friday, April 12.

Mastering Physics: 7 problems from chapter 9

Written Question: 10.80

Connected Objects Example

With what angular velocity must gear A rotate if we wish gear B to rotate at $100\,RPM$?



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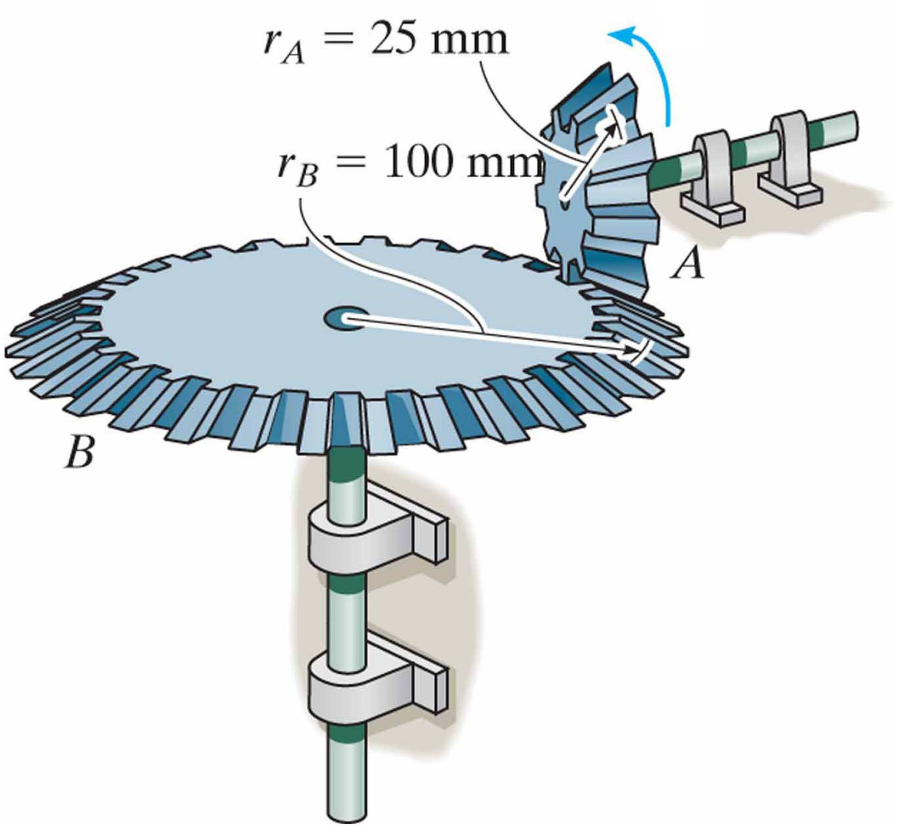

(a) $25\,RPM$

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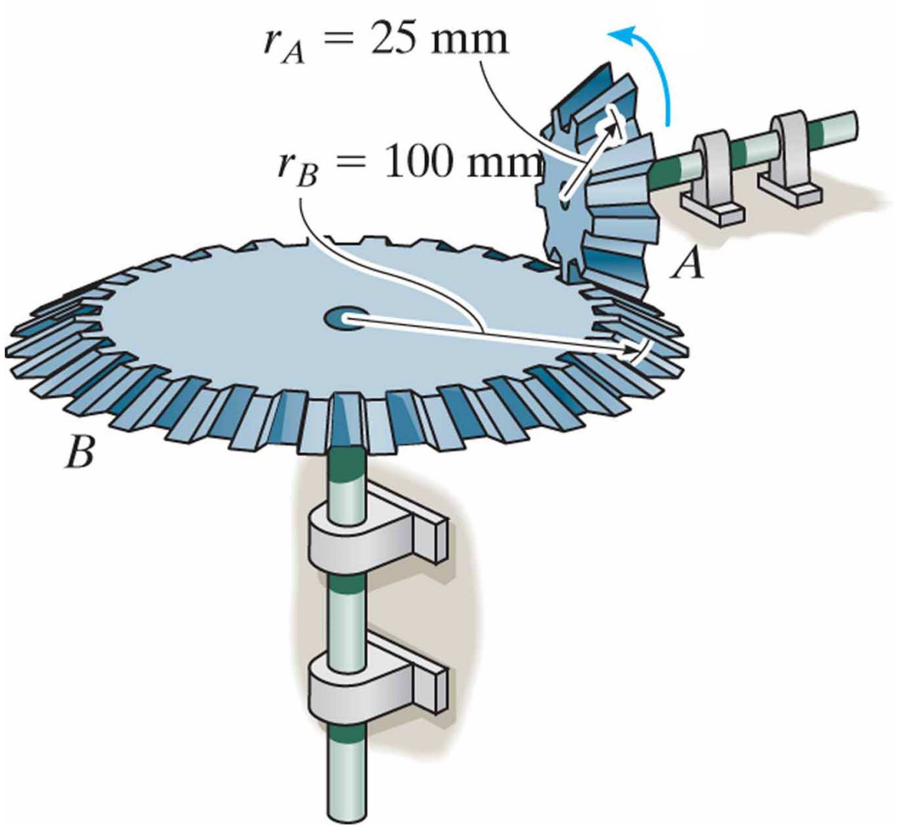

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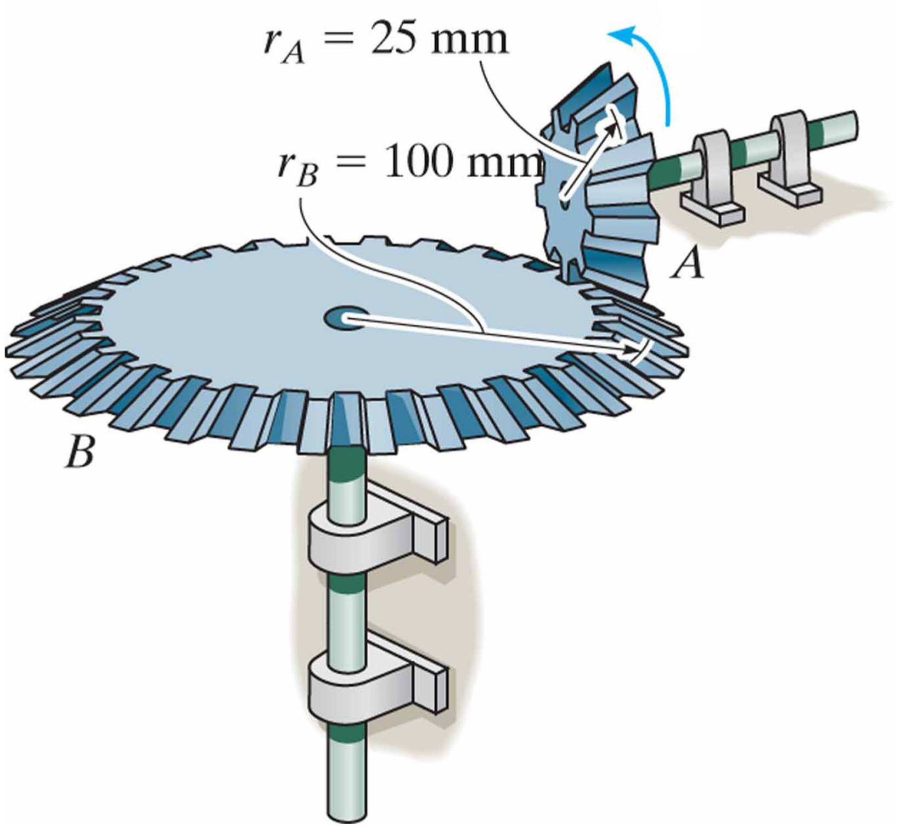

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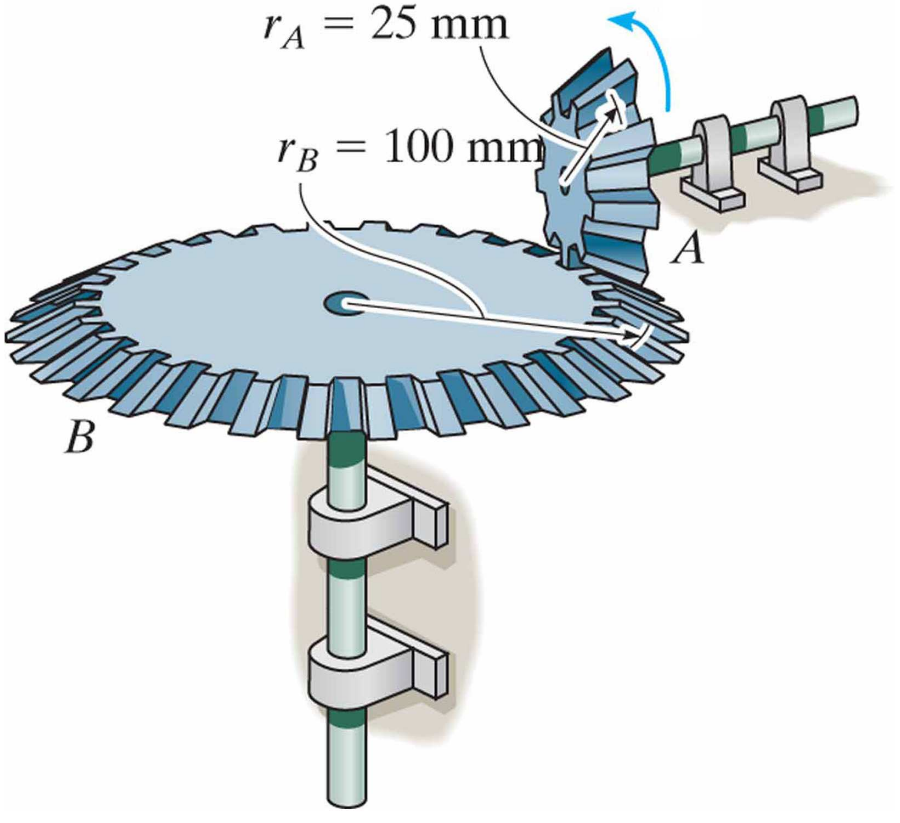

(a) $25\,RPM$

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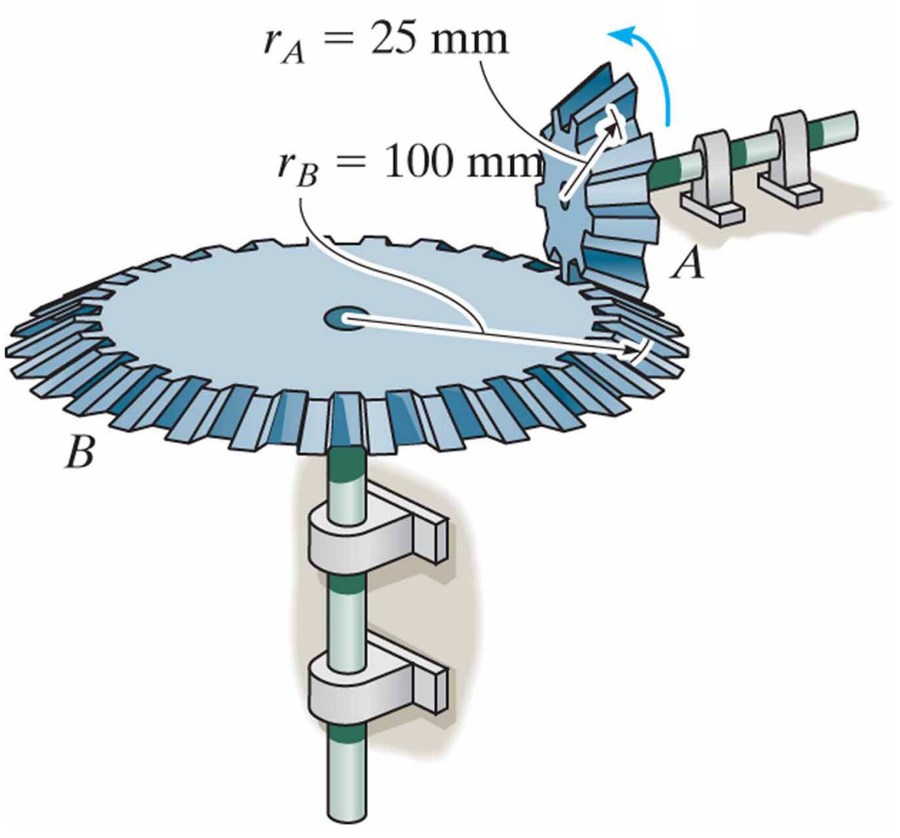

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(e) $400\,RPM$

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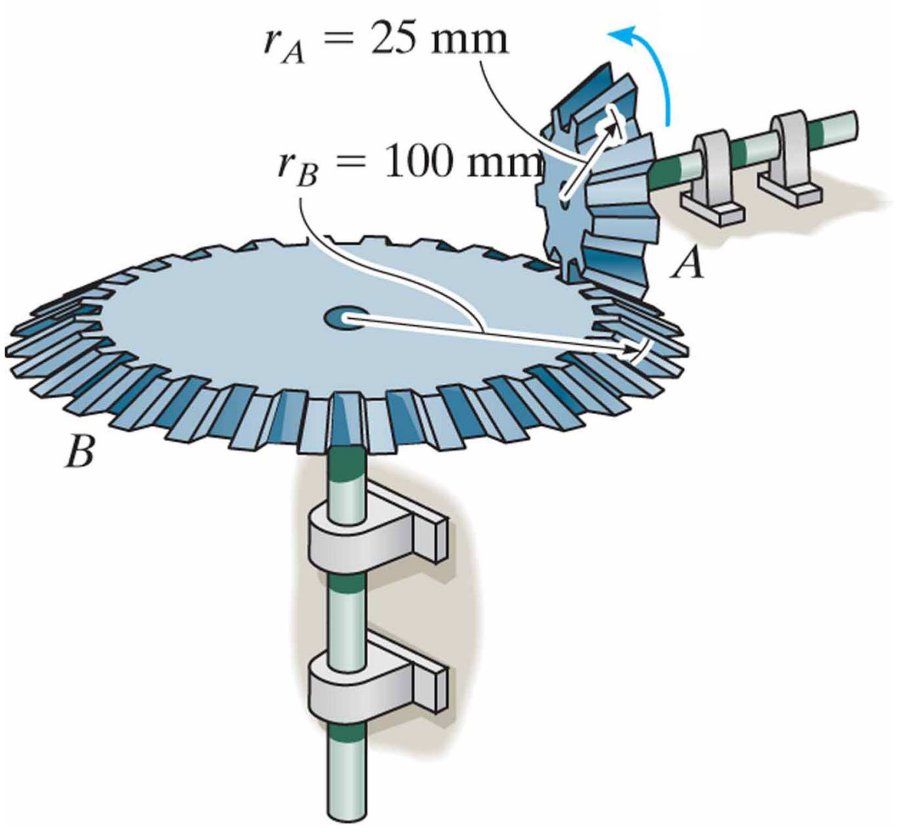

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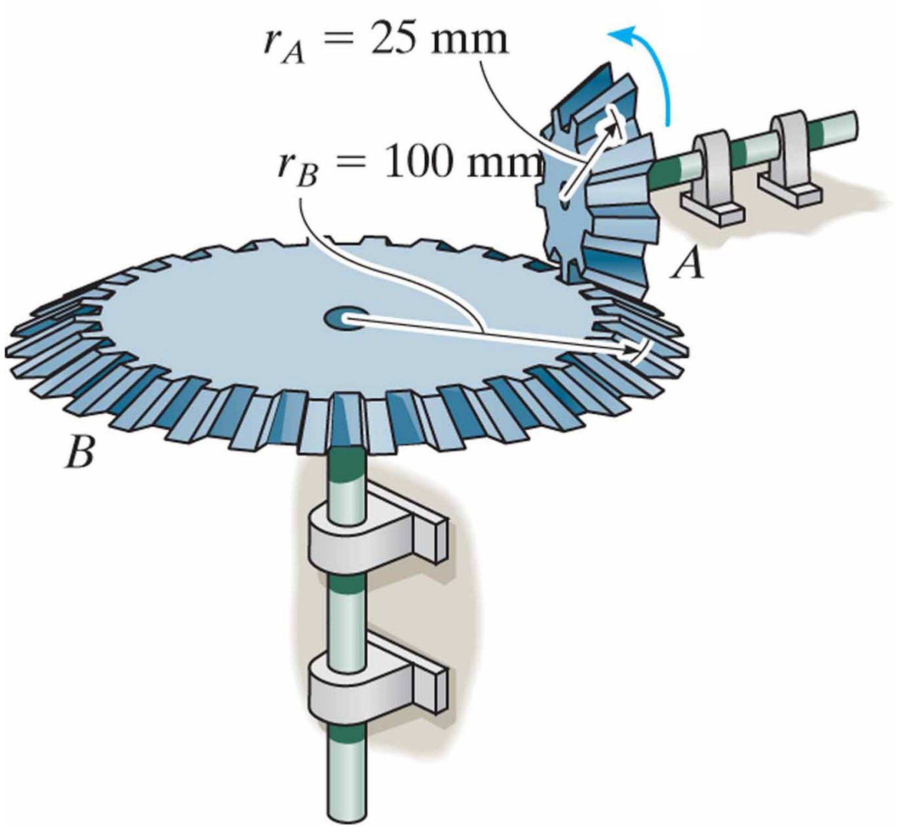


We can use any units in this equation as long as they are the same

$$r_1\omega_1 = r_2\omega_2 \Rightarrow$$

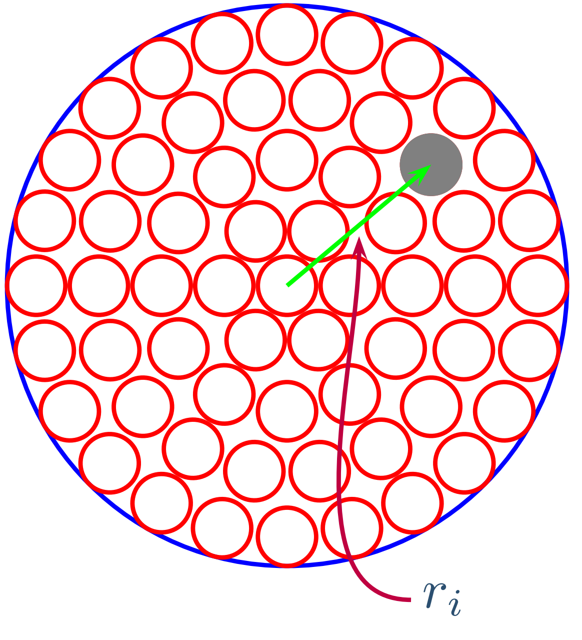
$$\omega_1 = \frac{(100\,mm)(100\,RPM)}{25\,mm}$$

(e) $400\,RPM$

Rotational Kinetic Energy II

Any rotating object has a kinetic energy due to its motion.

