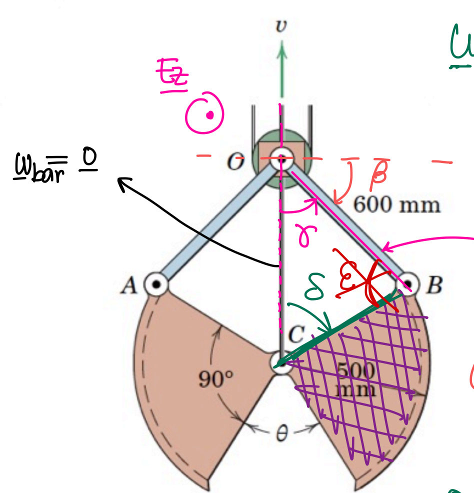
5/65 The elements of a simplified clam-shell bucket for a dredge are shown. The cable which opens and closes the bucket passes through the block at O. With O as a fixed point, determine the angular velocity ω of the bucket jaws when $\theta = 45°$ as they are closing. The upward velocity of the control cable is 0.5 m/s as it passes through the block.

5/69 SS A four-bar linkage is shown in the figure (the ground "link" OC is considered the fourth bar). If the drive link OA has a counterclockwise angular velocity $\omega_0 = 10$ rad/s, determine the angular velocities of links AB and BC.



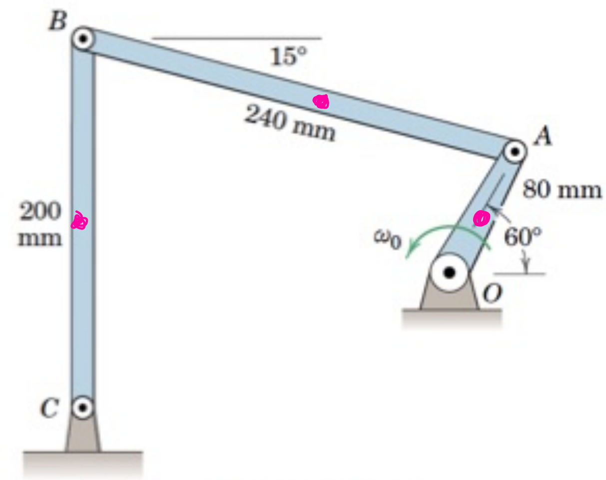
$\omega_{CB} = -\dot\delta E_z$

$\omega_{OB} = \dot\gamma E_z$
$= -\dot\beta E_z$

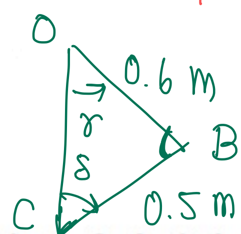
$(\gamma + \beta = \frac{\pi}{2})$

$\dot\gamma = -\dot\beta$

PROBLEM 5/65



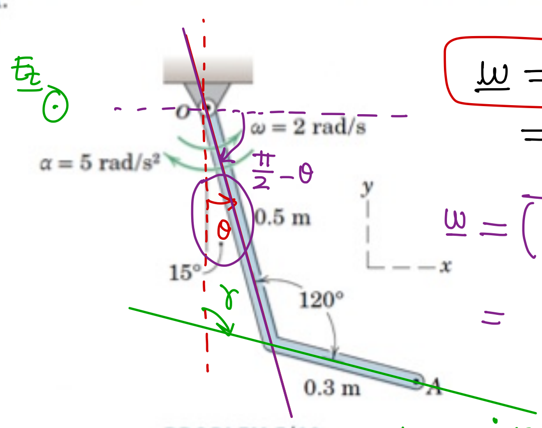
PROBLEM 5/69



$$\frac{\sin\delta}{0.6} = \frac{\sin\gamma}{0.5}$$

$$\boxed{\frac{\dot\delta\cos\delta}{0.6} = \frac{\dot\gamma\sin\gamma}{0.5}}$$

5/13 The bent flat bar rotates about a fixed axis through point O with the instantaneous angular properties indicated in the figure. Determine the velocity and acceleration of point A.



