There are 3 problems on this exam. The exam is closed notes and closed books; only the provided equation sheet can be used. Please show all your work.

1. The 0.8 Mg car travels over the hill having the shape of a parabola. When the car is at point $A$, it is traveling at 9 m/s and increasing its speed at 3 m/s$^2$. Determine both the resultant normal force and the resultant frictional force that all the wheels of the car exert on the road at this instant. Neglect the size of the car. **30 points**

   \( F_{BD} + 10 \)
   \( \rho + 5 \)
   \( \Sigma F_n + 7 \)
   \( \Sigma F_t + 7 \)
   \( \theta + 1 \)

2. If the slider block $A$ is moving to the right at $v_A = 8$ ft/s, determine the velocity of blocks $B$ and $C$ at the instant shown. Member $CD$ is pin connected to member $ADB$. **30 points**

   \( F_{BD} \circlearrowleft 0 ABD + 5 \)
   \( \dot{v}_B + 8 \)
   \( F_{BD} \circlearrowleft 0 CD + 5 \)
   \( \dot{v}_D + 4 \)
   \( \dot{v}_C + 4 \)

3. The 1.5 kg cylinder $C$ travels along the path described by $r = (0.6 \sin \theta)$. If arm $OA$ is rotating counterclockwise with a constant angular velocity of $\dot{\theta} = 3$ rad/s, determine the force exerted by the smooth slot in arm $OA$ on the cylinder at the instant $\theta = 60^\circ$. The spring has a stiffness of 100 N/m and is unstretched when $\theta = 30^\circ$. The cylinder is in contact with only one edge of the slotted arm. Neglect the size of the cylinder. Motion occurs in the *horizontal plane*. **40 points**

   \( F_{BD} + 10 \)
   \( \tan \psi + 5 \)
   \( r \cdot \dot{r} + 4 \)
   \( \Sigma F_{\theta} + q \rightarrow \Sigma F + 5 \ a_r + 4 \)
   \( \Sigma F + 5 \ a_6 + 4 \)
\[ y = 20 - \frac{20x^2}{6400} \]

\[ \frac{dy}{dx} = \frac{-40x}{6400} \]  
\[ \text{at } x = 80 \text{ m} \quad \frac{dy}{dx} = \frac{0(80)}{6400} = -0.5 \]

\[ \frac{d^2y}{dx^2} = \frac{-40}{6400} \]

\[ \rho = \frac{1 + (\frac{dy}{dx})^2}{|\frac{d^2y}{dx^2}|} \]

\[ \rho = \frac{1 + (-0.5)^2}{|-0.00625|} \]

\[ \rho = 223.6 \text{ m} \]

\[ \Sigma F_n = ma_n = \frac{mv^2}{\rho} \]
\[ W \cos 26.6^\circ - N = \frac{mv^2}{\rho} \]
\[ N = W \cos 26.6^\circ - \frac{mv^2}{\rho} = 7848 \text{ N} \cos 26.6^\circ - \frac{(0.8 \times 10^3 \text{ kg})(9 \text{ m/s})^2}{223.6 \text{ m}} \]
\[ N = 6727.5 \text{ N} = 6.73 \text{ kN} \]

\[ \Sigma F_t = ma_t = mv \]

\[ F_t + W \sin 26.6^\circ = mv \]

\[ F_t = mv - W \sin 26.6^\circ = 0.8 \times 10^3 \text{ kg}(3 \text{ m/s}^2) - 7848 \text{ N} \sin 26.6^\circ \]
\[ F_t = -1114 \text{ N} = -1.11 \text{ kN} \]

\[ m = 0.8 \times 10^3 \text{ kg} \]
\[ v = 9 \text{ m/s} \]
\[ a_t = 3 \text{ m/s}^2 \]
\[ w = 7848 \text{ N} \]
\[ V_A = 8 \text{ ft/s} \]

