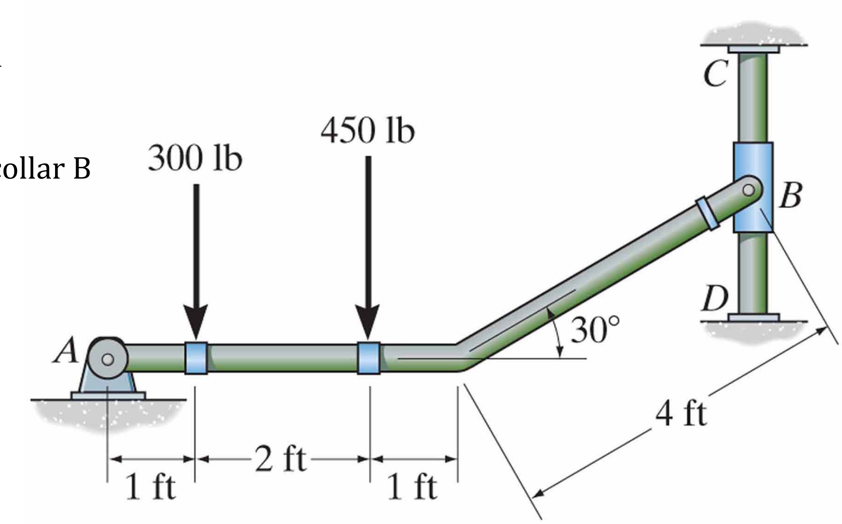
Problem 1 (10 Marks)

Ignore the weight of the frame AB and

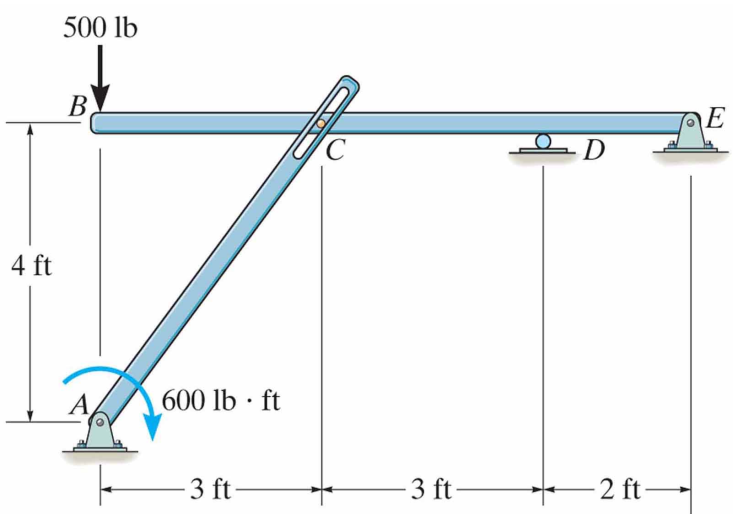
(a) Draw its Free Body Diagram
(b) Determine the reaction at A
(c) Determine the reaction at the collar B



Problem 2 (20 Marks)

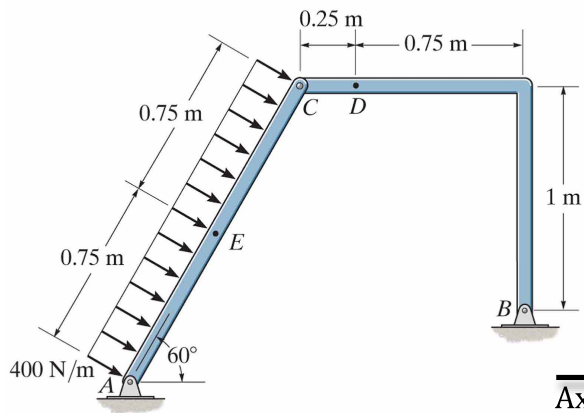
The pin at C is fixed to member BDE and passes through the smooth slot in member AC. Ignore the weight and

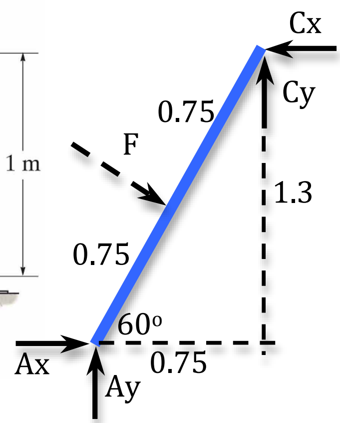
(a) Draw the Free Body Diagram for AC
(b) Draw the Free Body Diagram for ACDE
(c) Determine the reaction at supports A, D and E