We have to imagine splitting the rotating object up into many small pieces.



$$K \approx \frac{1}{2}\left(\sum_i M_i r_i^2\right)\omega^2$$

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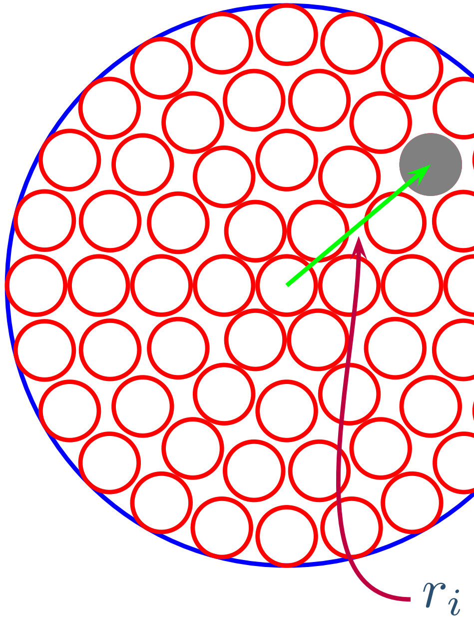

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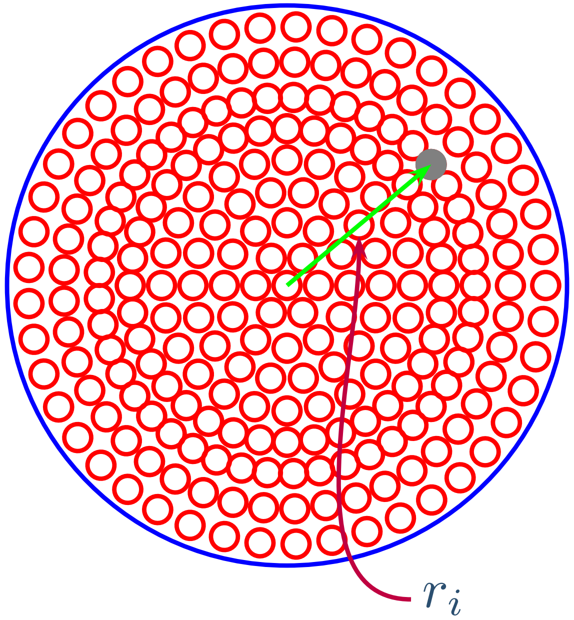

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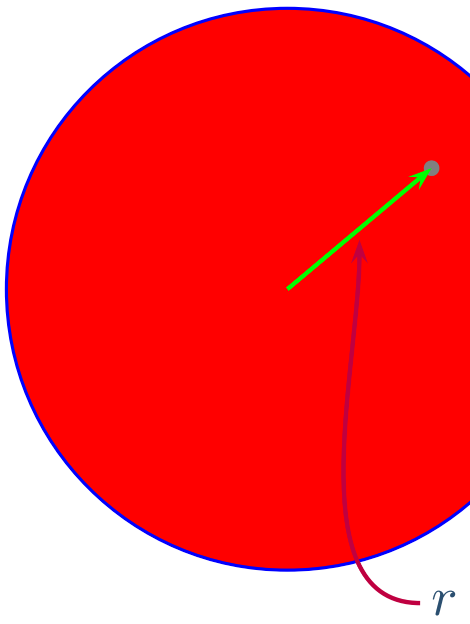

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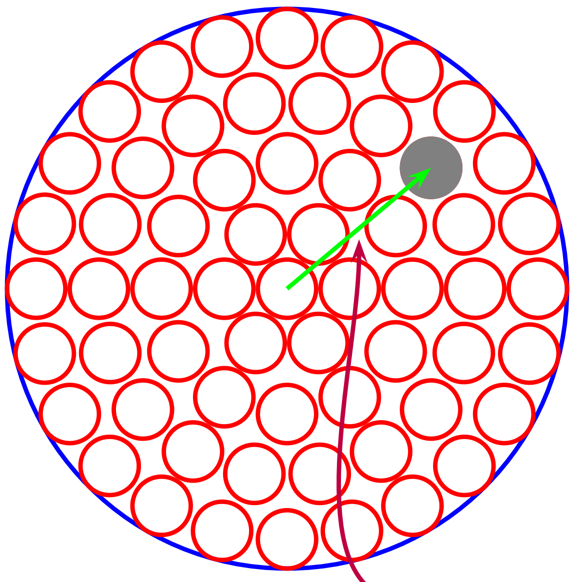

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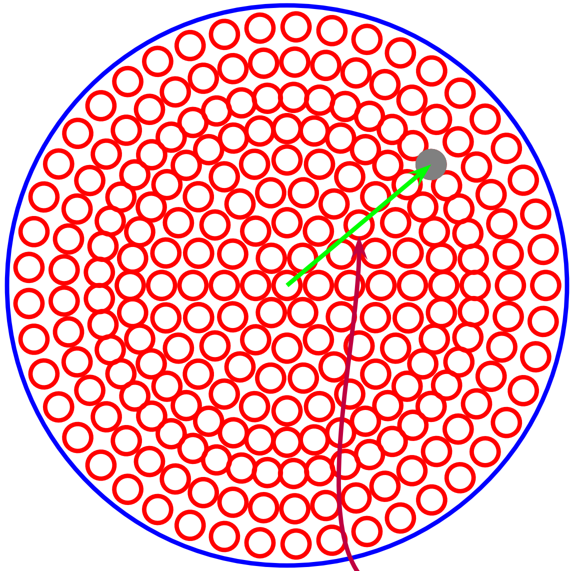

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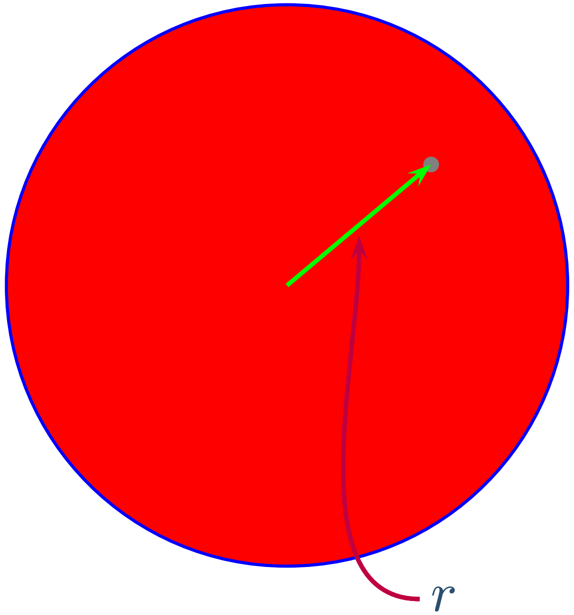

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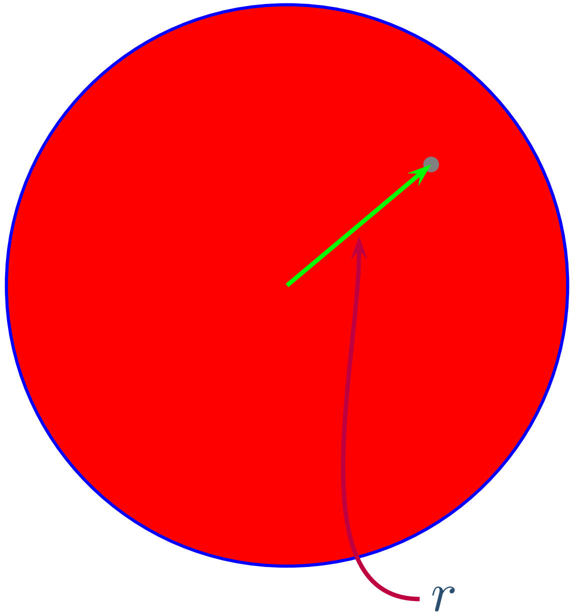

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(b) The axis of rotation.

(c) The total mass of the object.

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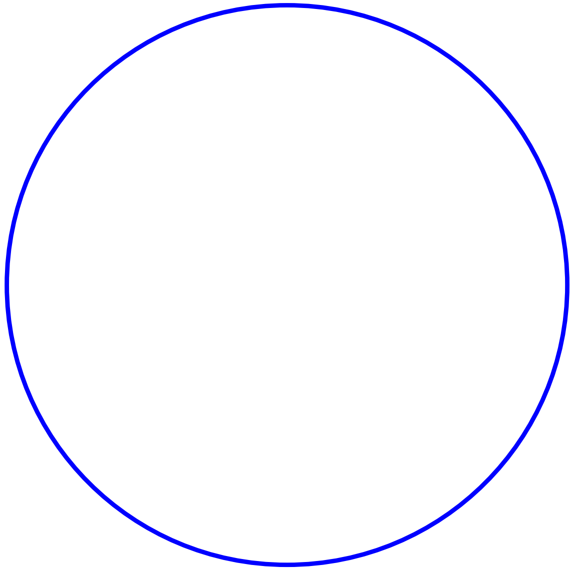

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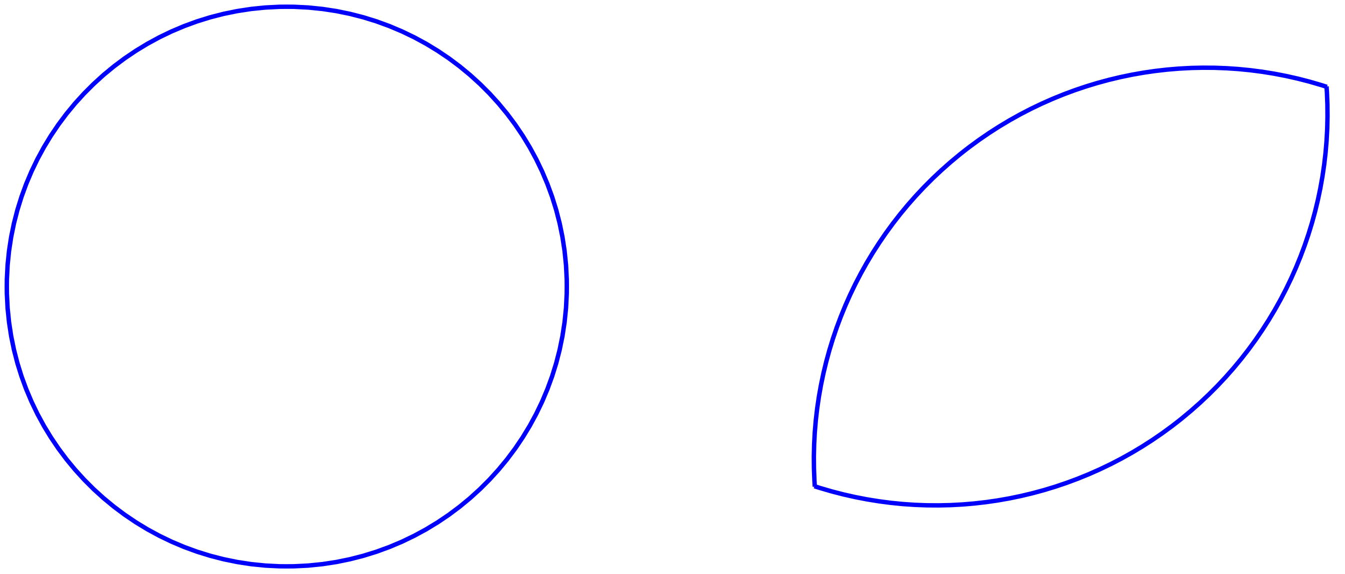

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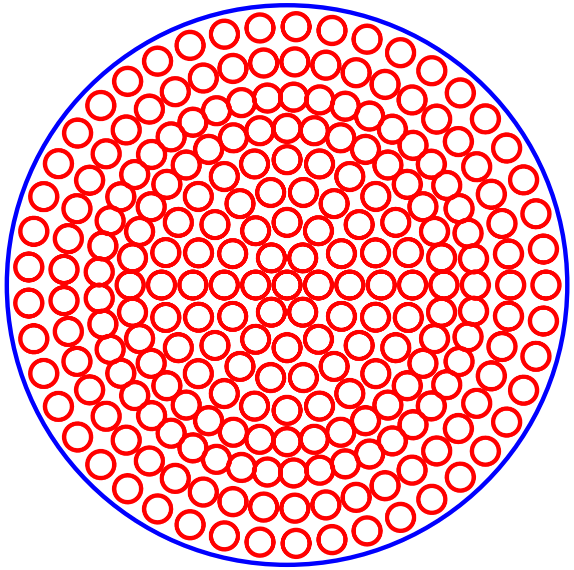

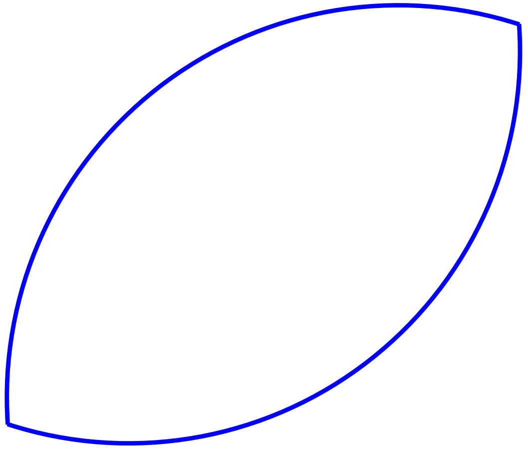

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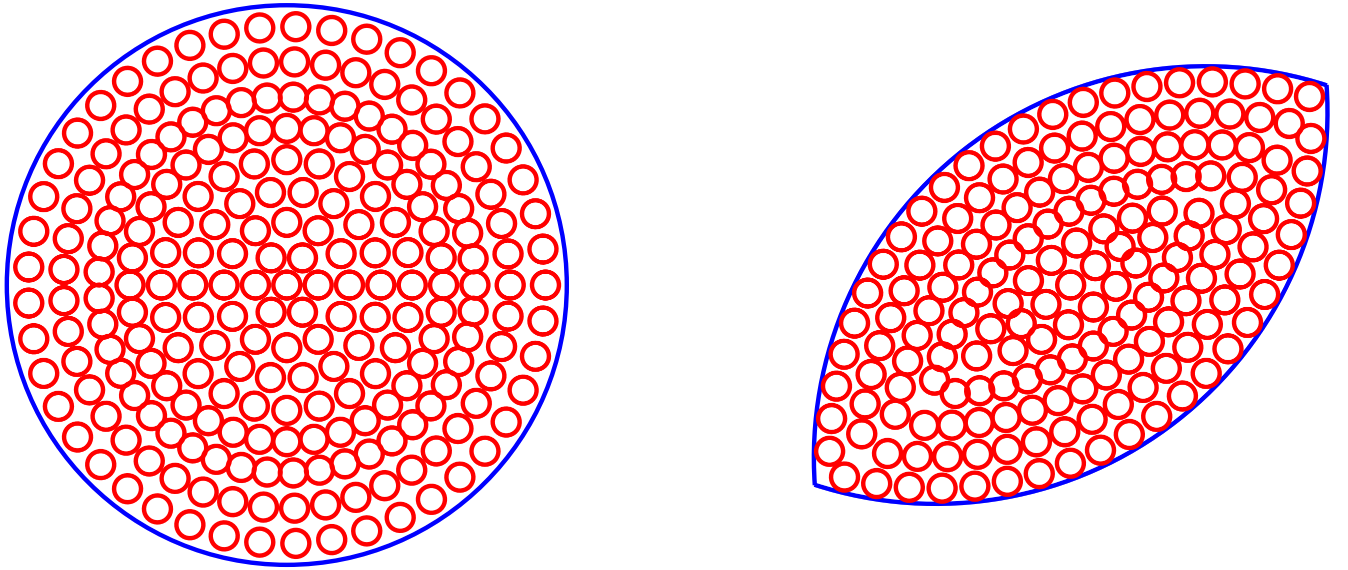