Use instantaneous center to find
\[ \vec{V}_B = \vec{w}_{AB} \times \vec{r}_{B/IC} \]
\[ \vec{V}_A = \vec{w}_{AB} \times \vec{r}_{B/IC} \]

\[ 8 \hat{y} = \vec{w}_{AB} \hat{k} \times -2.83 \hat{y} \]
\[ 8 \hat{y} = 2.83 \vec{w}_{AB} \hat{y} \]
\[ \vec{w}_{AB} = 2.83 \text{ rad/s} \hat{k} \]

\[ \vec{V}_B = \vec{w}_{AB} \times \vec{r}_{B/IC} \]
\[ \vec{V}_B = 2.83 \hat{k} \times 2.83 \hat{y} \]
\[ \vec{V}_B = 8 \text{ ft/s} \hat{y} \]

\[ \vec{V}_D = \vec{w}_{AB} \times \vec{r}_{D/IC} \]
\[ \vec{V}_D = 2.83 \hat{k} \times (2 \cos 45 \hat{x} - 2 \sin 45 \hat{y}) \]
\[ \vec{V}_D = 4 \hat{j} + 4 \hat{x} \text{ ft/s} \]

\[ \vec{w}_{CD} = ? \]
\[ \vec{V}_D = \vec{w}_{CD} \times \vec{r}_{D/IC} \]

Using law of sines
\[ \frac{2}{\text{dim} 135} = \frac{\text{CD/IC}}{\text{dim} 30} \]
\[ \frac{2}{\text{dim} 130} = \frac{\text{CD/IC}}{\text{dim} 15} \]
\[ \text{CD/IC} = 1.41 \text{ ft} \]
\[ \vec{p}_{D/IC} = 1.41 \cos 45 \hat{x} - 1.41 \sin 45 \hat{y} \]
\[ \text{CD/IC} = 0.732 \text{ ft} \]
\[ \vec{c}_{D/IC} = -0.732 \hat{z} \]
\[ \vec{V}_D = \vec{\omega}_{CD} \times \vec{r}_{PD/IC} \]

\[ 4 \hat{i} + 4 \hat{j} = \vec{\omega}_{CD} \hat{k} \times (1, 41 \cos 45^\circ - 1, 41 \sin 45^\circ \hat{j}) \]

\[ 4 \hat{i} + 4 \hat{j} = 0, 997 \vec{\omega}_{CD} \hat{j} + 0, 997 \vec{\omega}_{CD} \hat{i} \]

\[ \vec{\omega}_{CD} = \frac{4}{0, 997} = 4, 01 \ \text{rad/s} \]

\[ \vec{V}_C = \vec{\omega}_{CD} \times \vec{r}_{IC/CL} = 4, 01 \hat{k} \times -0, 732 \hat{i} \]

\[ \vec{V}_C = -2, 93 \hat{j} \ \frac{\text{ft}}{\text{s}} \]
\[ r = 0.6 \sin \theta = 0.5196 \text{ m} \quad m = 1.5 \text{ kg} \]
\[ \dot{r} = 0.6 \cos \theta \dot{\theta} = 0.9 \text{ m/s} \]
\[ \ddot{r} = -0.6 \sin \theta \dot{\theta}^2 + 0.6 \cos \theta \ddot{\theta} = -4.676 \text{ m/s}^2 \]

\[ \theta = 60^\circ \]
\[ \dot{\theta} = 3 \text{ rad/s} \]
\[ \ddot{\theta} = 0 \]

\[ \psi = \tan^{-1} \left( \frac{0.5196}{0.3} \right) = 60^\circ \]

\[ a_r = \ddot{r} - r \ddot{\theta}^2 = -4.676 - 0.5196(3)^2 \]
\[ a_r = -9.35 \text{ m/s}^2 \]

\[ a_\theta = r \ddot{\theta} + 2 \dot{r} \dot{\theta} = 2(0.9)(3) = 5.4 \text{ m/s}^2 \]

\[ F_s = \frac{m a_r}{\sin 60^\circ} = \frac{100 \text{ N}}{0.5196 - 0.6 \cdot 0.3 \cdot 30} \]
\[ F_s = 21.96 \text{ N} \]

\[ \xi F_r = m a_r + N \sin 60^\circ - F_s = m a_r \]
\[ N = m a_r + F_s \]
\[ \sin 60^\circ = \frac{1.5 \text{ kg} \cdot (-9.35 \text{ m/s}^2)}{\sin 60^\circ} + 21.96 \text{ N} \]
\[ N = 9.16 \text{ N} \]

\[ \xi F_\theta = m a_\theta \]

\[ F_{OA} - N \cos 60^\circ = ma_\theta \]
\[ F_{OA} = ma_\theta + N \cos 60^\circ \]

\[ F_{OA} = 1.5 \text{ kg} \cdot (5.4 \text{ m/s}^2) + 9.16 \cos 60^\circ \]
\[ F_{OA} = 12.68 \text{ N} \]