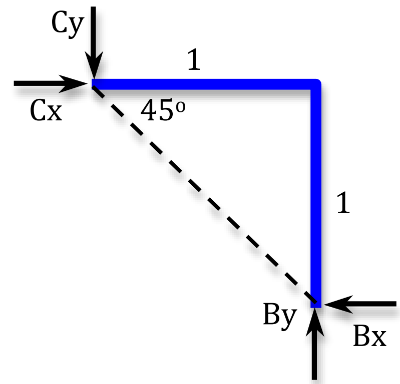


Problem 3 (20 Marks)

(a) Draw the Free Body Diagram for component AC **(4 marks)**
(b) Draw the Free Body Diagram for component CB **(4 marks)**
(c) Determine the reactions at support A **(4 marks)**
(d) Determine the reactions at support B **(4 marks)**
(e) Determine the internal forces (Axial, Shear and Bending Moment) at point D. **(4 marks)**







$F = 400\text{ N/m }(0.75\text{m} + 0.75\text{m}) = 600\text{ N}$

BC is a 2-force member

$Cx = Cy$

$Bx = By$

$C = B$

$\Sigma M_A = 0$

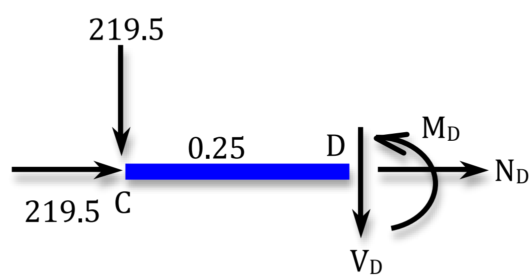
$-600(0.75) + Cx(1.3) + Cy(0.75) = 0$

$Cx = Cy$

$2.05Cx = 450$

$Cx = 219.5\text{ lb} \leftarrow$

$Cy = Cx = 219.5\text{ lb} \uparrow$



$\Sigma Fx = 0$

$Ax + F\sin 60 - Cx = 0$

$Ax = -519.6 + 219.5 = -300\text{ lb} \leftarrow \triangleleft$ Ans

$\Sigma Fy = 0$

$Ay - F\cos 60 + Cy = 0$

$Ay = 300 - 219.5 = 80.5\text{ lb} \leftarrow \triangleleft$ Ans

$A = \sqrt{A_x^2 + A_y^2} = 310.6\text{ lb}$

$\Sigma Fx = 0$

$N_D = -219.5\text{ lb} \leftarrow$ [Compression] $\triangleleft$ Ans

$\Sigma Fy = 0$

$V_D = -219.5\text{ lb} \uparrow\downarrow \triangleleft$ Ans

$\Sigma M_D = 0$

$M_D = -219.5\,(0.25) = -54.9\text{ lb-ft} \;\cap\triangleleft$ Ans

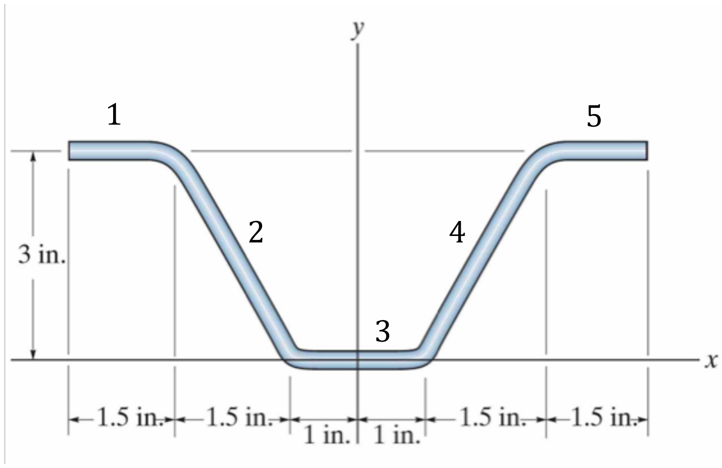
$Bx = By = Cx = Cy$

$Bx = 219.5\text{ lb} \leftarrow \triangleleft$ Ans

$By = 219.5\text{ lb} \uparrow \triangleleft$ Ans

$B = \sqrt{B_x^2 + B_y^2} = 310.4\text{ lb}$

Problem 4 (10 Marks)
Determine the location, $\bar{x}$ and $\bar{y}$, of the center of gravity for the wire shape shown. Use the table provided to organize your calculations.



