POSTAL BOOK PACKAGE 2025

MADE EASY PUBLICATIONS

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

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ENGINEERING MECHANICS

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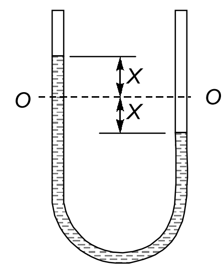
6 CHAPTER Work and Energy

Practice Questions

Q.1 A glass U-tube having a uniform bore of cross-sectional area A is open at both ends and contains a column of liquid of total length l and specific weight w as shown in figure. Using the law of conservation of energy, find the period t of free oscillations after being disturbed from the equilibrium position as shown in the figure. Neglect friction between the fluid and the walls of the tube.



Solution:

When the liquid is in equilibrium, the free surfaces in the two branches of the tube will be at the same level OO, and we take this as our references configuration as defined by the displacement x of the two free surfaces above and below the level OO. In any such configuration, all particles of the liquid are moving with the same velocity and the total kinetic energy of the system is

$$T = \frac{wAl}{g}\frac{\dot{x}^2}{2}$$

Potential energy, $V = wAx^2$

During motion, the total energy of the system (kinetic + potential) must remain constant. Hence the energy equation becomes

$$\frac{wAl}{g}\frac{\dot{x}^2}{2} + wAx^2 = C_1$$

At $t = 0$, $x = a$, $\dot{x} = 0$ Putting in equation, $C_1 = wAa^2$

$$\frac{wAl}{g}\frac{\dot{x}^2}{2} + wAx^2 = wAa^2$$

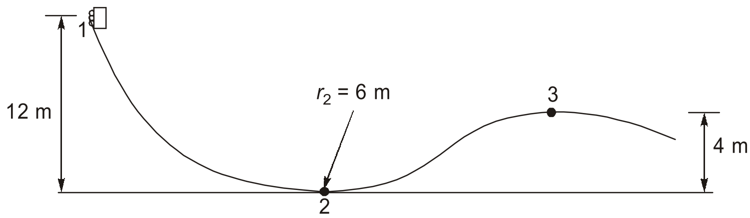
Velocity, $\dot{x} = \sqrt{\frac{2g}{l}(a^2 - x^2)}$

Introducing the notation $p = \sqrt{\frac{2g}{l}}$ may be written in the form

$$\frac{dx}{dt} = p\sqrt{a^2 - x^2}$$

Then separating variables, we have

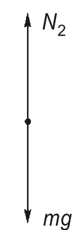
Q.4 A 900 kg roller coaster car starts from rest at point 1 and moves without friction down the track shown.
(i) Determine the force exerted by the track on the car at point 2, where the radius of curvature of the track is 6 m.
(ii) Determine the minimum safe value of the radius of curvature at point 3.



Solution:

(i)

As the car starts moving from point 1 its speed will increase because of gravitational work. Potential energy will be converted into kinetic energy as there is no loss.



So, $$mgh_1 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}mv_2^2$$

$\Rightarrow$ $$V_2^2 = 2gh_1 = 2 \times 9.81 \times 12 = 235.44\ (\text{m/s})^2$$

Drawing FBD at point 2:
As car is moving at radius of curvature equal to 6 m.

So, $$N_2 - mg = \frac{mv_2^2}{r_2}$$

$\Rightarrow$ $$N_2 = m\left(g + \frac{V_2^2}{r_2}\right) = 900\left(9.81 + \frac{235.44}{6}\right) = 44.145\ \text{kN}$$

(ii)

At point 3, due to centrifugal force car will try to lift itself. The minimum safe radius of curvature will be when normal force approaches to zero.
Energy conservation

$$mgh_1 + \frac{1}{2}mv_1^2 = mgh_3 + \frac{1}{2}mv_3^2$$

$\Rightarrow$ $$v_3^2 = 2 \times g \times (h_1 - h_3)$$
$$= 2 \times 9.81 \times (12 - 4) = 156.96\ (\text{m/s})^2$$

For minimum safe radius of curvature

$$mg - N_3 = \frac{mv_3^2}{r_3}$$

$$r_3 = \frac{v_3^2}{g} = 16\ \text{m} \qquad (N_3 = 0)$$

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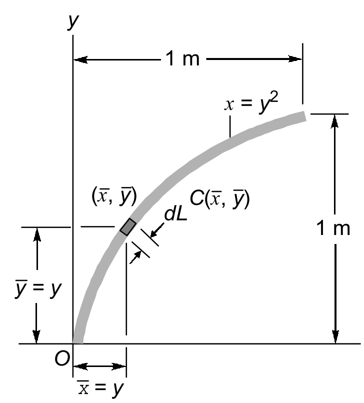
Center of Gravity and Moment of Inertia

Practice Questions

Q.1 Locate the centroid of the rod bent into the shape of a parabolic arc as shown in figure.