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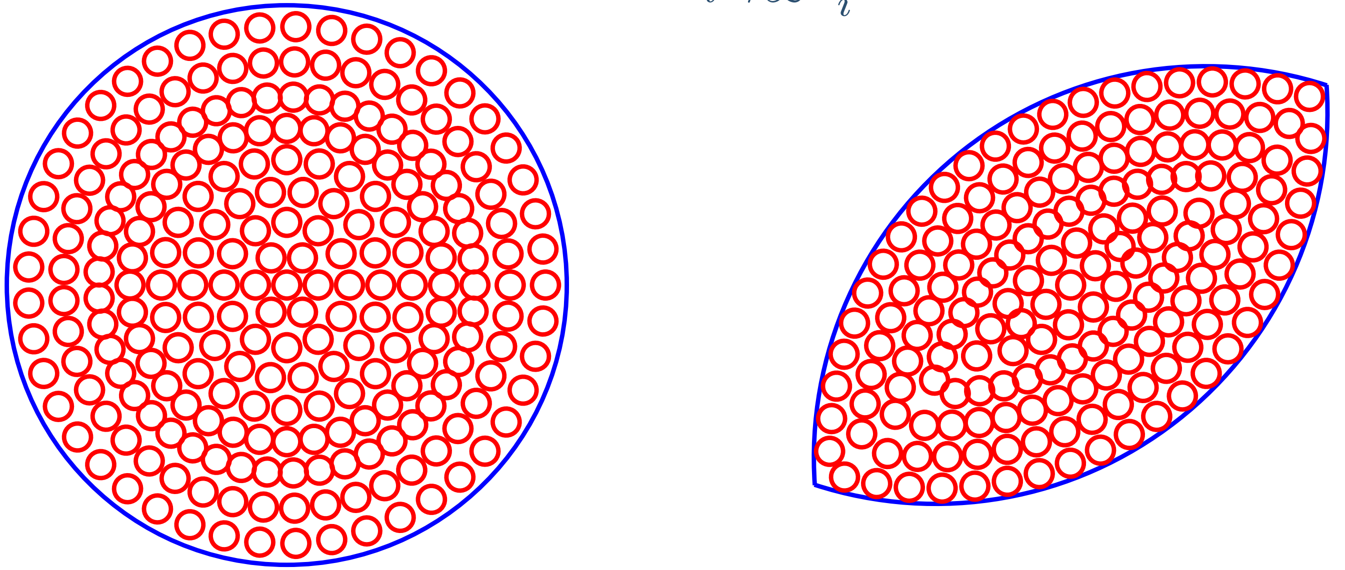

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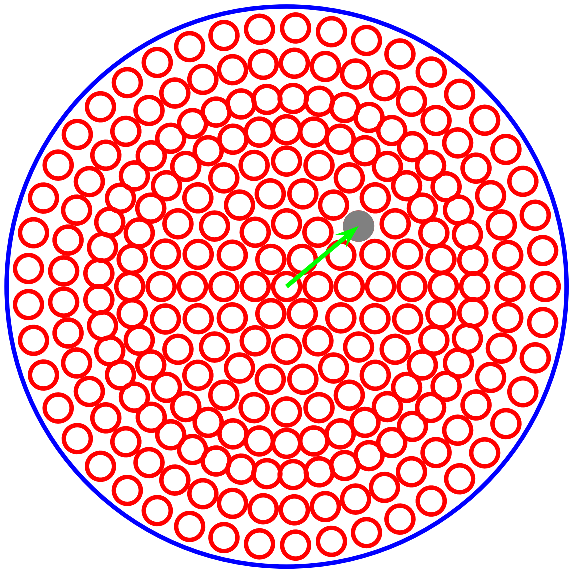

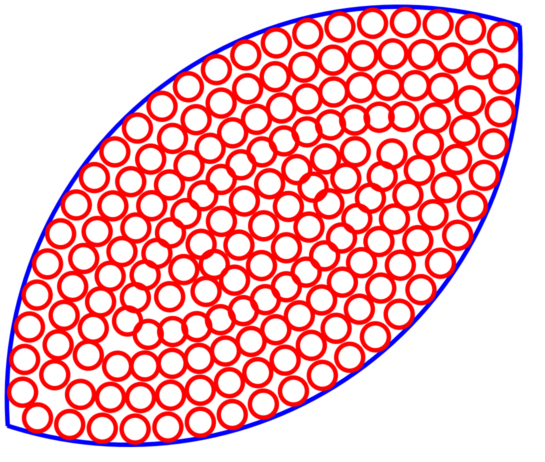

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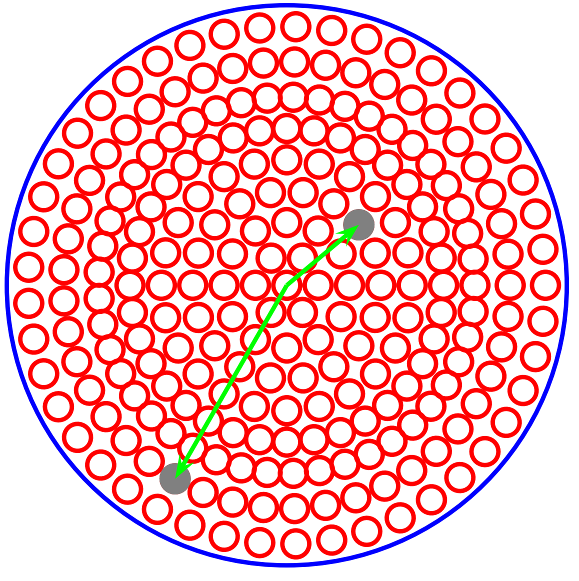

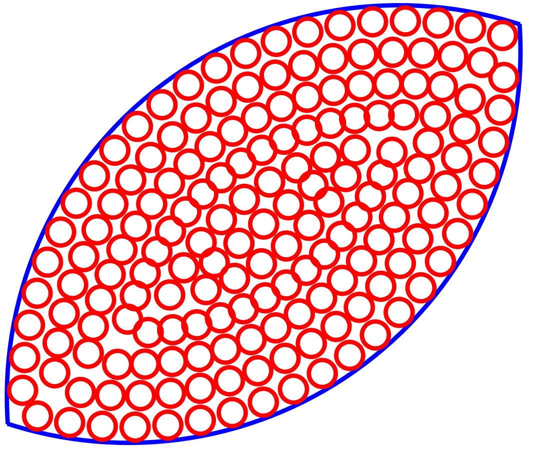

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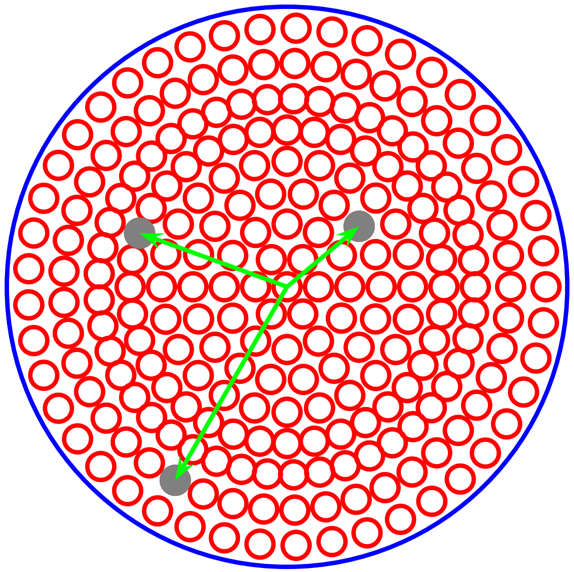

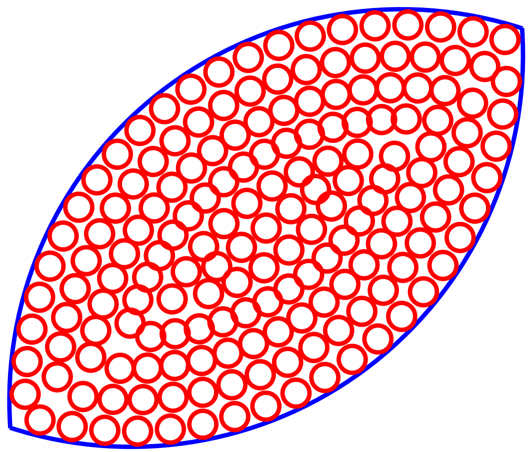

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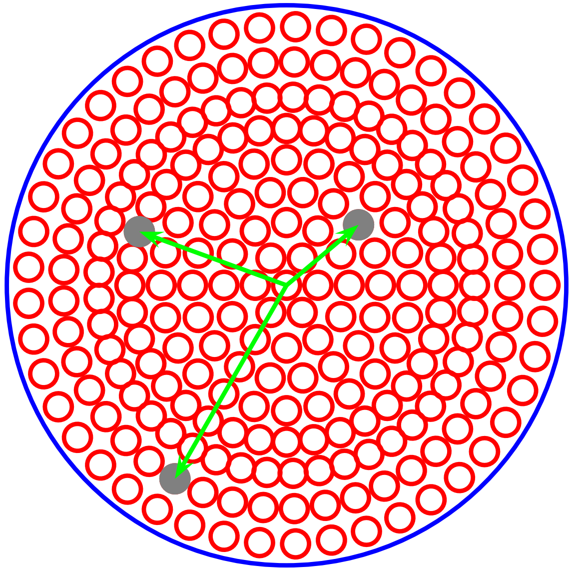

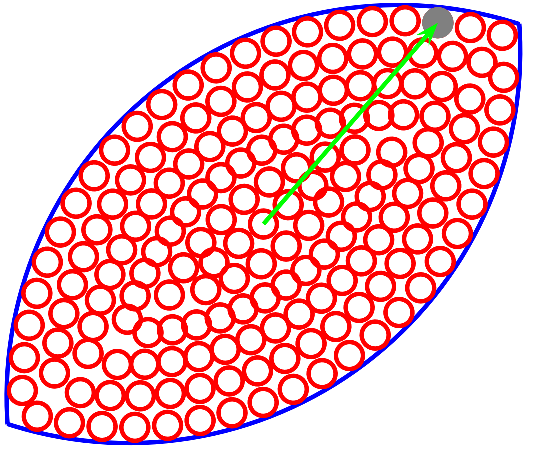

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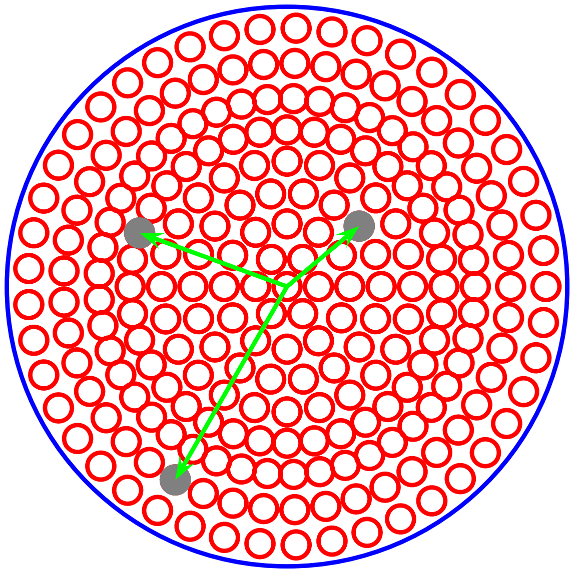

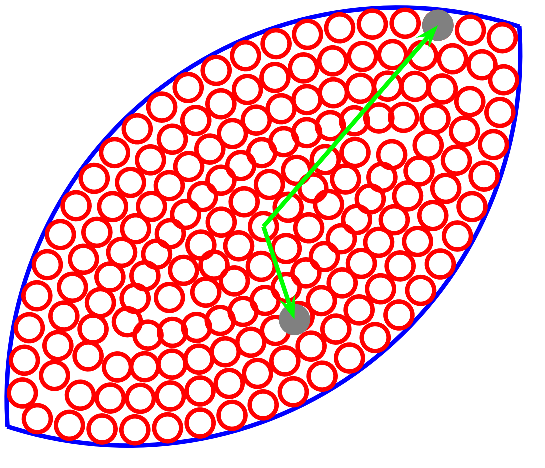

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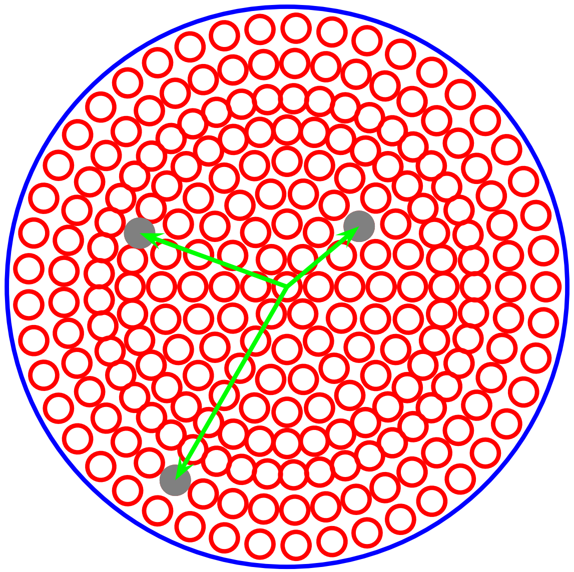

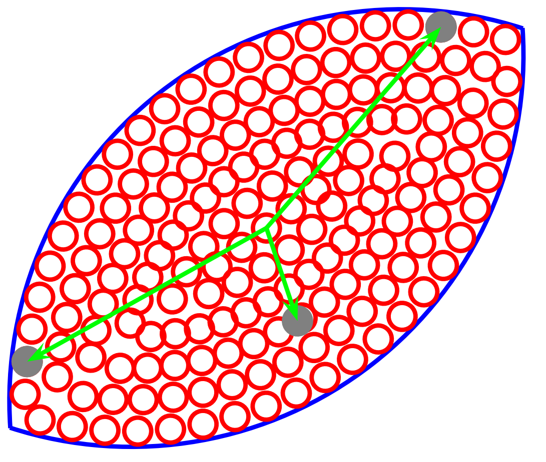

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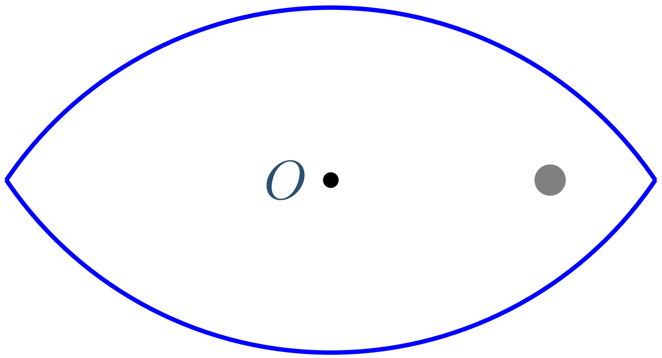

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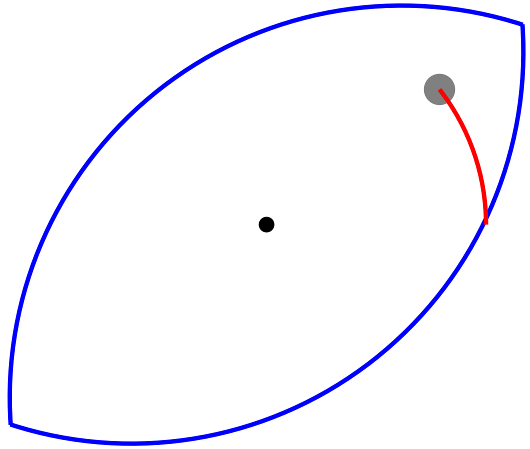

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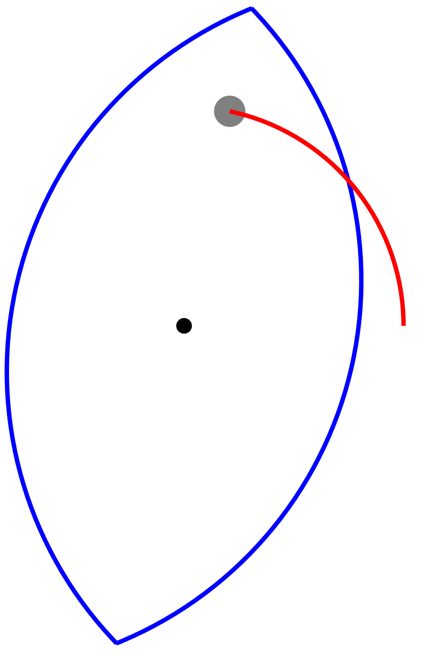