For a wire

$$\bar{X} = \frac{\Sigma\, L\, Xc}{\Sigma\, L} \quad \text{and}$$

$$\bar{Y} = \frac{\Sigma\, L\, Yc}{\Sigma\, L}$$

where Xc and Yc are coordinates of the centroid of each component

Note :

Components 2 and 4

$$L = \sqrt{1.5^2 + 3^2} = 3.354 \text{ in}$$

Comp	**L**	**Xc**	**Yc**	**L Xc**	**L Yc**
1	1.500	-3.25	3	-4.785	4.5
2	3.354	-1.75	1.5	-5.870	5.031
3	2.000	0	0	0	0
4	3.354	1.75	1.5	5.870	4.5
5	1.500	3.75	3	4.875	5.031
Sum	11.708			0	19.062

$$\bar{X} = \frac{\Sigma\, L\, Xc}{\Sigma\, L} = \frac{0}{11.708} = 0 \quad \triangleleft \quad \text{Ans}$$

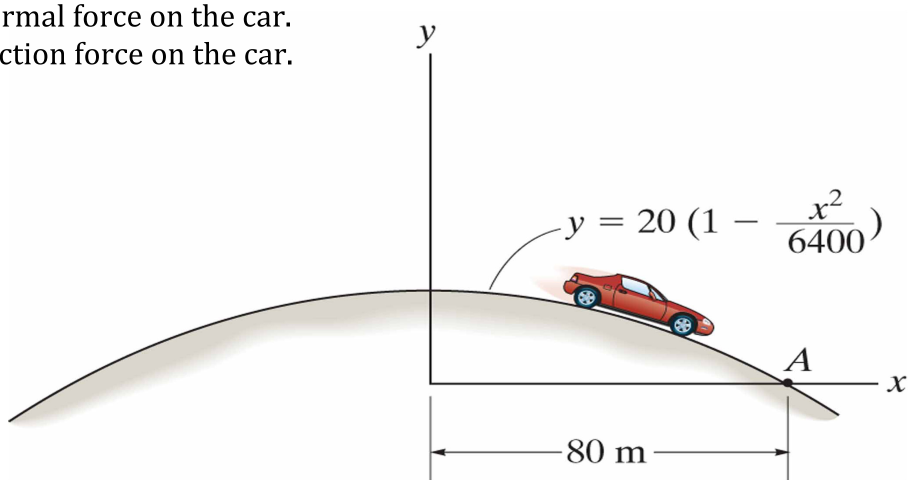
$$\bar{Y} = \frac{\Sigma\, L\, Yc}{\Sigma\, L} = \frac{19.062}{11.708} = 1.628 \text{ in} \quad \triangleleft \quad \text{Ans}$$

Marking
Xbar → 4 marks
Ybar → 6 marks

Problem 5 (20 Marks)

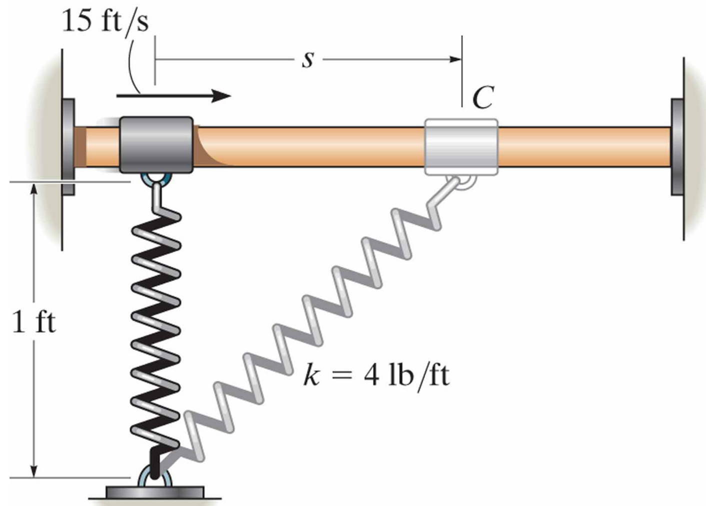
An 800 kg car travels along the vertical curve shown. At point A the car is traveling at 9 m/s and increasing its speed by 3 m/s^2.

(a) Draw a Free Body Diagram for all forces acting on the car.
(b) Draw a separate sketch for all velocities and accelerations acting on the car.
(c) Determine the total normal force on the car.
(d) Determine the total friction force on the car.



Problem 6 (20 Marks)

The 2-lb collar fits loosely on the smooth shaft. If the spring is unstretched when s = 0 and the collar has a velocity of 15 ft/s. Use the **Principle of Work and Energy** or the **Conservation of Energy Theorem** to determine the velocity of the collar when s = 1 ft



Fundamental Equations of Dynamics

KINEMATICS

Particle Rectilinear Motion

Variable a	Constant $a = a_c$
$a = \frac{dv}{dt}$	$v = v_0 + a_c t$
$v = \frac{ds}{dt}$	$s = s_0 + v_0 t + \frac{1}{2} a_c t^2$
$a\,ds = v\,dv$	$v^2 = v_0^2 + 2a_c(s - s_0)$