$$\boxed{\underline{\omega} = \dot\theta E_z}$$
$$= \omega E_z$$

$$\underline{\omega} = \left(\dot{\overline{\tfrac{\pi}{2} - \theta}}\right)(-E_z)$$
$$= \dot\theta E_z$$

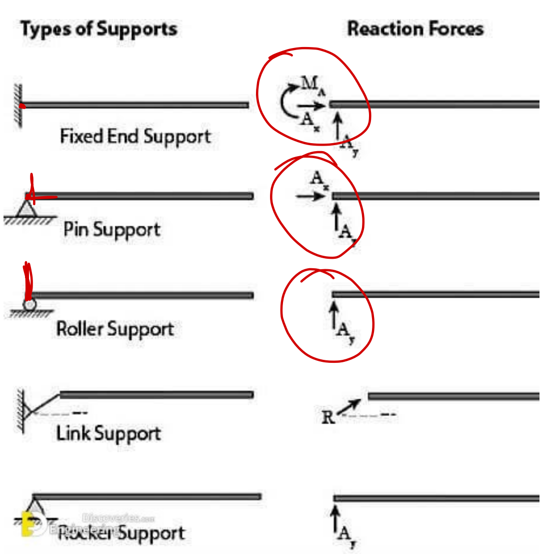
PROBLEM 5/13

$\underline{\omega} = -\dot\gamma E_z$
$= \dot\theta E_z$

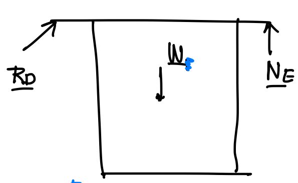
~~k set 11 p 4,~~

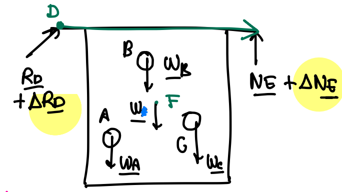
~~k set 9 p 8,~~

* sets 14

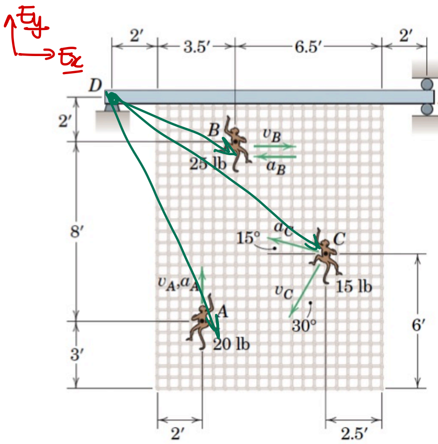


$\underline{w}$ weight of bar and rope.





4/9 The monkeys of Prob. 4/8 are now climbing along the heavy rope wall suspended from the uniform beam. If monkeys A, B, and C have velocities of 5, 3, and 2 ft/sec, and accelerations of 1.5, 0.5, and 2 ft/sec^2, respectively, determine the changes in the reactions at D and E caused by the motion and weight of the monkeys. The support at E makes contact with only one side of the beam at a time. Assume for this analysis that the rope wall remains rigid.



PROBLEM 4/9

$\underline{a}_B = -0.5\,\underline{E}_x$ ft/sec^2

$\underline{a}_A = 1.5\,\underline{E}_y$ ft/sec^2

$\underline{a}_c = 2(-\cos 15\,\underline{E}_x + \sin 15\,\underline{E}_y)$ ft/sec^2.

$\underline{F} = m\underline{a}_c$

BoLM $\boxed{\underline{R}_D + \underline{N}_E + \underline{W}_F = \underline{0}}$

$\cancel{\underline{R}_D} + \Delta \underline{R}_D + \cancel{\underline{N}_E} + \Delta \underline{N}_E + \underline{W}_A + \underline{W}_B + \underline{W}_C + \cancel{\underline{W}_F}$

$= \sum m_i \underline{a}_i = m\underline{a}_c$

$= m_A \underline{a}_A + m_B \underline{a}_B + m_C \underline{a}_C$

- 3 scalar unknown
- 2 scalar equations

$$\boxed{\begin{aligned}\underline{M}^D &= (\underline{r}_E - \underline{r}_D) \times \underline{N}_E \\ &+ (\underline{r}_F - \underline{r}_D) \times \underline{W} \\ &= \underline{0}\end{aligned}}$$