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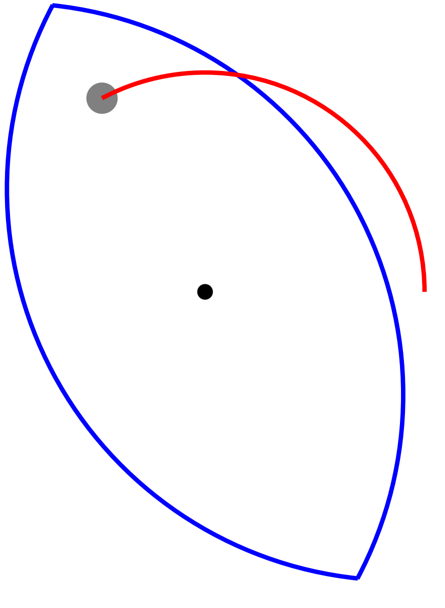

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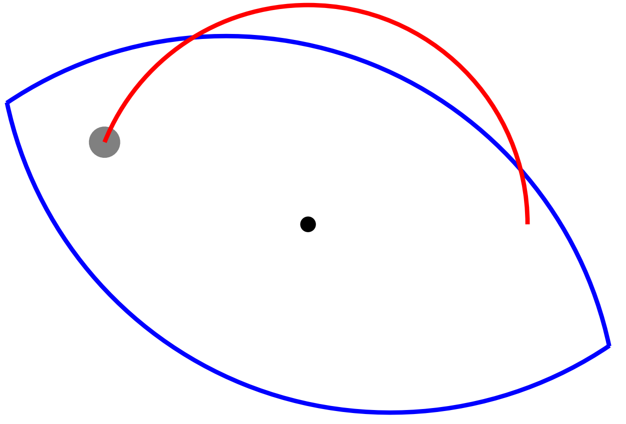

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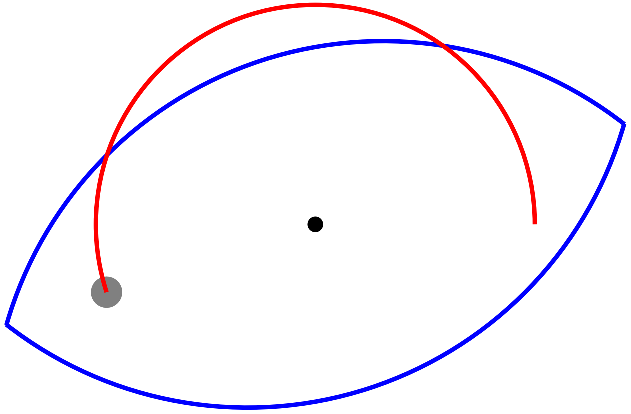

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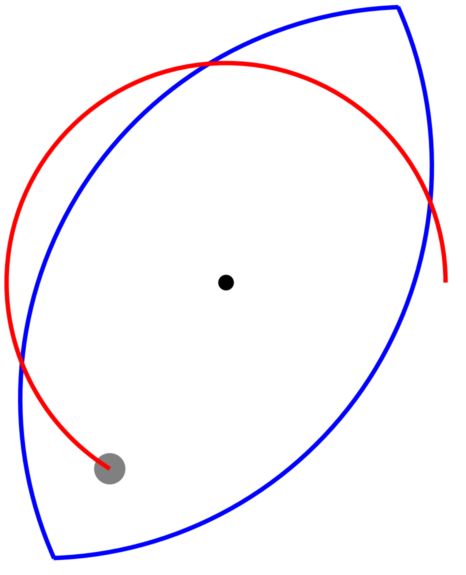

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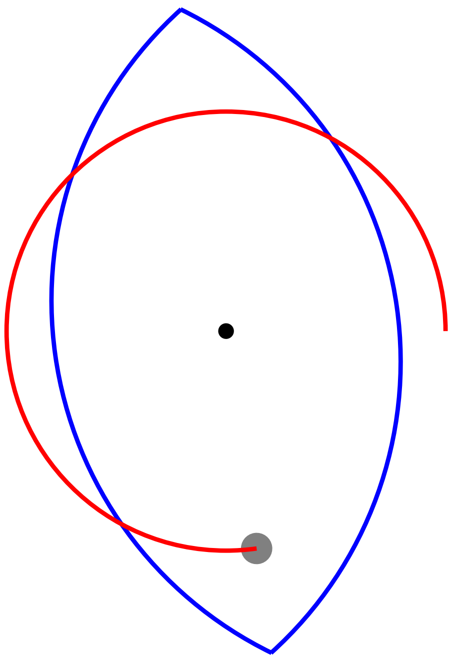

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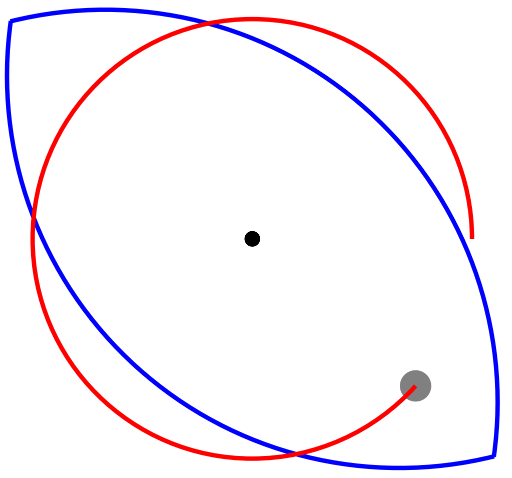

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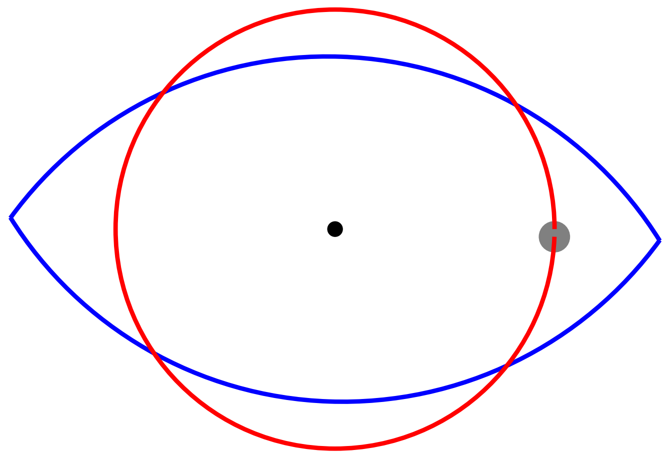

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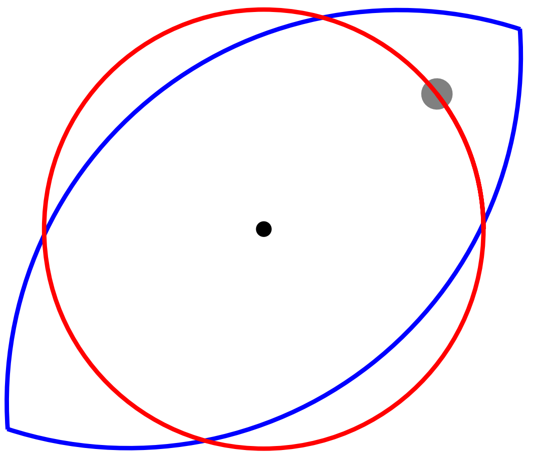

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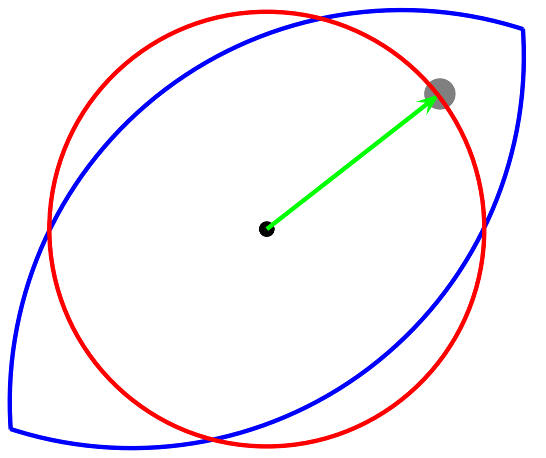

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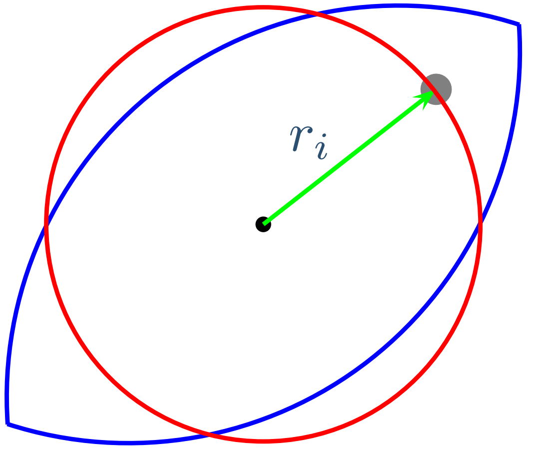

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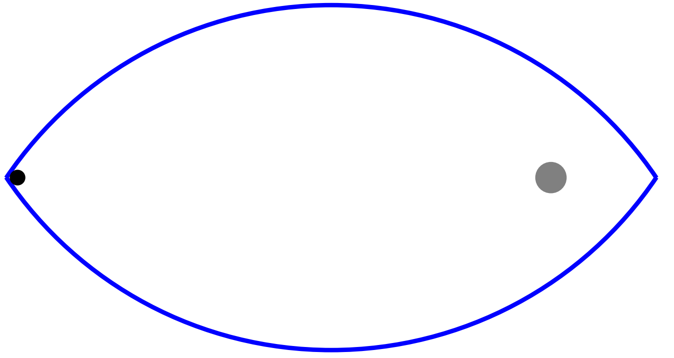

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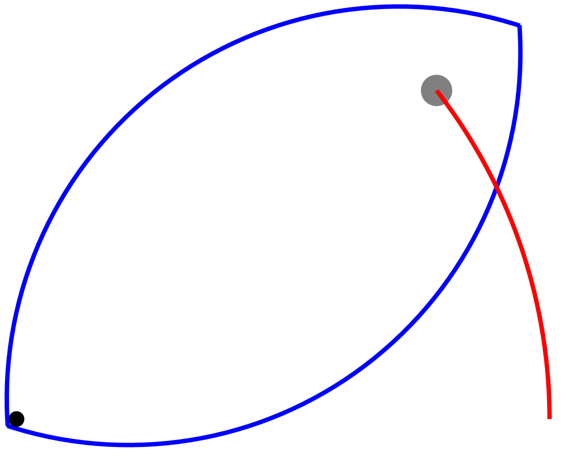

Axis of Rotation

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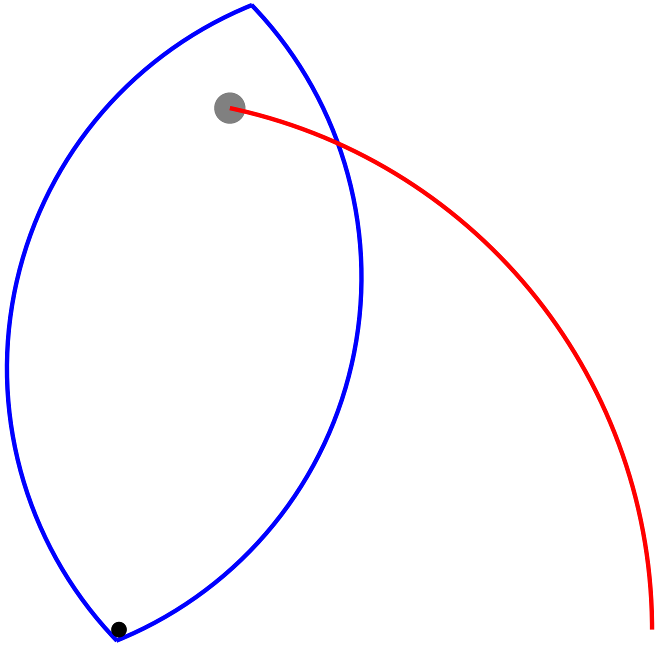

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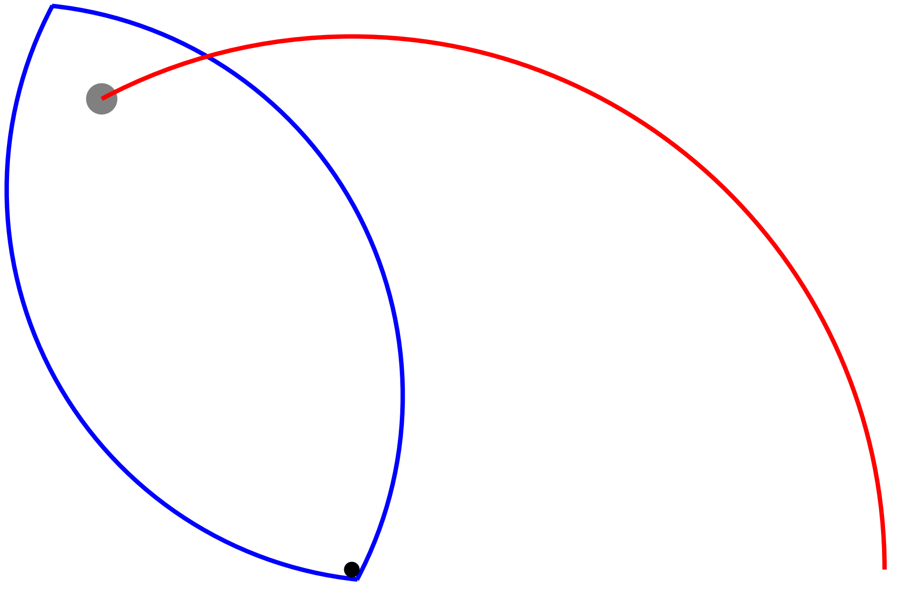

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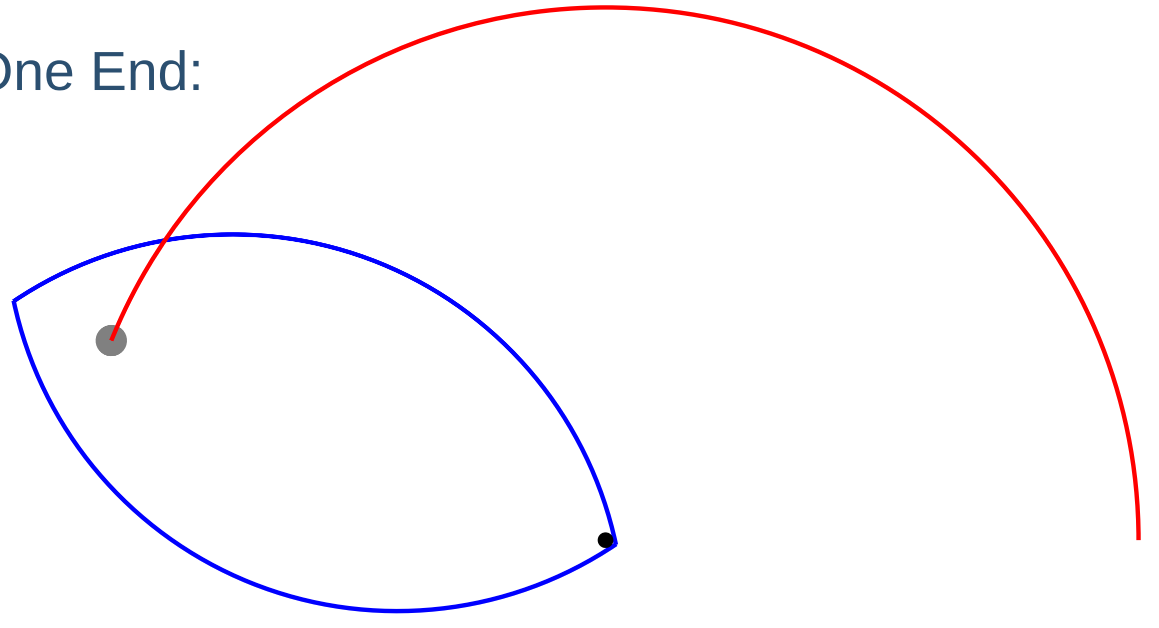

