\( \vec{r}, \vec{a}_e \) and \( \vec{v}_t \) rotate at \( \omega \)-radians per second. The angular velocity vector \( \vec{\omega} \) is constant and points in a direction perpendicular to the plane of motion.

Assume Counter clockwise rotation

\[ \omega_i = 0, \quad \omega_f = 33 \frac{1}{3} \text{ rev/min} \]

\[ \omega_f = 33.33 \frac{\text{rev}}{\text{min}} \times \frac{2\pi}{60 \text{ sec}} = 3.488 \frac{\text{rad}}{\text{sec}} \]

\[ \dot{\omega}_f = (\omega_i + \alpha t) \]

\[ \Rightarrow \alpha = \frac{\omega_f - \omega_i}{t} = \frac{3.488 - 0}{2} = 1.744 \frac{\text{rad}}{\text{sec}^2} \]

\[ \Theta = \Theta_i + \omega_i t + \frac{1}{2} \alpha t^2 = 0 + 0 + \frac{1}{2} \times 1.744 \times 25 \]

\[ = 21.8 \text{ rad} \]

\[ \Rightarrow \text{Revolution} = \frac{21.8}{2\pi} \approx 3.5 \]

\[ 60\times \frac{2\pi}{t} = \frac{1}{2} \times 1.744 \times t^2 \]

\[ t = \left( \frac{8 \times 3.142}{1.744} \right)^{\frac{1}{2}} = 3.8 \text{ secs} \]

\[ \vec{a}_c = -\vec{r} \omega^2 \quad \Rightarrow \vec{a}_c = \vec{r} \alpha \]

Now at \( t = 1 \text{ sec} \) \( \omega_f = \omega_i + \alpha t \]

\[ = 0 + 1.744 \times 1 = 1.744 \frac{\text{rad}}{\text{sec}} \]

\[ \vec{a}_c = -0.15 \times (1.744)^2 = -0.456 \frac{\text{m}}{\text{sec}^2} \]

\[ \vec{a}_c = 0.15 \times 1.744 = 0.2616 \frac{\text{m}}{\text{sec}^2} \]

Radial acceleration is centripetal acceleration.
10-3 \[ \alpha = \omega ^2 \]  
\[ \alpha = \text{centripetal acceleration} = -r\omega^2 \]  
and \[ \alpha_t = \text{tangential acceleration} = r\alpha \]  
\[ \therefore \text{Net acceleration } A = \sqrt{\alpha_c^2 + \alpha_t^2} \]  
\[ = \sqrt{r^2 \omega^4 + r^2 \alpha^2} \]  
\[ = r (\omega^4 + \alpha^2)^{1/2} \]

10-4 Area of the parallelogram = base \times \text{altitude}  
\[ = AH \]  
\[ = AH \text{ } m^2. \]

Now from \( \Delta ABC \); \[ \sin \theta = \frac{H}{B} \]  
\[ \Rightarrow H = BS\sin \theta \]

\[ \therefore \text{Area } = AH = AB \sin \theta \text{ } m^2 \]

But \[ |A \times B| = AB \sin \theta \text{ } m^2 = |AB| \]
Direction of \( \alpha = A \times B \) is perpendicular to the plane and in our diagram; points out of the paper [Right-Hand Rule]

10-5 Force causes translation and hence linear acceleration; \( MA = \tau \)

Torque causes rotation and hence angular acceleration; \( I \alpha = \tau \)

In order to have a torque, the force must be applied at some distance \( x \) from the axis of rotation and the force must be perpendicular to \( \Delta \)

10-6 \[ \dot{V}_{CM} = 2 \overrightarrow{MA}; \text{ } x = 0.5 \text{ } m \]

\[ \text{i}, \text{velocity } \dot{V}_p = 0 \text{ at all times for a perfectly rolling body without slip.} \]

\[ \text{ii}, \text{ } \omega = 2\omega_{r}\dot{A} = -0.5 \times 2\dot{A} = -1 \text{ rad/sec} = \]  
(points anti-clockwise)

\[ \text{paper} \]
The object will leave the cylinder where the normal reaction vanishes. The centripetal force at the instant of losing contact is

\[ F_c = mg \cos \theta \]

\[ mg \cos \theta = \frac{mv^2}{r} \quad \text{(velocity at the instant of losing contact)} \]

\[ \Rightarrow g \cos \theta = \frac{v^2}{r} = \frac{v^2}{2} \quad (1) \]

Now using conservation of energy:

\[ PE_f - PE_i = KE_f - KE_i \]

\[ mg (y_f - y_i) = -KE_f \]

\[ mg (R(1+\cos \theta) - 2R) = -\frac{1}{2} mv^2 \]

\[ gR(\cos \theta - 1) = -\frac{1}{2} v^2 \]

\[ \Rightarrow g(1-\cos \theta) = \frac{v^2}{2} \quad (2) \]

\[ g - g \cos \theta = \frac{v^2}{2} \]

Substituting (1) in (2),

\[ g - \frac{v^2}{2} = \frac{v^2}{2} \Rightarrow g = \frac{3v^2}{2} \quad (3) \]

Substituting (3) back in (1),

\[ \frac{3v^2}{2} \cos \theta = \frac{v^2}{2} \]

\[ \Rightarrow \cos \theta = \frac{2}{3} \]

\[ \Rightarrow \theta = 48.2^\circ \]

Velocity at this point from equation (1) is

\[ g \cos \theta = v^2 \]

\[ v = \sqrt{g \cos \theta} = \sqrt{9.8 \times \frac{2}{3}} = 2.56 \text{ m/s} \]
\[ V_T = \sqrt{rg} \]
\[
\Rightarrow \frac{mv^2}{R} = \frac{m \cdot rg}{R} = mg
\]
\[
\Rightarrow \text{centripetal force is provided by } mg + N_k \text{ and } N_k \text{ must be greater than zero.}
\]
This is a risky situation. We need some normal reaction so that we do not fall off. Hence, \( V_T \) has to be slightly greater than \( \sqrt{rg} \).

10-9

Yes, for rolling without slipping, a torque is required which is provided by the friction at the point of contact \( P \).

In pure rolling situation, velocity of point \( P \) on wheel = 0 \( \Rightarrow \) displacement = 0 \( \Rightarrow \) work done by friction = 0.

velocity at top \( = \sqrt{rg} \).

By conservation of energy
\[
mgh = mg \cdot 2R + \frac{1}{2}mv^2
\]
\[
= mg \cdot 2R + \frac{1}{2}m \cdot r^2
\]
\[
= \frac{5Rmg}{2}
\]
\[
\Rightarrow H = \frac{5R}{2}
\]

This is the minimum height, but the body should be dropped from a slightly higher height to ensure \( N \neq 0 \) on top.

10-10

\( H = 0.3 \)

\[ \text{max friction} = HMg \cdot \text{This provides acceleration } a_{max} \]
\[ : \quad HMg = Maaa \Rightarrow a_{max} = Hg = 0.3 \times 9.8 = 2.94 \text{ m/s}^2. \]