Particle Curvilinear Motion

x, y, z Coordinates		r, θ, z Coordinates	
$v_x = \dot{x}$	$a_x = \ddot{x}$	$v_r = \dot{r}$	$a_r = \ddot{r} - r\dot{\theta}^2$
$v_y = \dot{y}$	$a_y = \ddot{y}$	$v_\theta = r\dot{\theta}$	$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$
$v_z = \dot{z}$	$a_z = \ddot{z}$	$v_z = \dot{z}$	$a_z = \ddot{z}$

n, t, b Coordinates

$v = \dot{s}$	$a_t = \dot{v} = v\frac{dv}{ds}$
	$a_n = \frac{v^2}{\rho} \quad \rho = \frac{[1 + (dy/dx)^2]^{3/2}}{\lvert d^2y/dx^2 \rvert}$

Relative Motion

$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{B/A} \quad \mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$

Rigid Body Motion About a Fixed Axis

Variable α	Constant $\alpha = \alpha_c$
$\alpha = \frac{d\omega}{dt}$	$\omega = \omega_0 + \alpha_c t$
$\omega = \frac{d\theta}{dt}$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$
$\omega\,d\omega = \alpha\,d\theta$	$\omega = \omega_0^2 + 2\alpha_c(\theta - \theta_0)$

For Point P

$s = \theta r \quad v = \omega r \quad a_t = \alpha r \quad a_n = \omega^2 r$

Relative General Plane Motion—Translating Axes

$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{B/A(\text{pin})} \quad \mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A(\text{pin})}$

Relative General Plane Motion—Trans. and Rot. Axis

$$\mathbf{v}_B = \mathbf{v}_A + \boldsymbol{\Omega} \times \mathbf{r}_{B/A} + (\mathbf{v}_{B/A})_{xyz}$$

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\boldsymbol{\Omega}} \times \mathbf{r}_{B/A} + \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \mathbf{r}_{B/A}) + 2\boldsymbol{\Omega} \times (\mathbf{v}_{B/A})_{xyz} + (\mathbf{a}_{B/A})_{xyz}$$

KINETICS

Mass Moment of Inertia $I = \int r^2\,dm$

Parallel-Axis Theorem $I = I_G + md^2$

Radius of Gyration $k = \sqrt{\frac{I}{m}}$

Equations of Motion

Particle	$\Sigma\mathbf{F} = m\mathbf{a}$
Rigid Body (Plane Motion)	$\Sigma F_x = m(a_G)_x$ $\Sigma F_y = m(a_G)_y$ $\Sigma M_G = I_G\alpha$ or $\Sigma M_P = \Sigma(\mathcal{M}_k)_P$

Principle of Work and Energy

$T_1 + U_{1-2} = T_2$

Kinetic Energy

Particle	$T = \frac{1}{2}mv^2$
Rigid Body (Plane Motion)	$T = \frac{1}{2}mv_G^2 + \frac{1}{2}I_G\omega^2$

Work

Variable force $U_F = \int F\cos\theta\,ds$

Constant force $U_F = (F_c\cos\theta)\,\Delta s$

Weight $U_W = -W\,\Delta y$

Spring $U_s = -(\frac{1}{2}ks_2^2 - \frac{1}{2}ks_1^2)$

Couple moment $U_M = M\,\Delta\theta$

Power and Efficiency

$P = \frac{dU}{dt} = \mathbf{F}\cdot\mathbf{v} \quad \epsilon = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{U_{\text{out}}}{U_{\text{in}}}$

Conservation of Energy Theorem

$T_1 + V_1 = T_2 + V_2$

Potential Energy

$V = V_g + V_e$, where $V_g = \pm Wy$, $V_e = +\frac{1}{2}ks^2$

Principle of Linear Impulse and Momentum

Particle	$m\mathbf{v}_1 + \Sigma\int \mathbf{F}\,dt = m\mathbf{v}_2$
Rigid Body	$m(\mathbf{v}_G)_1 + \Sigma\int \mathbf{F}\,dt = m(\mathbf{v}_G)_2$

Conservation of Linear Momentum

$\Sigma(\text{syst. } m\mathbf{v})_1 = \Sigma(\text{syst. } m\mathbf{v})_2$

Coefficient of Restitution $e = \frac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1}$

Principle of Angular Impulse and Momentum

Particle	$(\mathbf{H}_O)_1 + \Sigma\int \mathbf{M}_O\,dt = (\mathbf{H}_O)_2$ where $H_O = (d)(mv)$
Rigid Body (Plane motion)	$(\mathbf{H}_G)_1 + \Sigma\int \mathbf{M}_G\,dt = (\mathbf{H}_G)_2$ where $H_G = I_G\omega$ $(\mathbf{H}_O)_1 + \Sigma\int \mathbf{M}_O\,dt = (\mathbf{H}_O)_2$ where $H_O = I_O\omega$

Conservation of Angular Momentum

$\Sigma(\text{syst. } \mathbf{H})_1 = \Sigma(\text{syst. } \mathbf{H})_2$