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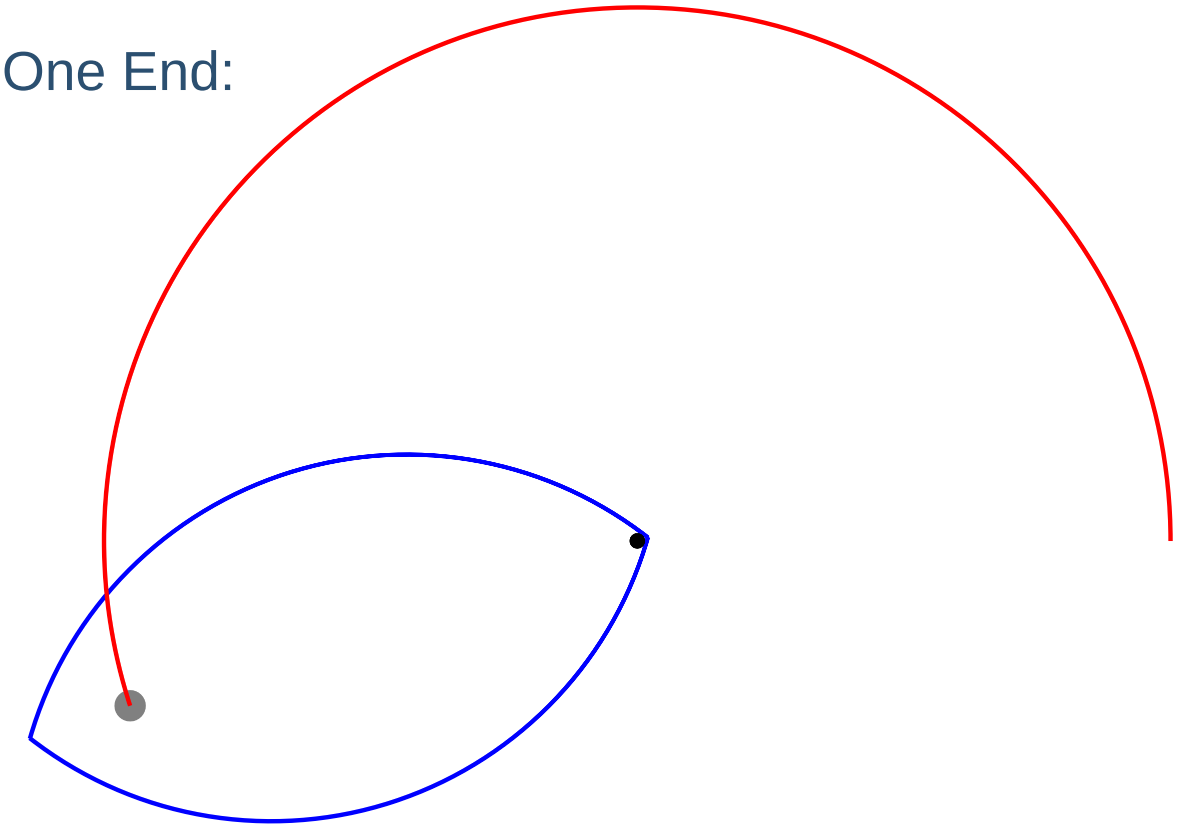

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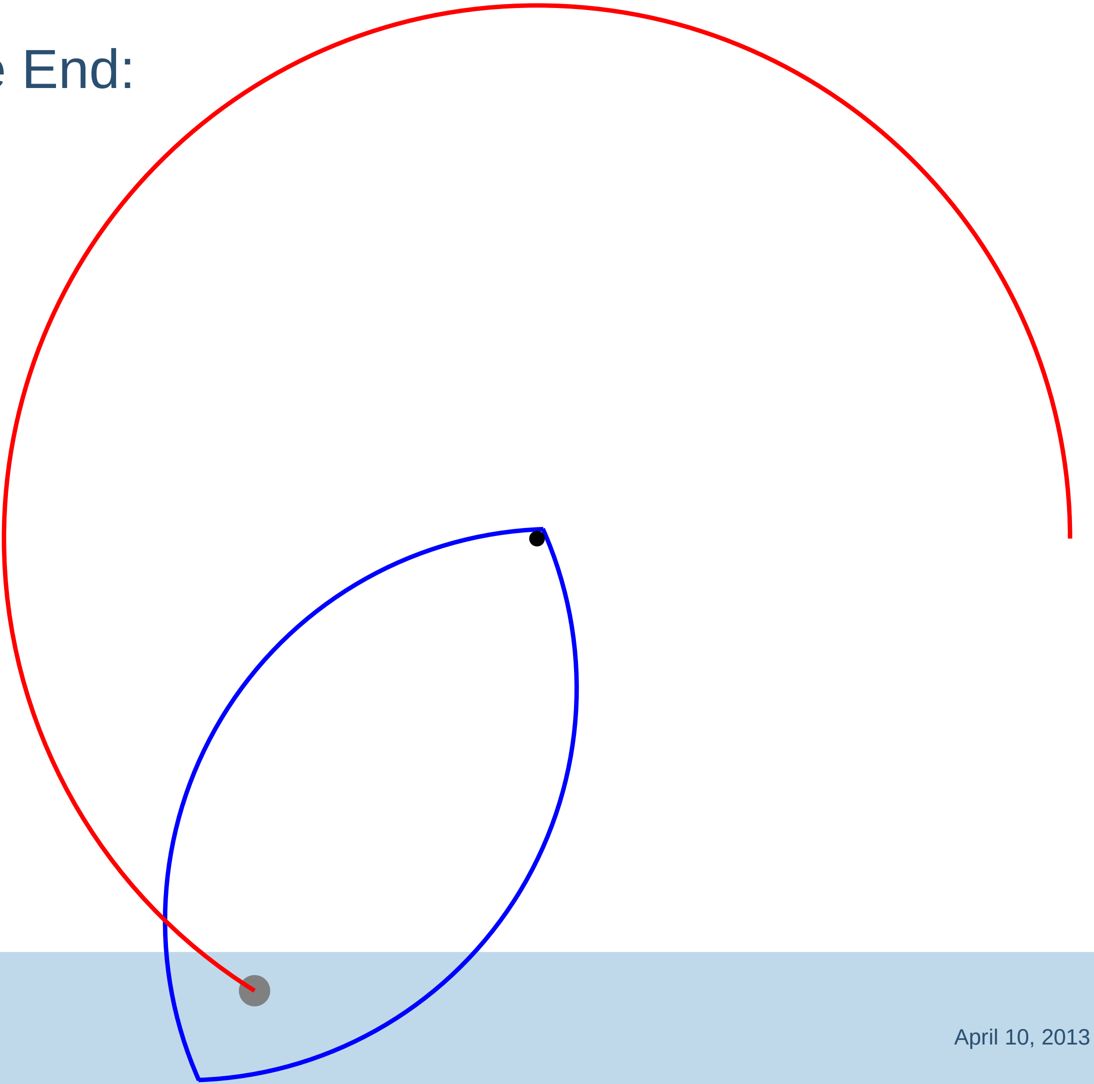

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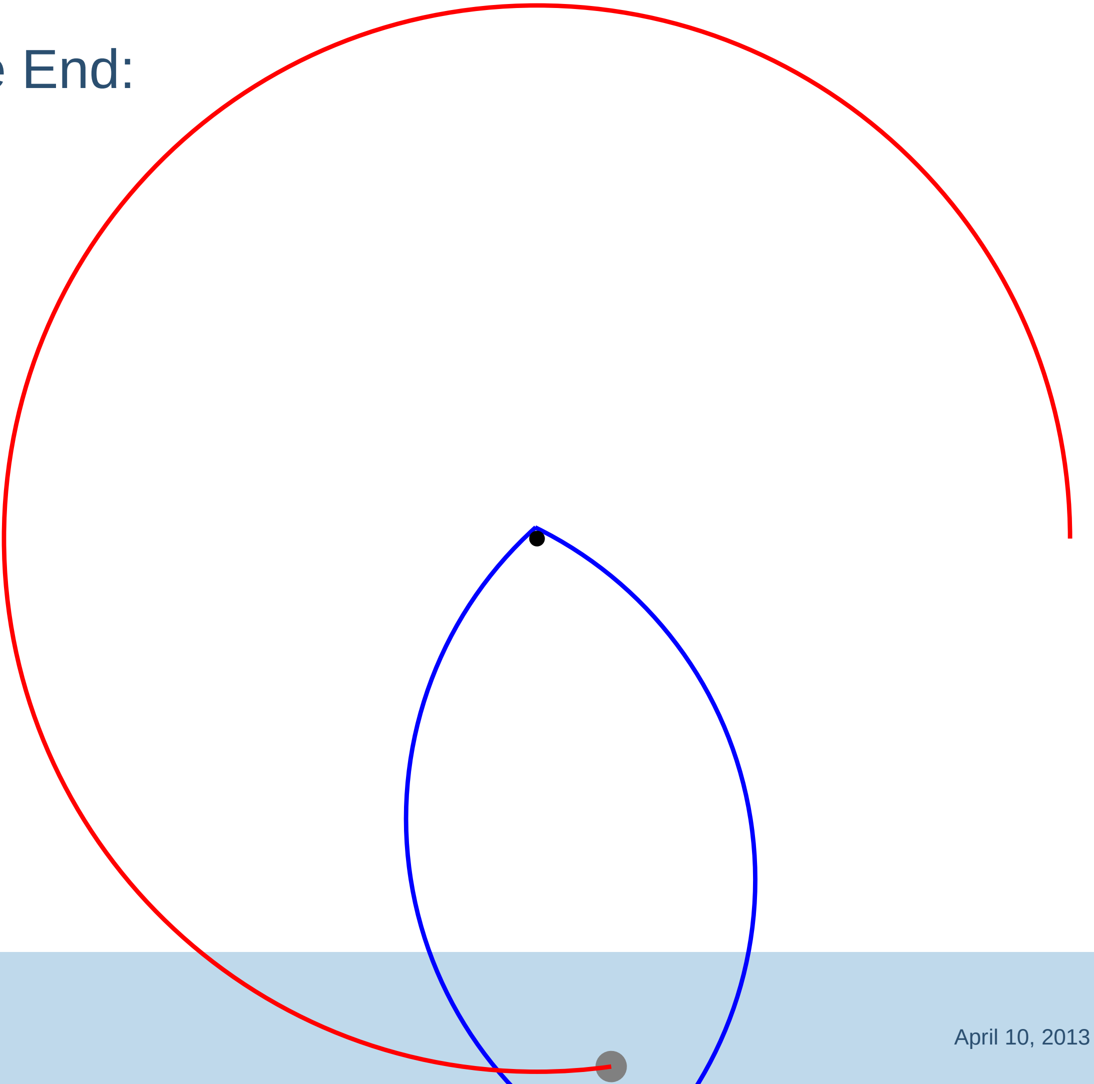

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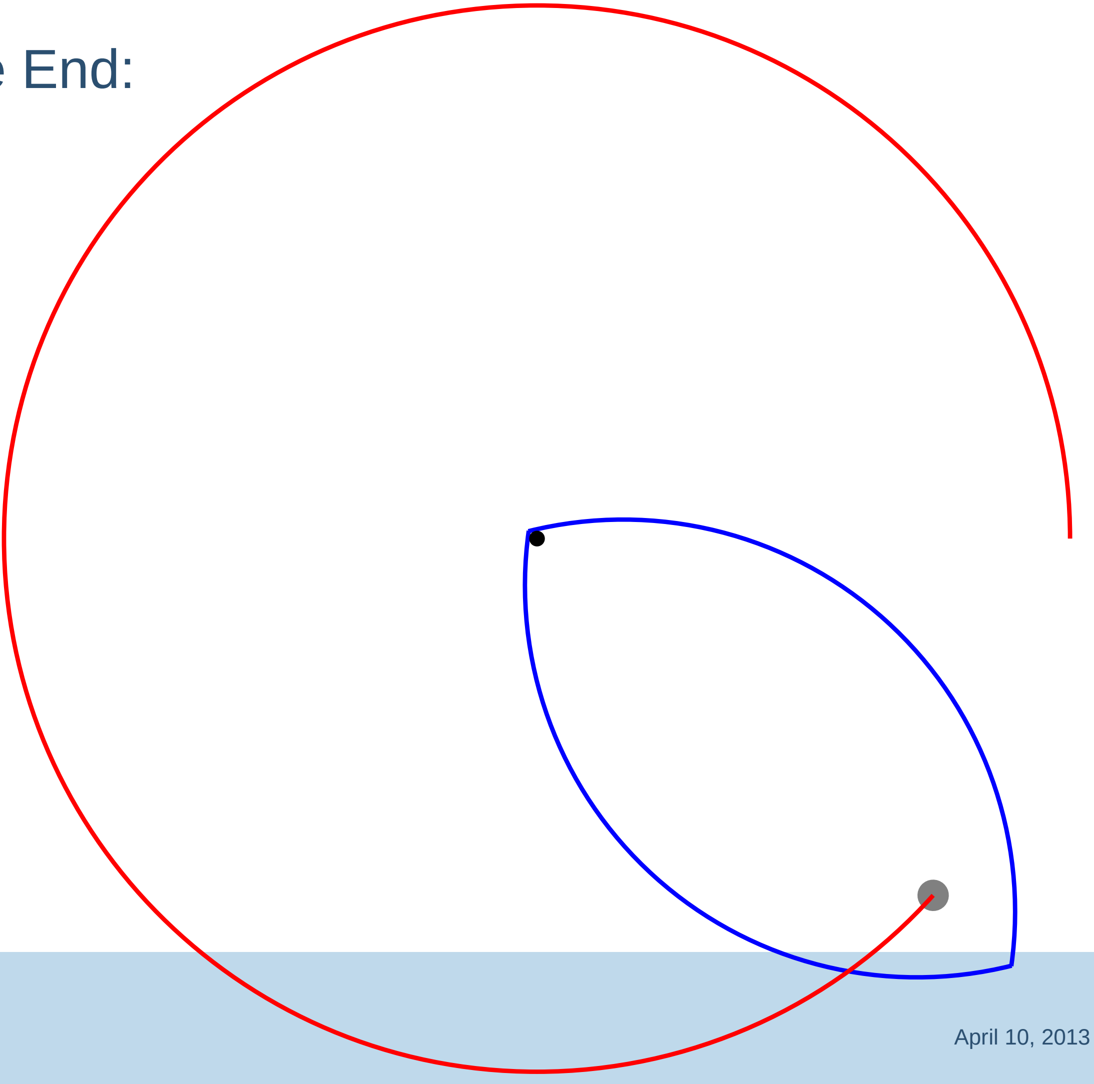

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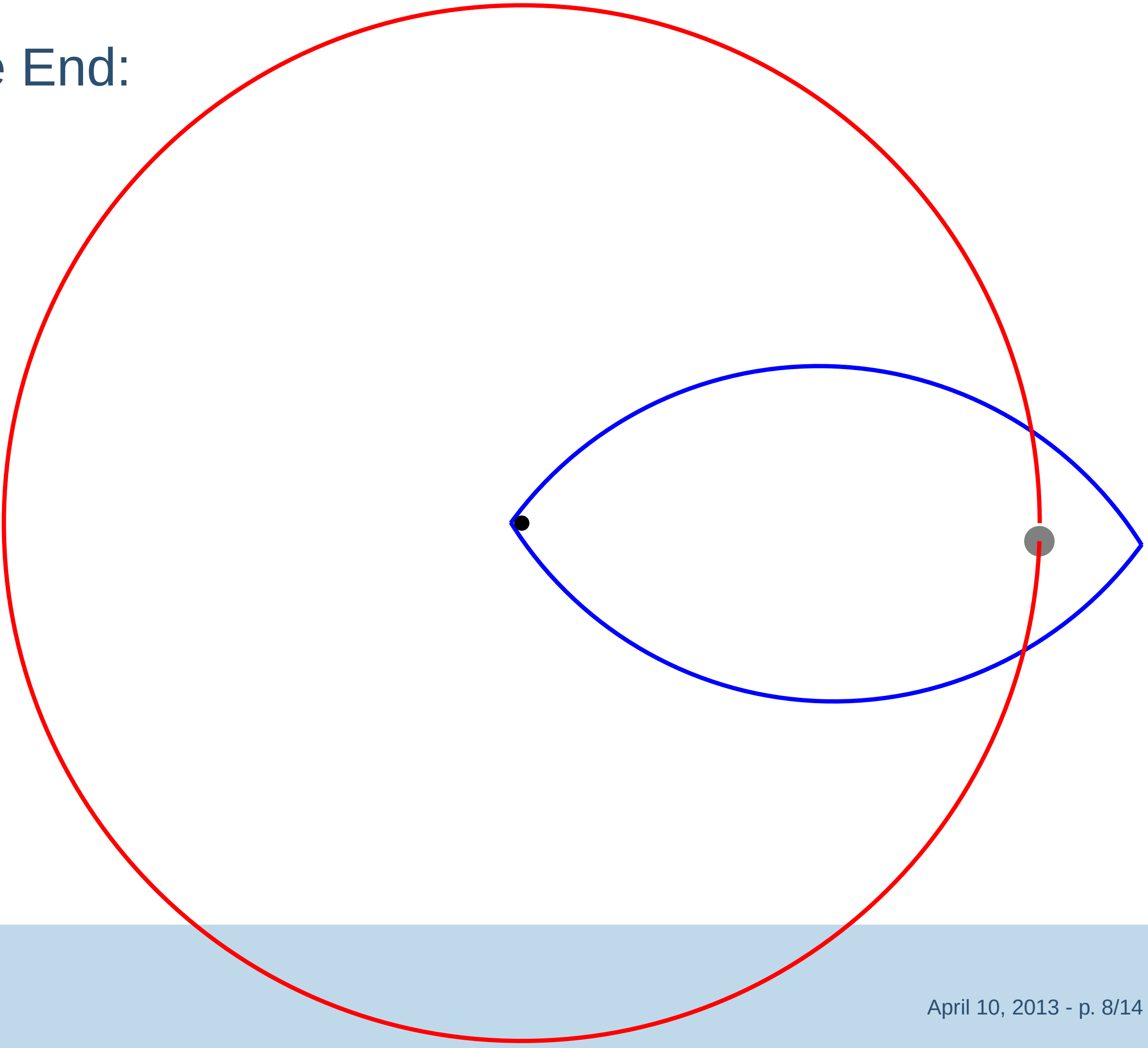