BoAM about D (fixed point)

$\underline{M}^D = \dot{\underline{H}}^D$

$\Delta N_E \underline{E}_y$

$$\underline{M}^D = (\underline{r}_E - \underline{r}_D) \times (\cancel{\underline{N}_E} + \Delta \underline{N}_E) + (\underline{r}_B - \underline{r}_D) \times \underline{W}_B + (\underline{r}_A - \underline{r}_D) \times \underline{W}_A + (\underline{r}_C - \underline{r}_D) \times \underline{W}_C + \cancel{(\underline{r}_F - \underline{r}_D) \times \underline{W}}$$

$$\underline{H}^D = \sum (\underline{r}_i - \underline{r}_D) \times m_i \underline{v}_i$$

$$= (\underline{r}_A - \underline{r}_D) \times m_A \underline{v}_A + (\underline{r}_B - \underline{r}_D) \times m_B \underline{v}_B + (\underline{r}_C - \underline{r}_D) \times m_C \underline{v}_C$$

$$\dot{\underline{H}}^D = \cancel{(\underline{v}_A - \underbrace{\underline{v}_D}_{0}) \times m_A \underline{v}_A}_{0} + (\underline{r}_A - \underline{r}_D) \times m_A \underline{a}_A + (\underline{r}_B - \underline{r}_D) \times m_B \underline{a}_B + (\underline{r}_C - \underline{r}_D) \times m_C \underline{a}_C.$$

$\underline{M}^D = \dot{\underline{H}}^D \Rightarrow$ solve for $\Delta \underline{N}_E$

8. [03-192] To avoid confusion label r in the figure R and the angle θ requested in the solution as β.

Step 1. Choose the origin O to be at the bottom of the funnel and setup the cylinderical-polar coordinate system. Derive $\mathbf{v}$ but not $\mathbf{a}$, we will not need it as we will solve the problem by exploiting conservations. The particle is constrained to move on a surface of revolution given by $z^2+(r-1.15R)^2 = R^2$. A time derivative of this expression yields $z\dot{z} + \dot{r}(r - 1.15R) = 0$.

Step 2. Draw a free-body diagram of the particle. Express the normal force as $\mathbf{N} = N\mathbf{n}$, where $\mathbf{n}$ is a unit direction normal to the surface of revolution. In theory, $\mathbf{n}$ could be computed from a gradient of $z^2 + (r - 1.15R)^2 = R^2$, but you don't need to do that here. You only need to note that $\mathbf{N}$ has $\mathbf{e}_r$ and $\mathbf{E}_z$ components.

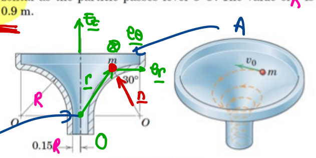
Step 3. In Step III, prove a conservation on the total mechanical energy E and a conservation of $\mathbf{E}_z$ components of the angular momentum $\mathbf{H}^O$. You will need to refer to your FBD to identify these conserved quantities.

Step 4. Calculate the numerical values of E and and $\mathbf{H}_O \cdot \mathbf{E}_z$ using the initial conditions and complete your analysis.

$\underline{r} = r\underline{e_r} + z\underline{E_z}$

$\dot{\underline{r}} = \dot{r}\underline{e_r} + r\dot{\theta}\underline{e_\theta} + \dot{z}\underline{E_z}$

3/192 A particle is launched with a horizontal velocity $v_0 = 0.55$ m/s from the 30° position shown and then slides without friction along the funnel-like surface. Determine the angle β which its velocity vector makes with the horizontal as the particle passes level O-O. The value of R is 0.9 m.



PROBLEM 3/192

1) $z^2 + (r - 1.15R)^2 = R^2$

$z\dot{z} + (r - 1.15R)\dot{r} = 0$

2) $\underline{W} = -mg\underline{E_z}$

$\underline{N} = N\underline{n}$

$n_r\underline{e_r} + n_z\underline{E_z}$

Conservative

workless $\underline{N}.\underline{v} = 0$

3) All the forces doing work on the system are Conservative $\Rightarrow$ so the energy of the system is conserved.