Solution:

Area and Moment Arms: the different element of length dL can be expressed in terms of the differentials dx and dy using the Pythagorean theorem.

$$dL = \sqrt{(dx)^2 + (dy)^2} = \left(\sqrt{\left(\frac{dx}{dy}\right)^2 + 1}\right)dy$$

Since $x = y^2$, then $\frac{dx}{dy} = 2$ y. Therefore, expressing dL in terms of y and dy,

$$dL = \sqrt{(2y)^2 + 1}\, dy$$

As shown in figure, the centroid of the element is located at $x = x$, $y = y$.

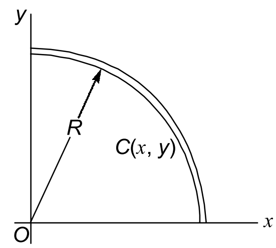
Integrations: Applying equations using the formulas in Appendix A to evaluate the integrals, we get

$$\bar{x} = \frac{\int_L x\, dL}{\int_L dL} = \frac{\int_0^{1\,\text{m}} x\sqrt{4y^2 + 1}\, dy}{\int_0^{1\,\text{m}} \sqrt{4y^2 + 1}\, dy} = \frac{\int_0^{1\,\text{m}} y^2\sqrt{4y^2 + 1}\, dy}{\int_0^{1\,\text{m}} \sqrt{4y^2 + 1}\, dy}$$

$$= \frac{0.6063}{1.479} = 0.410 \text{ m}$$

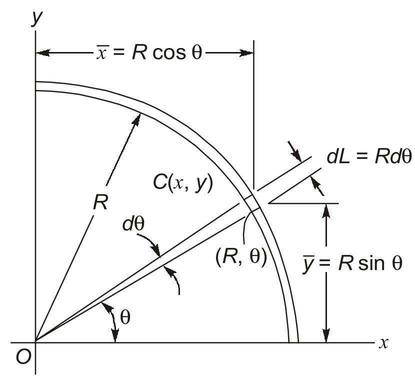
$$\bar{y} = \frac{\int_L \tilde{y}\, dL}{\int_L dL} = \frac{\int_0^{1\text{m}} y\sqrt{4y^2 + 1}\, dy}{\int_0^{1\,\text{m}} \sqrt{4y^2 + 1}\, dy} = \frac{0.8484}{1.479} = 0.574 \text{ m}$$

Q.2 Locate the centroid of the circular wire segment shown in figure.



Solution:

Differential Element: The differential circular arc is selected as shown in the figure. This element intersects the curve at (R, θ).

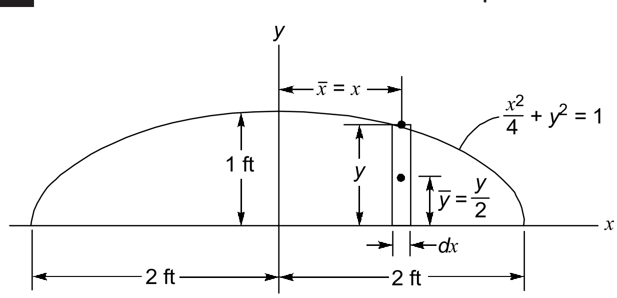


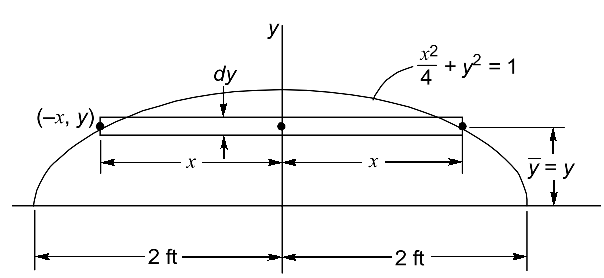
The length of the differential element is $dL = Rd\theta$, and its centroid is located at $\bar{x} = R\cos\theta$ and $\bar{y} = R\sin\theta$

$$\bar{x} = \frac{\int_L \bar{x}\,dL}{\int_L dL} = \frac{\int_0^{\pi/2}(R\cos\theta)Rd\theta}{\int_0^{\pi/2}Rd\theta} = \frac{R^2\int_0^{\pi/2}\cos\theta\,d\theta}{R\int_0^{\pi/2}d\theta} = \frac{2R}{\pi}$$

$$\bar{y} = \frac{\int_L \tilde{y}\,dL}{\int_L dL} = \frac{\int_0^{\pi/2}(R\sin\theta)R\,d\theta}{\int_0^{\pi/2}R\,d\theta} = \frac{R^2\int_0^{\pi/2}\sin\theta\,d\theta}{R\int_0^{\pi/2}d\theta} = \frac{2R}{\pi}$$

Q.3 Locate the centroid of the semi-elliptical area shown in figure.





Solution:

Differential Element: The rectangular differential element parallel to the y axis shown in figure will be considered. This element has a thickness of dx and a height of y.

Area and moment arms: Thus the area is $dA = y\,dx$, and its centroid is located at $\tilde{x} = x$ and $\tilde{y} = \frac{y}{2}$

Integration: Since the area is symmetrical about the y axis,

$$\bar{x} = 0$$