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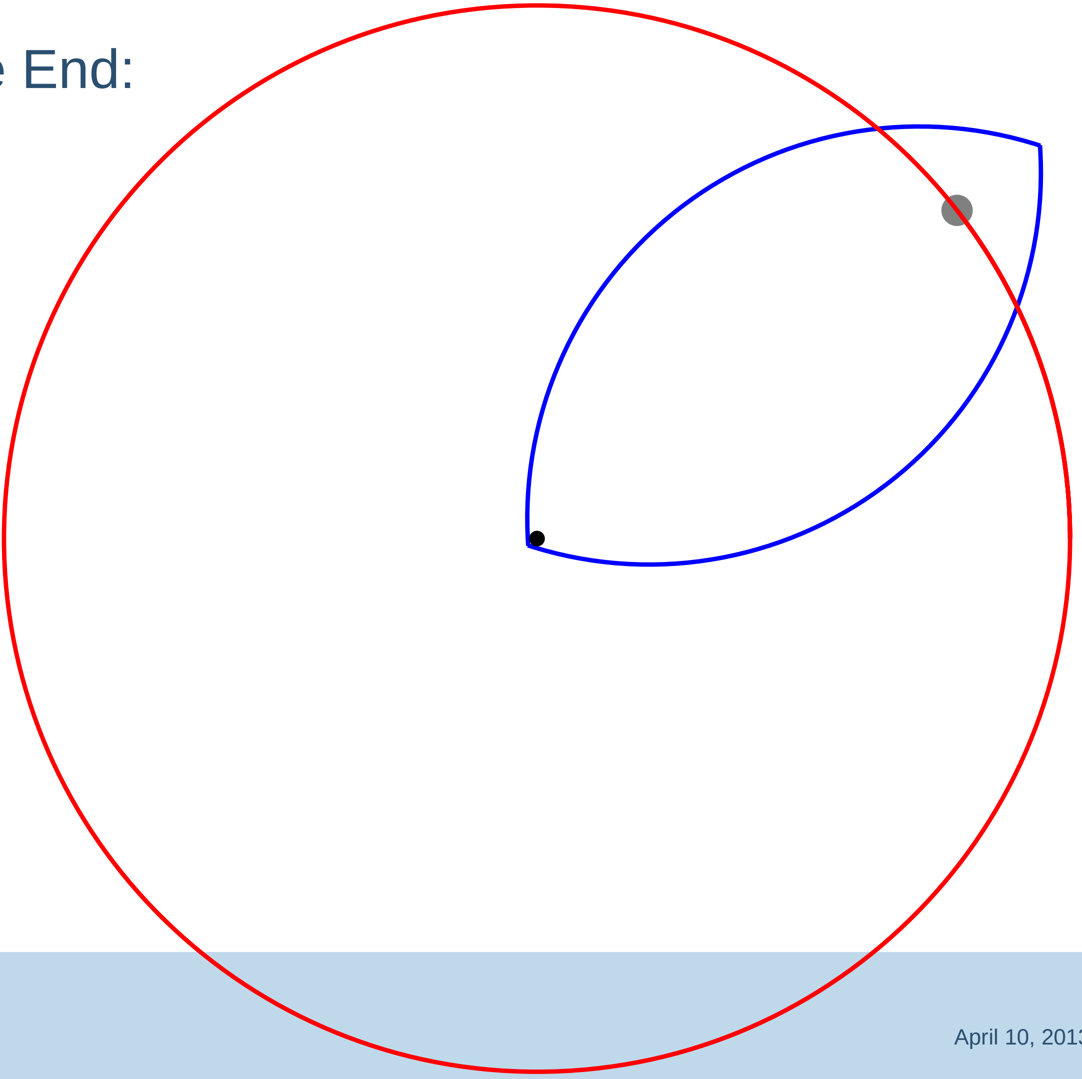

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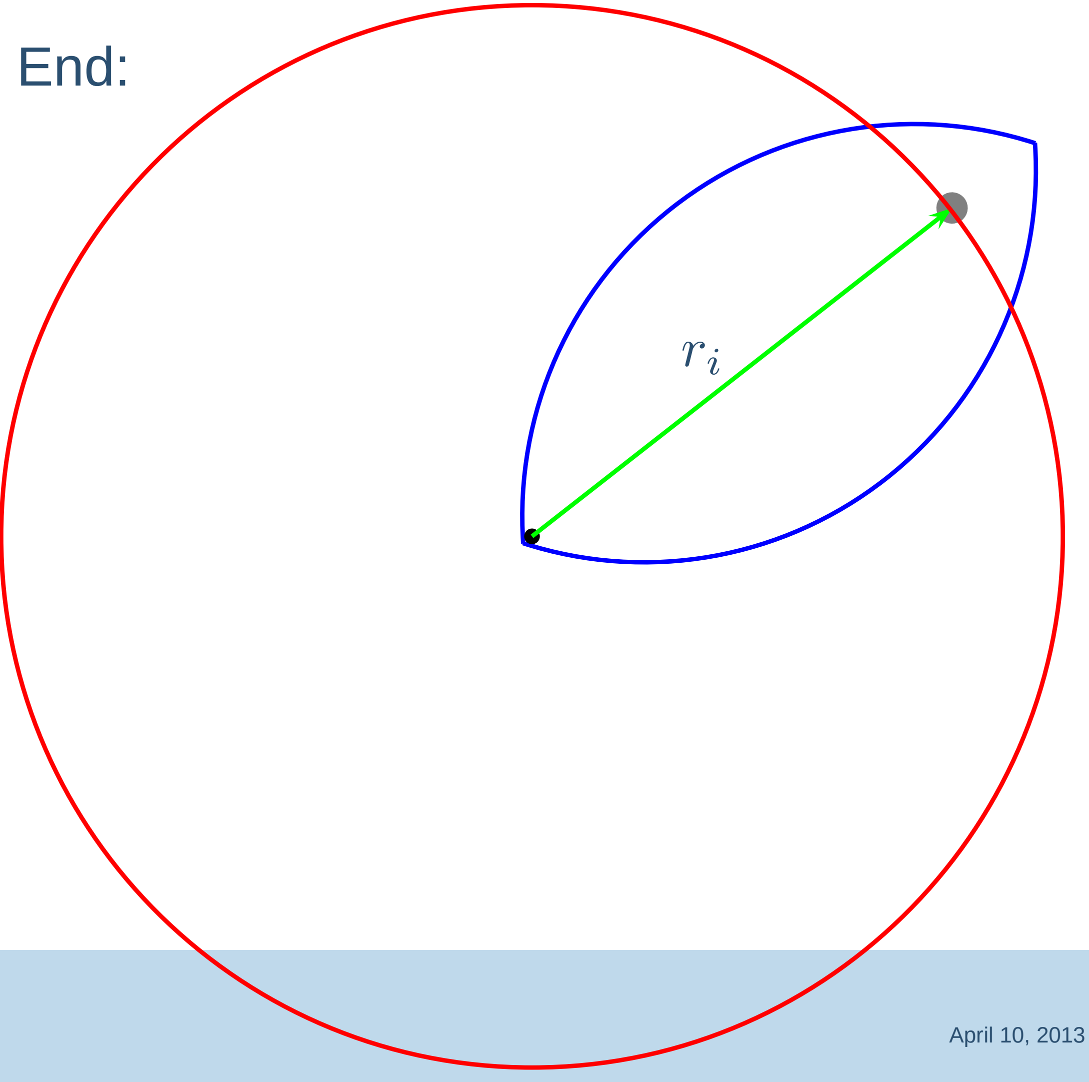

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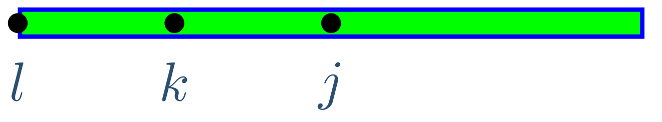

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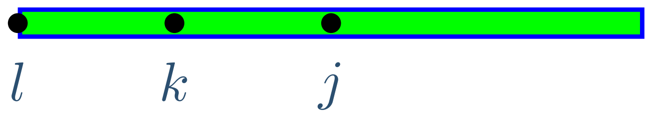

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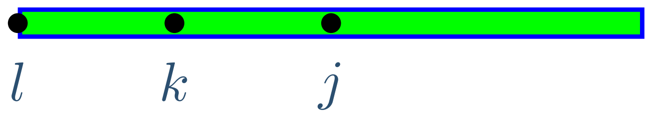

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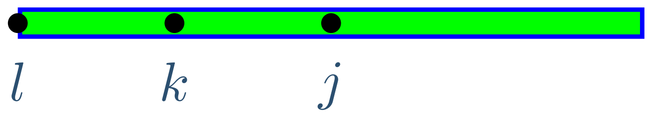

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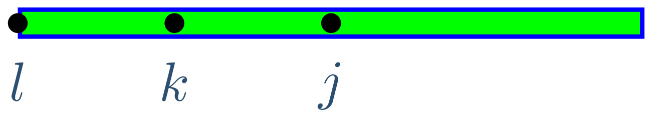

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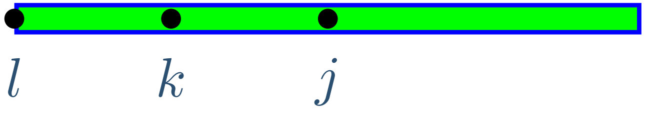

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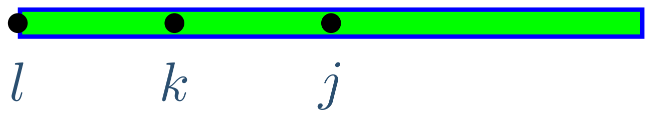

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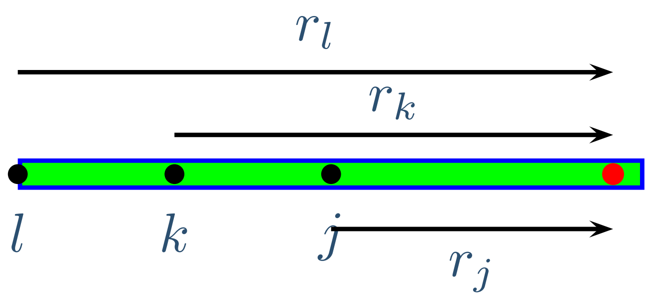

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Standard Shapes

For standard shapes and axes, equations for moments of inertia have already been calculated.

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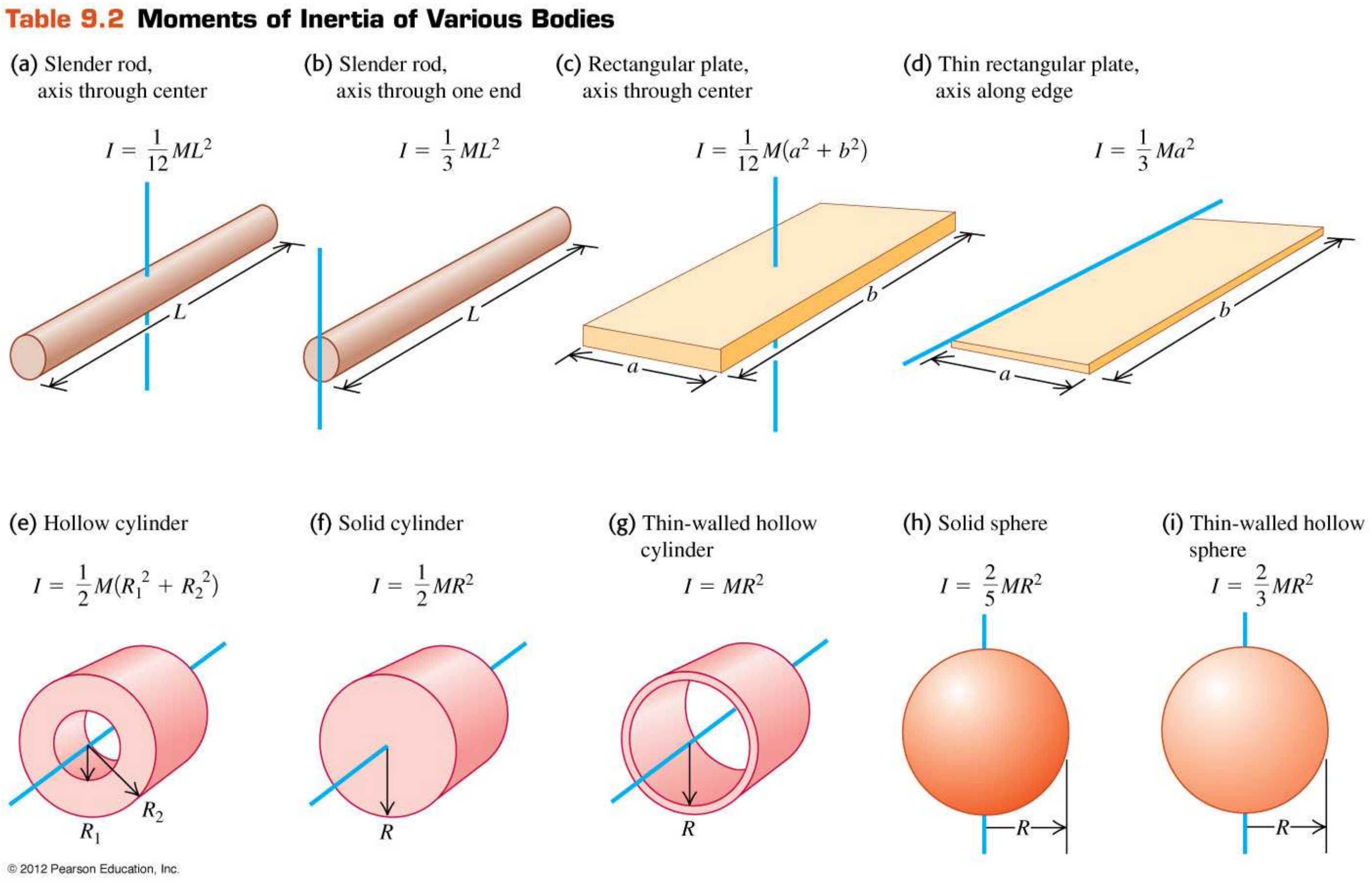

Gravitational Potential Energy

To find the gravitational potential energy of a rigid body, we use the center of gravity.