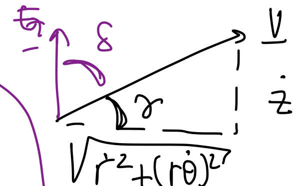
$T_B - T_A = W_{W,AB} = U_A - U_B$.

$U = +mg\underline{E_z}\cdot\underline{r} = mgz$

$(= -\underline{G}.\underline{r})$

$\frac{1}{2}mv_B^2 + mgz_B = \frac{1}{2}mv_A^2 + mgz_A$.

$\underline{v} = \dot{r}\underline{e_r} + r\dot{\theta}\underline{e_\theta} + \dot{z}\underline{E_z}$



$\tan\gamma = \frac{\dot{z}}{\sqrt{(\dot{r})^2 + (r\dot{\theta})^2}}$

$\underline{v}.\underline{E_z} = \|\underline{v}\|\cos\delta$

$\frac{\pi}{2} - \delta = \gamma$

show that $\underline{H}^O.\underline{E_z}$ is conserved?

If $\underline{M}^O.\underline{E_z} = 0 \Rightarrow \underline{H}^O.\underline{E_z}$ is conserved.

$\underline{M}^O = \underline{r}\times\underline{f} = (r\underline{e_r} + z\underline{E_z})\times(-mg\underline{E_z} + N(n_r\underline{e_r} + n_z\underline{E_z}))$

$= -rmg(-\underline{e_\theta}) - rn_zN(\underline{e_\theta}) + zNn_r\underline{e_\theta}$

$\underline{M}^O.\underline{E_z} = 0 \Rightarrow \underline{H}^O.\underline{E_z}$ is conserved!

We want to calculate $\underline{v_B}$.

$\underline{H}^O = \underline{r}\times m\underline{v}$

$= m[(r\underline{e_r} + z\underline{E_z})\times m(\dot{r}\underline{e_r} + r\dot{\theta}\underline{e_\theta} + \dot{z}\underline{E_z})]$

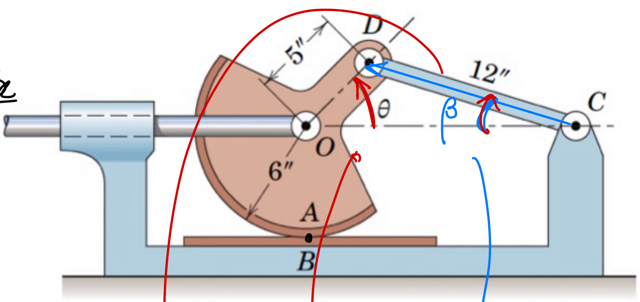
$= m[r^2\dot{\theta}\underline{E_z} + r\dot{z}(-\underline{e_\theta}) + mz\dot{r}\underline{e_\theta} - r\dot{\theta}z\underline{e_r}]$

$\underline{H}^O.\underline{E_z} = mr^2\dot{\theta}$

$\cancel{m}r_A^2\dot{\theta}_A = \cancel{m}r_B^2\dot{\theta}_B$

5/93 A device which tests the resistance to wear of two materials A and B is shown. If the link EO has a velocity of 4 ft/sec to the right when $\theta = 45°$, determine the rubbing velocity v_A.

e_y, e_x, e_z



PROBLEM 5/93

find v_A

$\underline{v}_O = 4\underline{e}_x$ ft/sec

$\star\ \underline{v}_D - \underline{v}_O = \underline{\omega}_{OD} \times (\underline{r}_D - \underline{r}_O)$

$\underline{\omega}_{OD} = \omega_{OD}\underline{e}_z \qquad \overline{OD}(\cos\theta\,\underline{e}_x + \sin\theta\,\underline{e}_y)$

$\star\ \underline{v}_A - \underline{v}_O = \underline{\omega}_{OD} \times (\underline{r}_A - \underline{r}_O)$

$-\overline{OA}\,\underline{e}_y$

$\underline{v}_A = 4\underline{e}_x + \omega_{OD}\underline{e}_z \times (-\overline{OA}\,\underline{e}_y)$

$= (4 + \omega_{OD}\overline{OA})\underline{e}_x$

$\star\ \underline{v}_D - \cancel{\underline{v}_C} = \underline{\omega}_{CD} \times (\underline{r}_D - \underline{r}_C)$

$\omega_{CD}\underline{e}_z \qquad \overline{CD}(-\cos\beta\,\underline{e}_x + \sin\beta\,\underline{e}_y)$

$\underline{v}_D = \underline{v}_D$

$\dfrac{\sin\theta}{12} = \dfrac{\sin\beta}{5}$

(1) $4\underline{e}_x + \omega_{OD}\underline{e}_z \times \overline{OA}(\cos\theta\,\underline{e}_x + \sin\theta\,\underline{e}_y) = \omega_{CD}\underline{e}_z \times \overline{CD}(-\cos\beta\,\underline{e}_x + \sin\beta\,\underline{e}_y)$

$\underline{\omega}_{OD} = \dot\theta\,\underline{e}_z$

$\underline{\omega}_{DC} = \dot\beta(-\underline{e}_z)$

$\boxed{\dfrac{\dot\theta\cos\theta}{12} = \dfrac{\dot\beta\cos\beta}{5}} \Rightarrow \dfrac{\omega_{OD}\cos\theta}{12} = -\dfrac{\omega_{DC}\cos\beta}{5}$ (2)

$\dot\theta = \dfrac{\text{rad}}{\text{sec}}$

rad

1 rev = 2π rad

$\dot\theta = \dfrac{\frac{1}{2\pi}\text{rev}}{\text{sec}}$

rad = $\dfrac{1\text{ rev}}{2\pi}$

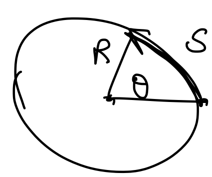
$\dfrac{1\text{ rev}}{\text{sec}} = \dfrac{2\pi\text{ rad}}{\text{sec}}$

$N = 2\pi\dot\theta = \dfrac{\text{rev}}{\text{sec}}$

$\dot\theta = \dfrac{N}{2\pi}$

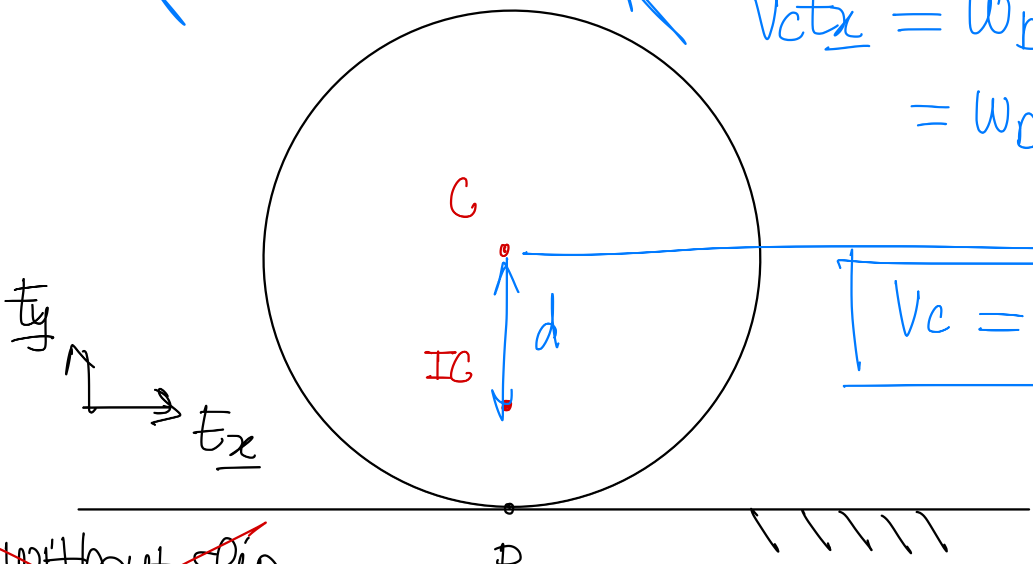
N = rev/sec

$\theta = \dfrac{S}{R}$



$$\underline{v}_C - \cancel{\underline{v}_{IC}}^{\,0} = \underline{\omega}_{Disk} \times (\underline{r}_C - \underline{r}_{IC})$$