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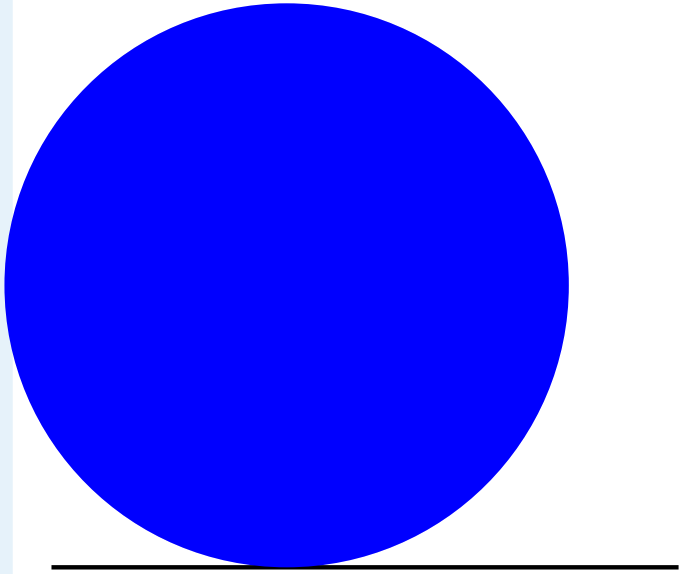

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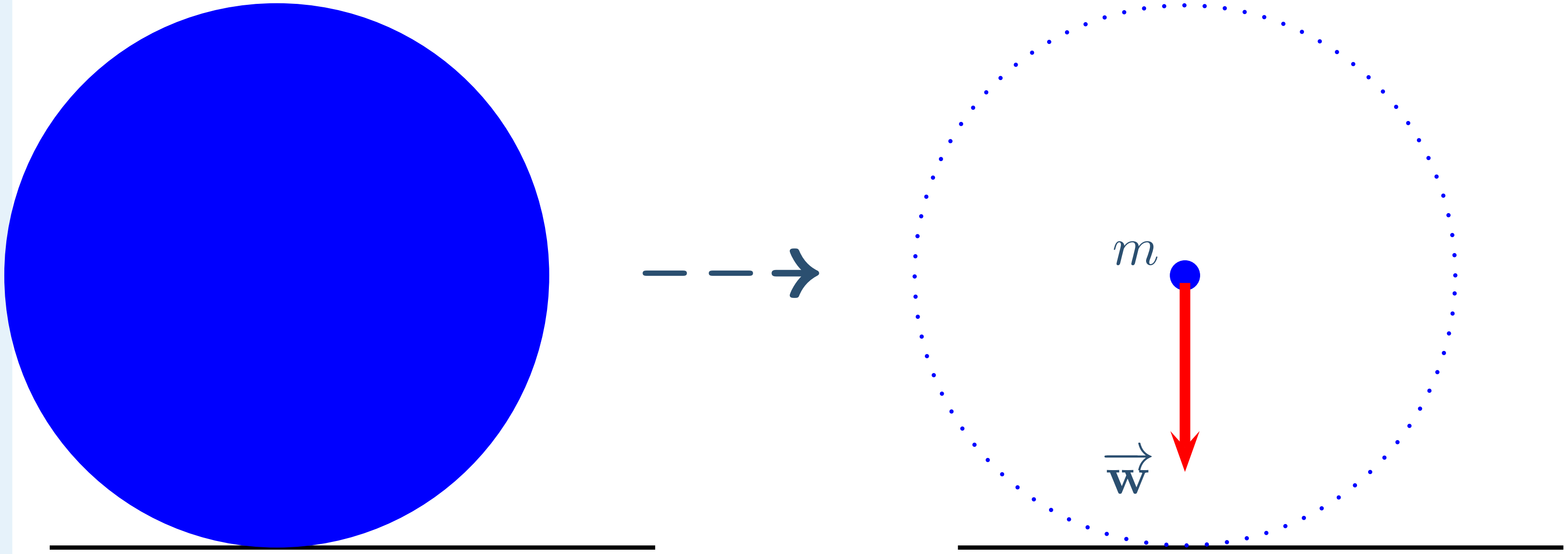

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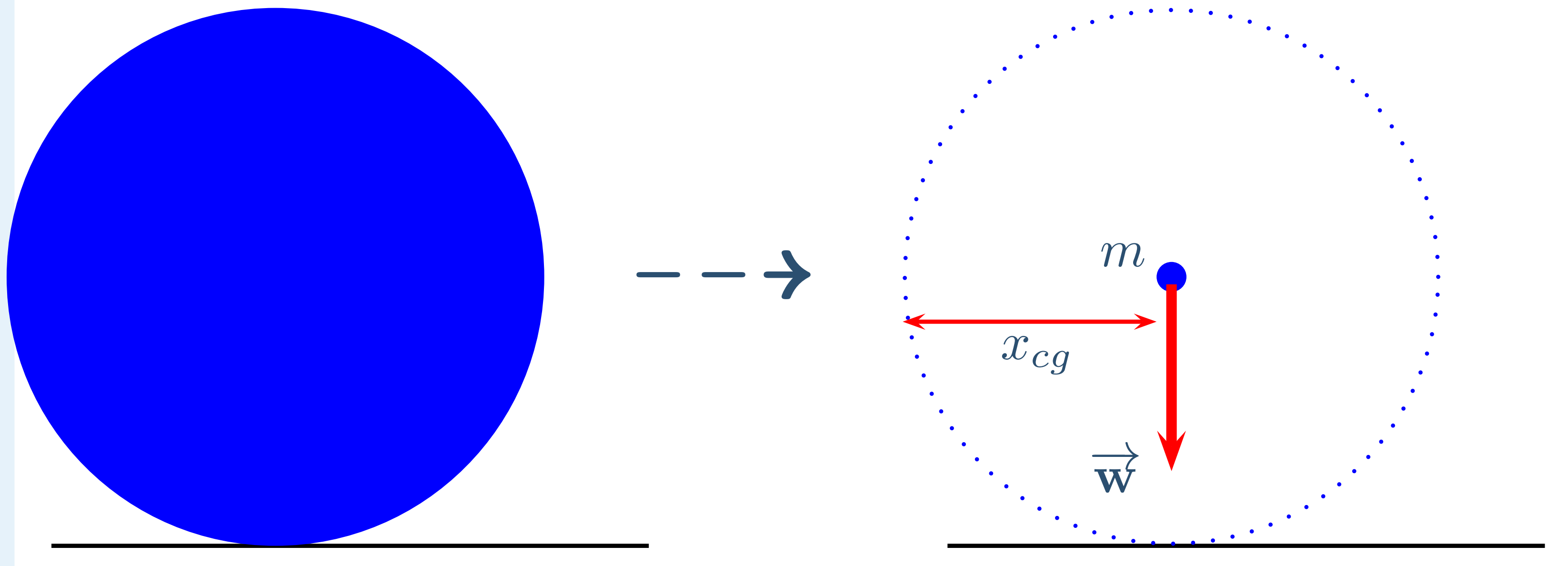

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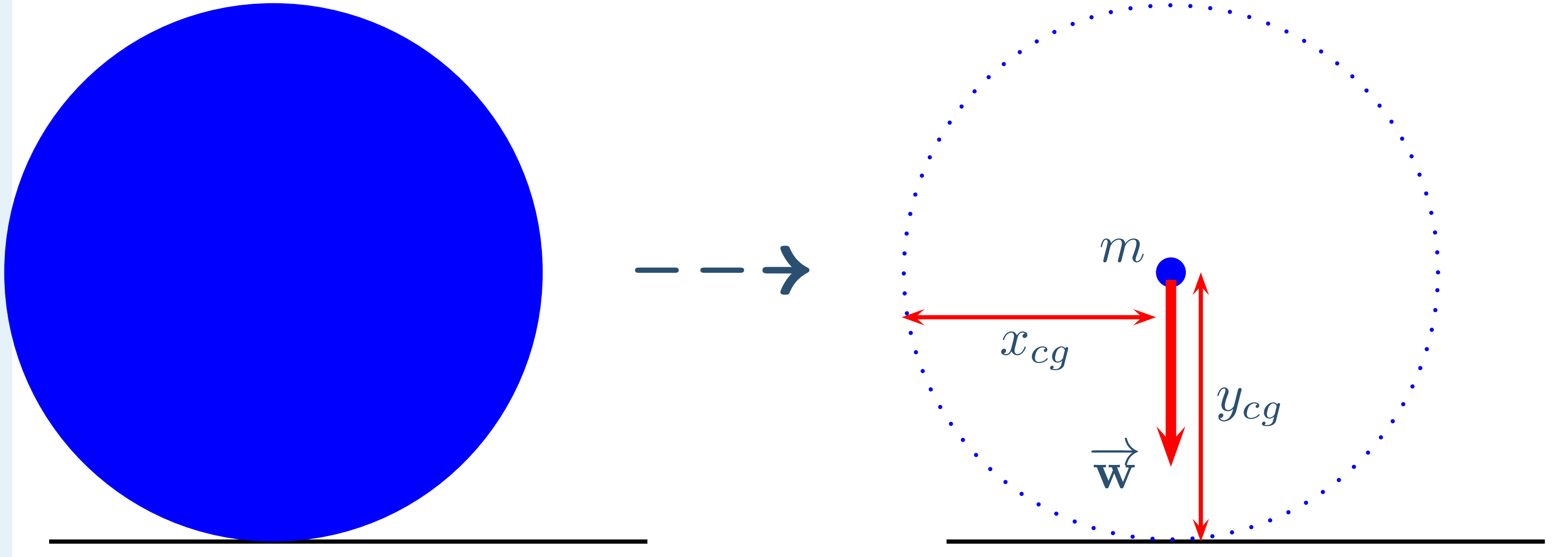

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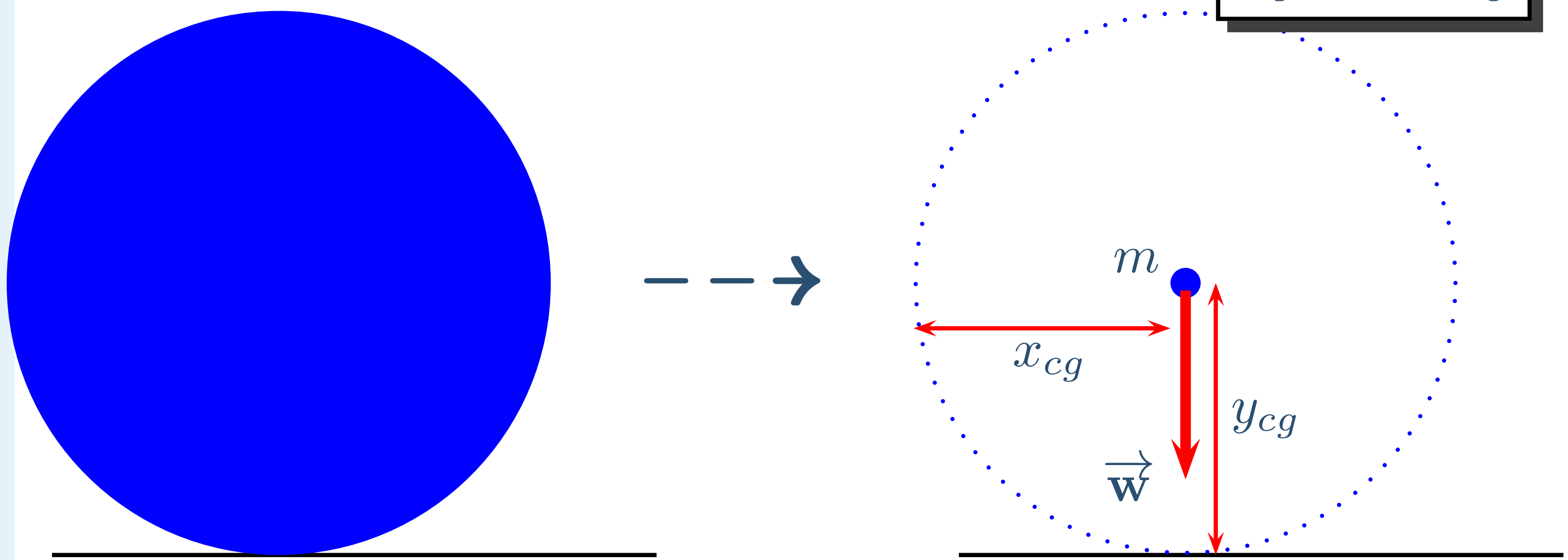
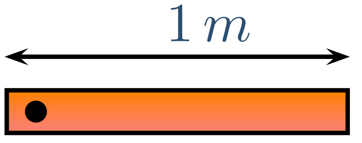
$$U_g = mgy_{cg}$$



Potential Energy exercise

A 0.15-kg uniform meter stick is held $1\,m$ above the ground by one end. What is the change in its gravitational potential energy, ΔU_g, when it swings through the vertical?



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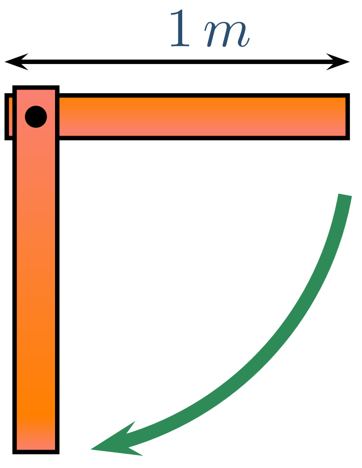

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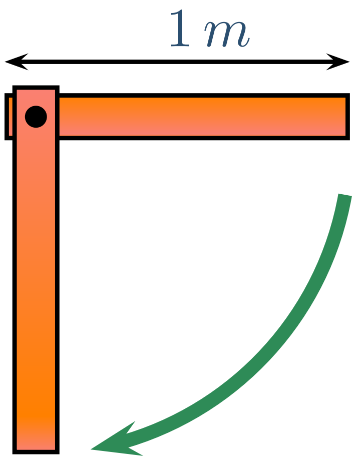

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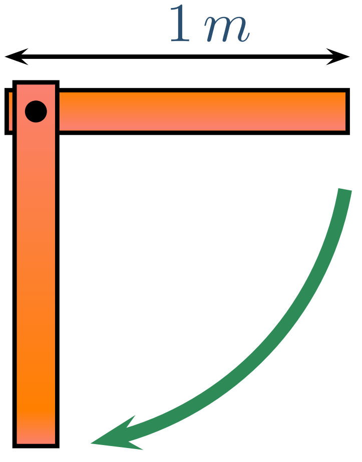

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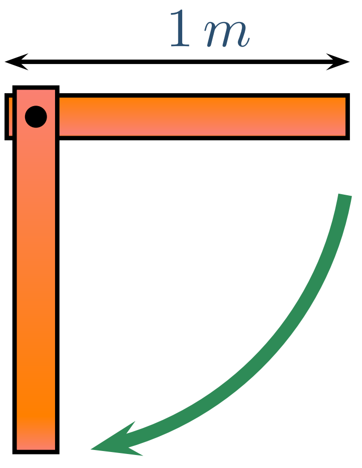

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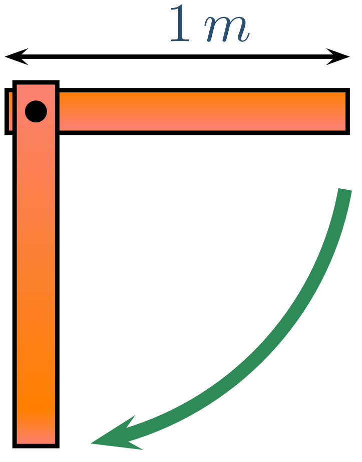

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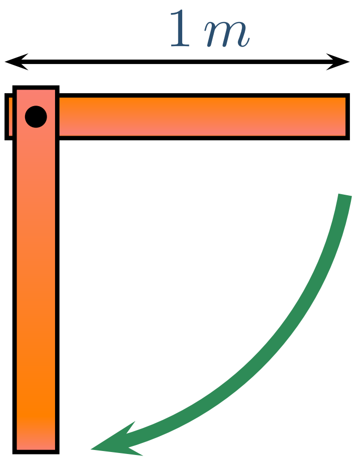

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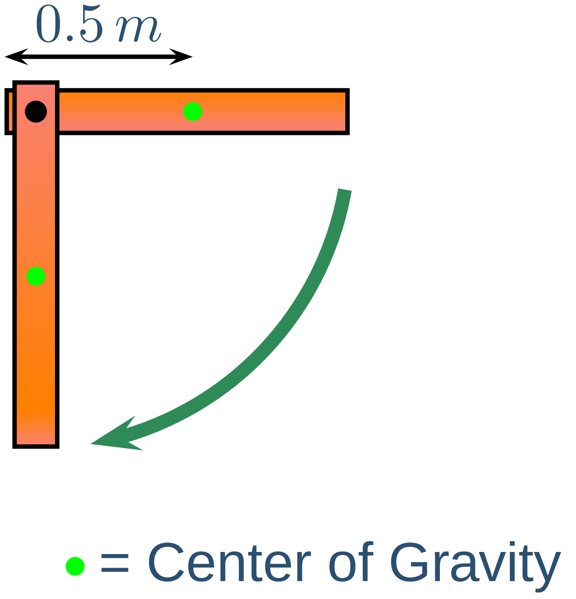

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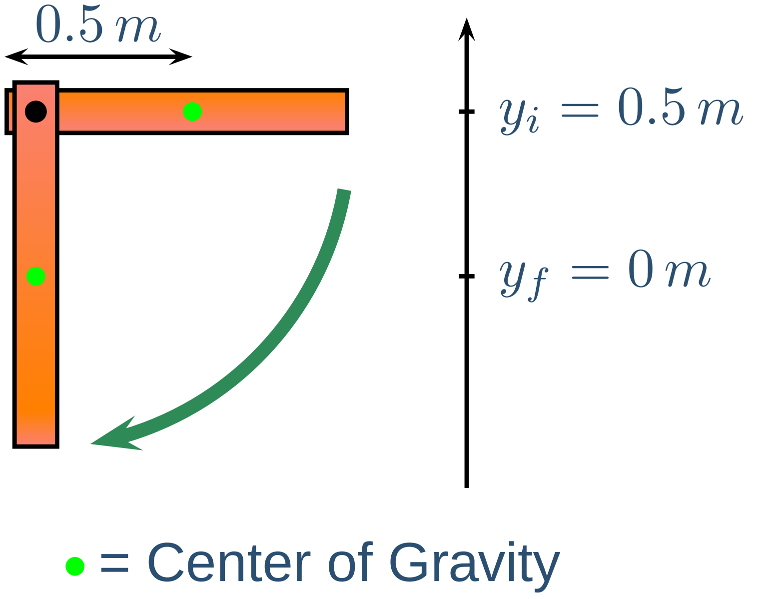