$$v_C \underline{E}_x = \omega_{Disk} \underline{E}_z \times d\,\underline{E}_y$$
$$= \omega_{Disk}\, d\,(-\underline{E}_x)$$



$$\boxed{v_C = d\,\omega_{Disk}}$$

~~roll without slip~~

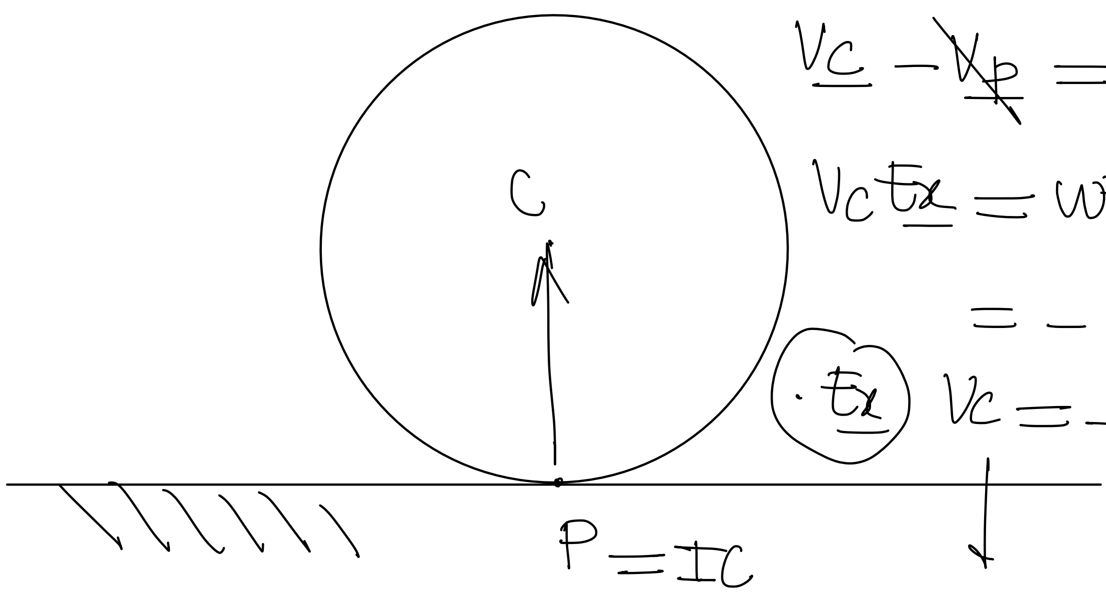
$\cancel{\underline{v}_P = \underline{0}}$

roll with slip

$$\underline{v}_P \neq \underline{0}$$

$$\underline{v}_P \cdot \underline{E}_y = 0$$

$$1\ \frac{rev}{min} = \frac{2\pi\ rad}{60\ s}$$



$$\underline{v}_C - \cancel{\underline{v}_P}^{\,0} = \underline{\omega} \times (\underline{r}_C - \underline{r}_P)$$

$$v_C \underline{E}_x = \omega \underline{E}_z \times R\underline{E}_y$$
$$= -\omega R \underline{E}_x$$

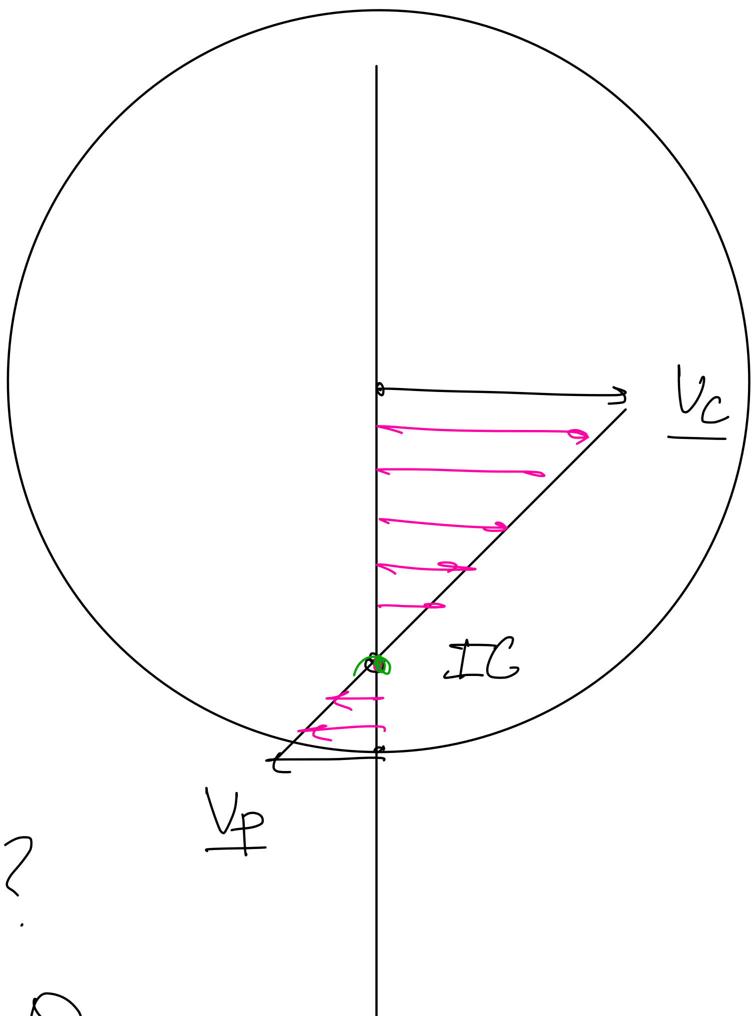
$\cdot\,\underline{E}_x$ $\quad v_C = -\omega R$

$$a_C = -\alpha R$$

$$\underline{a}_C = -\alpha R \underline{E}_z$$

$$\underline{a_c} - \underline{a_p} = \underline{\alpha} \times (\underline{r_c} - \underline{r_p}) + \underline{\omega} \times (\underline{v_c} - \underline{v_p})$$

$$\underline{a_p} = \ldots \quad \underline{t_y}$$



$$\underline{r_{IC}} = ?$$

$$\underline{v_c} - \cancel{\underline{v_{IC}}}^{\,0} = \underline{\omega} \times (\underline{r_c} - \underline{r_{IC}})$$

$$\underline{v_p} - \cancel{v_{IC}}^{\,0} = \underline{\omega} \times (\underline{r_p} - \underline{r_{IC}})$$

2 equations, 2 unknowns.

$$\int_0^5 \underline{M}^O \, dt = \underline{H}^O(t=5) - \cancel{\underline{H}^O(t=0)}$$

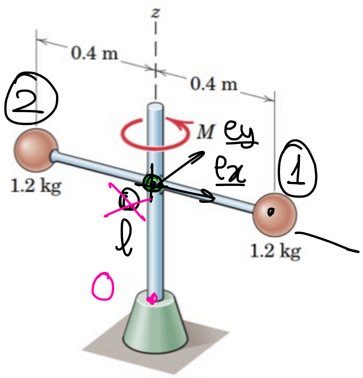
0

3/178 The rigid assembly which consists of light rods and two 1.2-kg spheres rotates freely about a vertical axis. The assembly is initially at rest and then a constant couple $M = 2$ N·m is applied for 5 s. Determine the final angular velocity of the assembly. Treat the small spheres as particles.

$$\underline{H}^O = (\cancel{l\underline{e_z}} + 0.4\underline{e_x}) \times m(+0.4\dot{\theta}\underline{e_y})$$

$$+ (\cancel{l\underline{e_z}} - 0.4\underline{e_x}) \times m(-0.4\dot{\theta}\underline{e_y})$$