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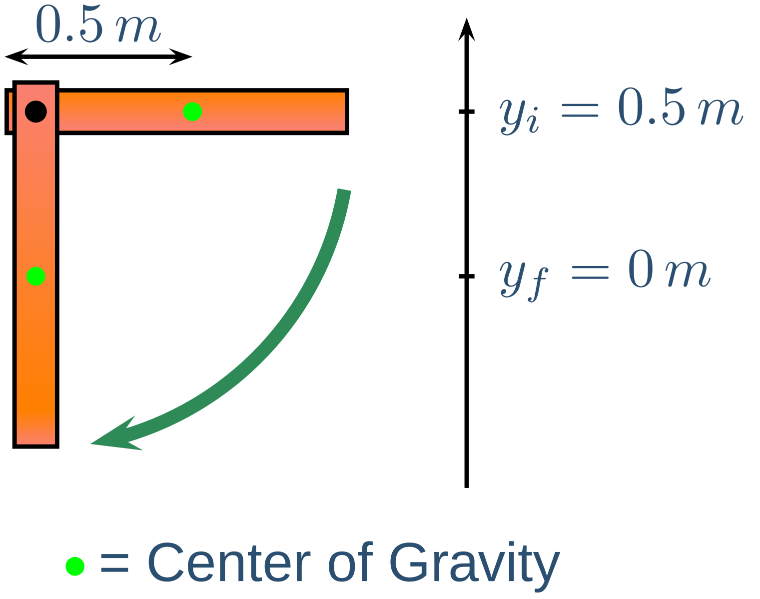

$$\Delta U_g = mgy_{cg,f} - mgy_{cg,i}$$
$$= 0 - mgy_{cg,i}$$

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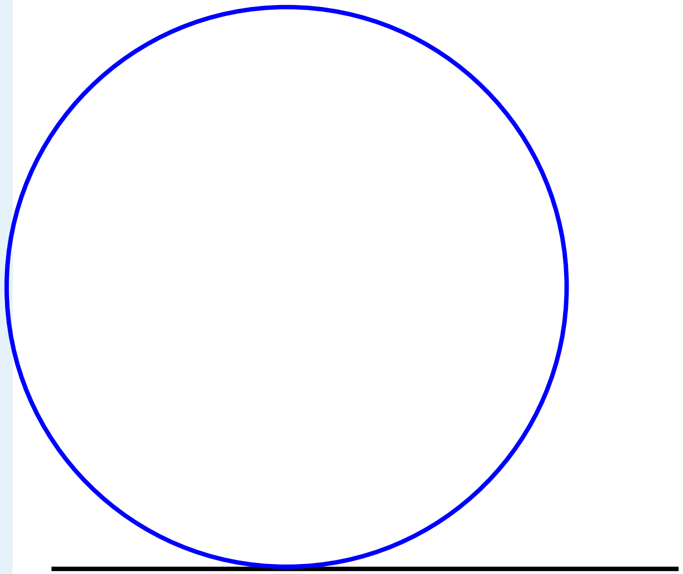
Conservation of Rotational energy

If gravity is the only force doing work on a rigid body:

$$\frac{1}{2}I\omega_i^2 + mgy_{cg,i} = \frac{1}{2}I\omega_f^2 + mgy_{cg,f}$$

Rolling

When an object rolls, it rotates and its center moves.



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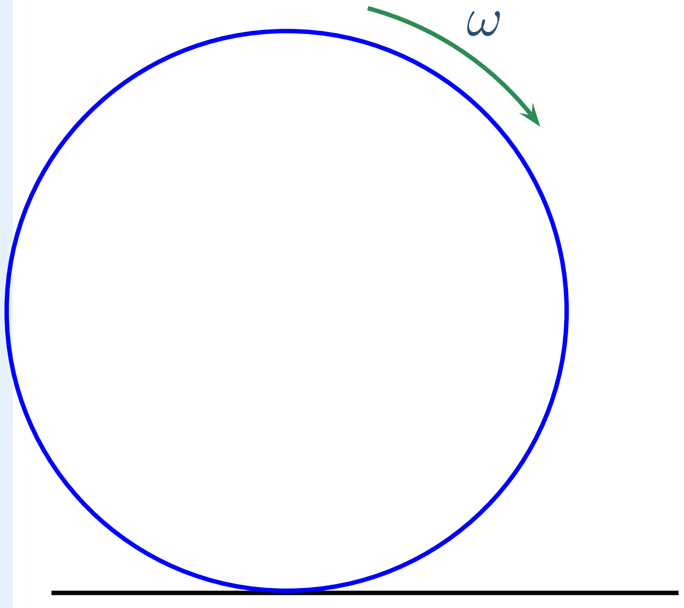

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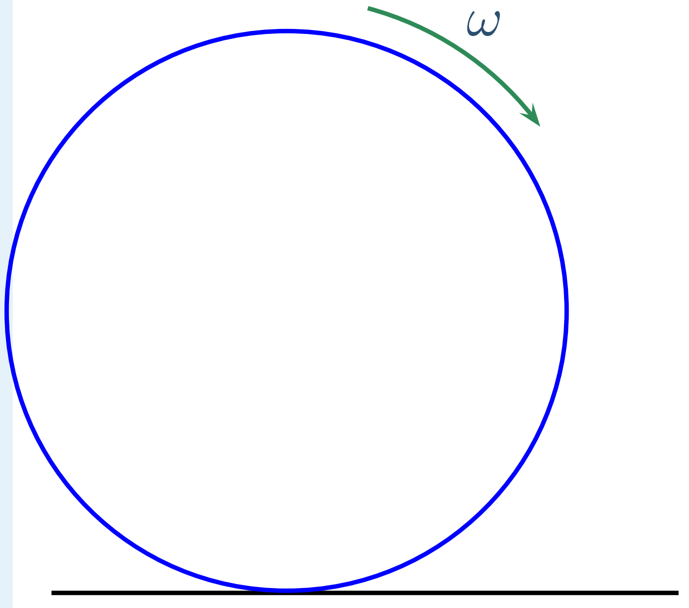

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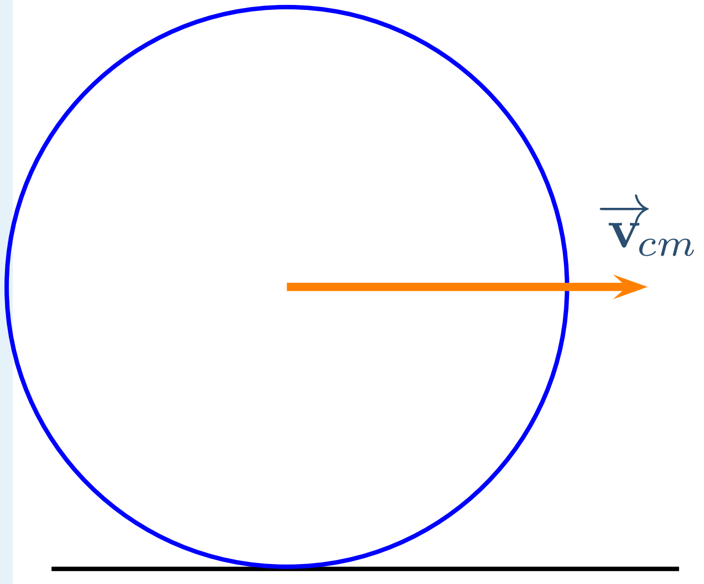

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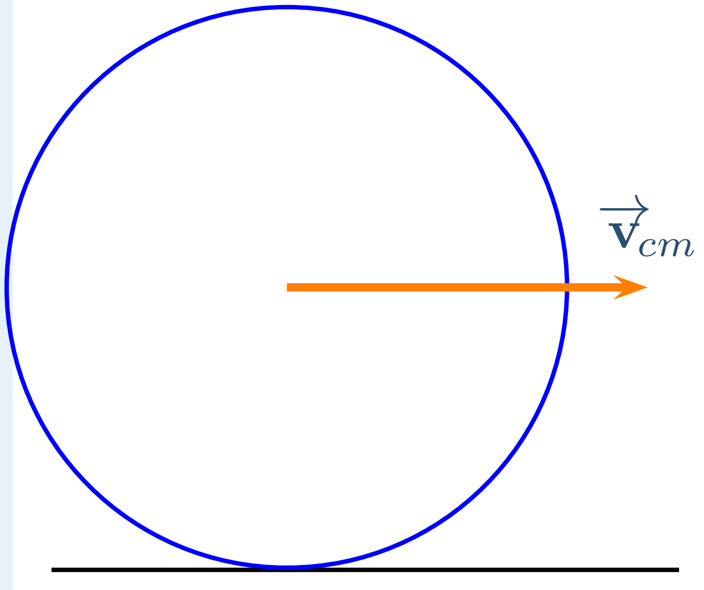

Translational: $K_t = \frac{1}{2}mv_{cm}^2$

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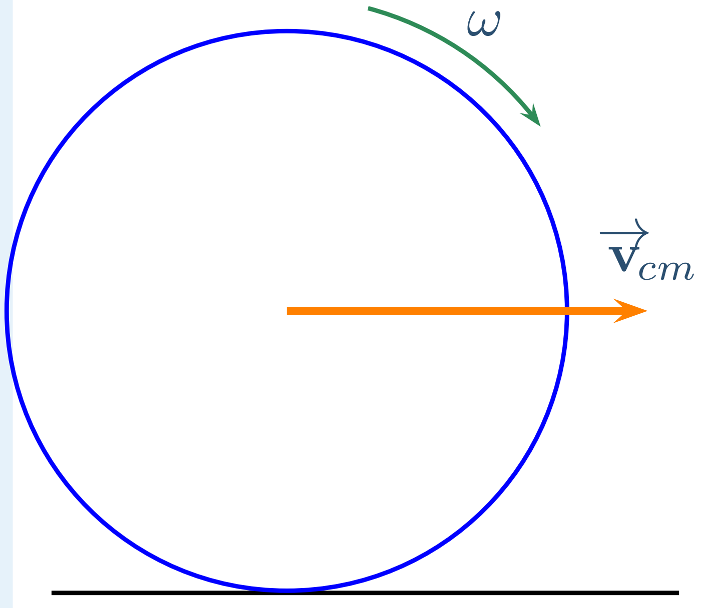

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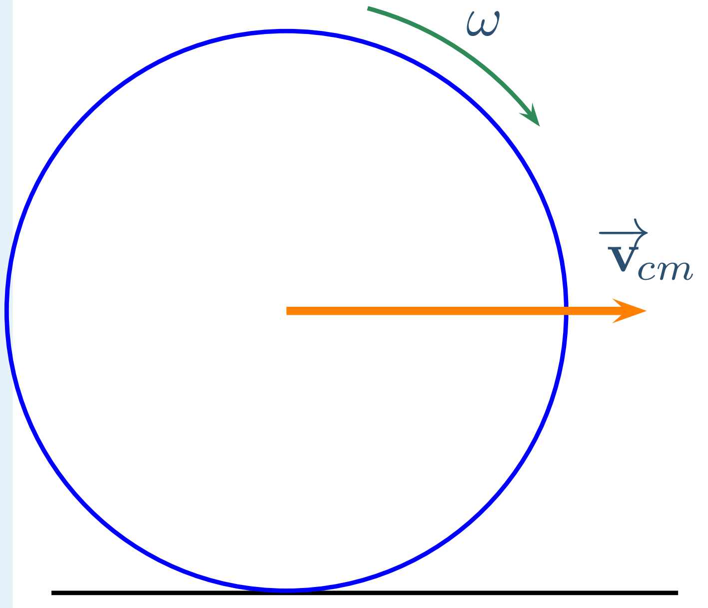

Translational: $K_t = \frac{1}{2}mv_{cm}^2$

Rotational: $K_r = \frac{1}{2}I\omega^2$

Total: $K = K_t + K_r = \frac{1}{2}mv_{cm}^2 + \frac{1}{2}I\omega^2$

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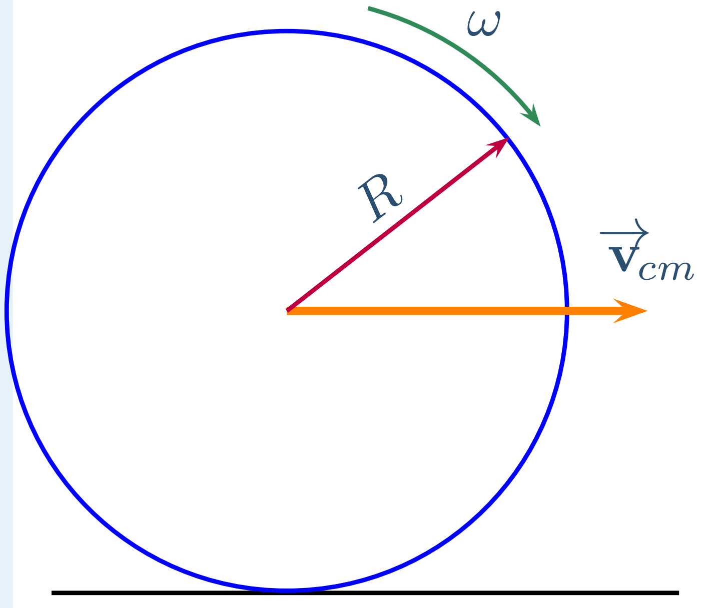

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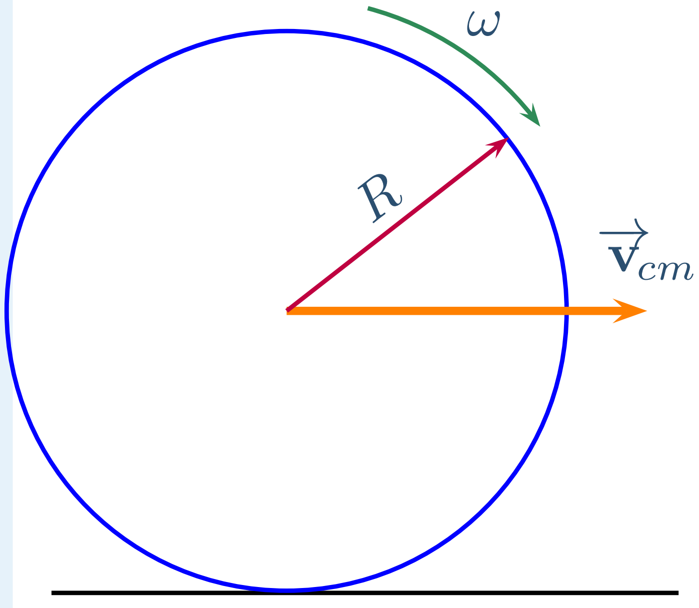

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Rotational: $K_r = \frac{1}{2}I\omega^2$

Total: $K = K_t + K_r = \frac{1}{2}mv_{cm}^2 + \frac{1}{2}I\omega^2$

Rolling without slipping: $v_{cm} = \omega R$

Rolling

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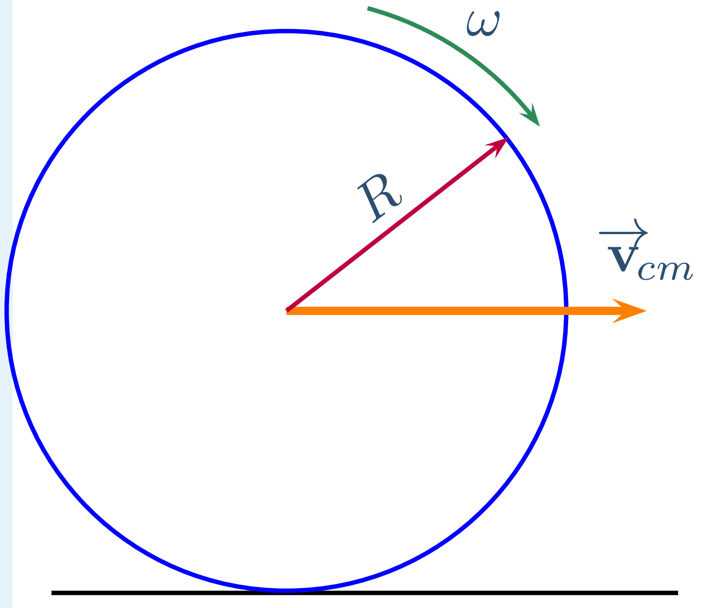

Translational: $K_t = \frac{1}{2} m v_{cm}^2$

Rotational: $K_r = \frac{1}{2} I \omega^2$

Total: $K = K_t + K_r = \frac{1}{2} m v_{cm}^2 + \frac{1}{2} I \omega^2$

Rolling without slipping: $v_{cm} = \omega R$

$$K = \frac{1}{2} m v_{cm}^2 \left(1 + \frac{I}{mR^2}\right)$$