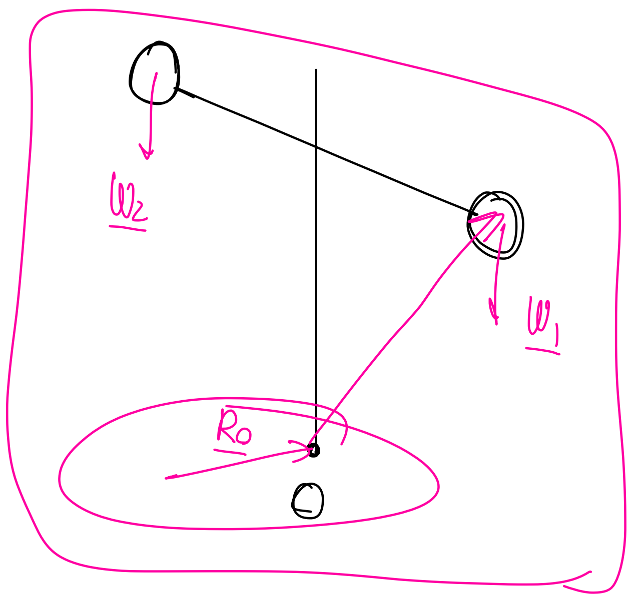
$\underline{e_z}$



PROBLEM 3/178

$$\underline{r_1} = 0.4\underline{e_x}$$

$$\underline{v_1} = 0.4\dot{\theta}\underline{e_y}$$



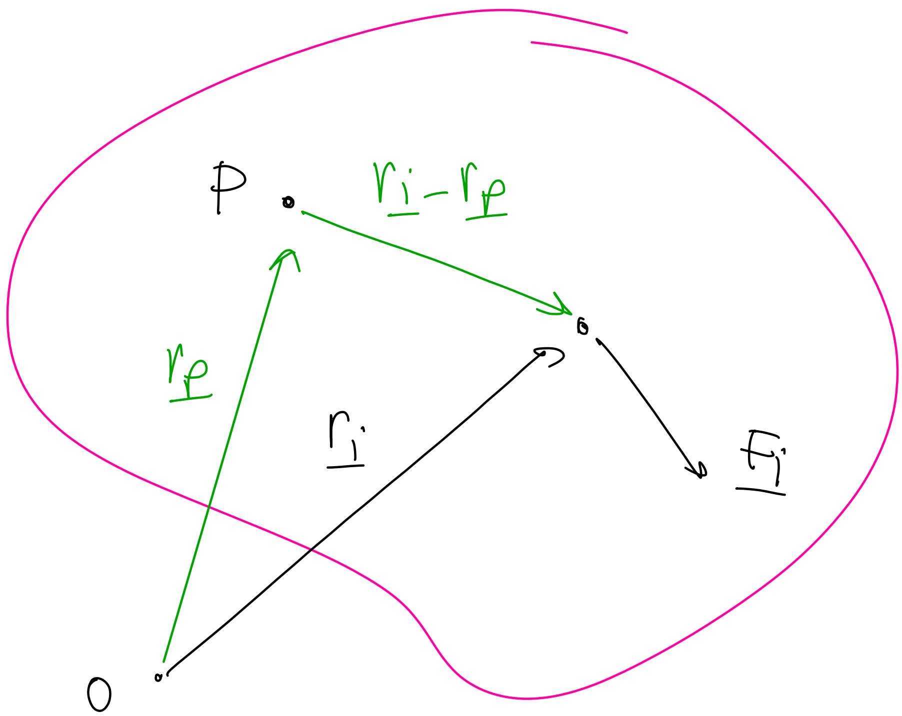
$$\underline{r_1} \times \underline{W_1} + \underline{r_2} \times \underline{W_2} + \underline{M}$$

$$= (l\underline{e_z} + 0.4\underline{e_x}) \times -mg\underline{e_z} + (l\underline{e_z} - 0.4\underline{e_x}) \times -m_2 g\underline{e_z} + \underline{M}$$

$$= \underline{M}$$

$$(2)(5)\underline{e_z} = (2)(0.4)^2(m)\dot{\theta}\underline{e_z}$$

at $t=5$


P
$\underline{r_i} - \underline{r_P}$
$\underline{r_P}$
$\underline{r_i}$
$\underline{F_i}$
O