

 $H_1 = R (I - \cos \phi_0)$ $H_2 = R (I - \cos \phi_0)$

Case 1:- If $V_0 > \sqrt{2gH_2}$,

the ball will leave the surface of bowl and projectile there after.

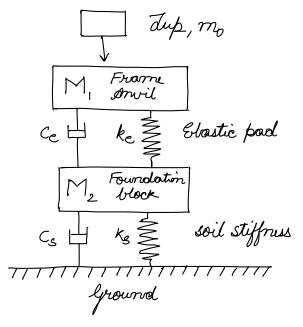
So only ϕ as $\Phi \circ F$ is not sufficient

Case 2: If $V_0 < \sqrt{2gH_2}$ the ball will be in contact with bowl and its single degree of freedom. We can take ϕ as DoF.

This is one solution. There can be many.

Solution 2:- Part @

As the anvil and foundational block are quite stiff as compared to the elastic pad and



Part (b)

Bilinear Stiffness

Modified

Results

The foundation

Lyound

K1

WWW-1

K2-K1

A0

Ce K1 W K2-K1

Foundation

Lyound

Solution 3

Median is idealised as beam Abstraction 1 Pectoral idealised Antirior dorsal idealised as point mass as beam Petric fin idealised as beam Posterior Dousal Coudal fin Median is idealised as beam Abstraction 2 Pectoral Pectoral fin (Right) fin (left) prtinor Dorsal Pelvic fin (rught) Pelvic fin (left) Posterior Dousal Coudal fin

Abstraction 3

rectoral fin (right)

Petro Petrol fin (Right)

Petro Petrol fin (Right)

Petro Petro fin (rught)

Posterior Dorsal

Candal

Median

Abstraction 4

Solution 4:

Hamilton's principle
$$t_2 \int (ST - SV + SW) dt = 0$$

$$t_1$$
Here $SW = 0$

$$\int_{t_{1}}^{t_{2}} S T dt = \int_{t_{1}}^{t_{2}} \int_{t_{1}}^{t_{2}} P A \left(\frac{\partial u}{\partial t} \right)^{2} dx + \frac{1}{2} M \left(\frac{\partial u(L,t)}{\partial t} \right)^{2} dt$$

$$t_{1} \qquad t_{2} \qquad t_{3} \qquad t_{4} \qquad t_{5} \qquad t_{5$$

Using integration by parts to expression 2

$$t_{2}$$
 $\int M \frac{\partial u(L,t)}{\partial t} \left(\partial \underbrace{\delta u(L,t)}_{\partial t} \right) dt = -\int M \frac{\partial^{2} u(L,t)}{\partial t^{2}} \int u(L,t) dt$
 t_{1}
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 t_{5

Hence
$$t_{2} = - \iint_{\partial t} (fA \partial u) Su dt dx$$

$$t_{1} = - \iint_{\partial t} (fA \partial u) Su dt dx$$

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$$t_{3} = - \iint_{\partial t} (fA \partial u) Su dt dx$$

$$t_{4} = - \iint_{\partial t} (fA \partial u) Su dt dx$$

$$= -\int \int \int \frac{\partial}{\partial t} \left(P A \frac{\partial u}{\partial t} \right) dx \, \delta u + M \frac{\partial^2 u(L,t)}{\partial t^2} \, \delta u(L,t) \, dt$$

$$= -\int \int \int \frac{\partial}{\partial t} \left(P A \frac{\partial u}{\partial t} \right) dx \, \delta u + M \frac{\partial^2 u(L,t)}{\partial t^2} \, \delta u(L,t) \, dt$$

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$$= -\int \int \int \frac{\partial}{\partial t} \left(P A \frac{\partial u}{\partial t} \right) dx \, \delta u + M \frac{\partial^2 u}{\partial t^2} \, \delta u(L,t) \, dt$$

$$= -\int \int \int \frac{\partial}{\partial t} \left(P A \frac{\partial u}{\partial t} \right) dx \, dx \, dt$$

Now
$$t_{2} \int S V dt = \int S \left(\int \frac{EA}{2} \left(\frac{\partial u}{\partial x} \right)^{2} dx + \frac{k}{2} \left(u(L,t) \right)^{2} \right) dt$$

$$t_{1} \int \left(EA \frac{\partial u}{\partial x} \frac{\partial Su}{\partial x} dx + k u(L,t) S(u(L,t)) \right) dt$$

$$t_{2} \int \left(\partial \left(EA \frac{\partial u}{\partial x} \right) dx Su + \int S(u(L,t)) dx \right) dt$$

$$= \int \int \left(E \frac{\partial u}{\partial n} \frac{\partial Su}{\partial n} dn + k u(L,t) S(u(L,t)) \right) dt$$

$$t = \int \int \left(\frac{E}{\partial n} \frac{\partial u}{\partial n} \frac{\partial Su}{\partial n} dn + k u(L,t) S(u(L,t)) \right) dt$$

$$t_{2} \int_{-L}^{L} \left(\frac{\partial}{\partial x} \left(\frac{EA}{\partial x} \frac{\partial u}{\partial x} \right) dx S u + \left[\frac{EA}{\partial x} \frac{\partial u}{\partial x} S u \right]_{0}^{L} + k u(L,t) S u(L,t) \right) dt$$

$$t_{1} = \int_{-L}^{L} \left(\frac{\partial}{\partial x} \left(\frac{EA}{\partial x} \frac{\partial u}{\partial x} \right) dx S u + \left[\frac{EA}{\partial x} \frac{\partial u}{\partial x} S u \right]_{0}^{L} + k u(L,t) S u(L,t) \right) dt$$

$$t_{l} = \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) \\ t_{l} = \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) \\ \int_{0}^{L} \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) dt \\ \int_{0}^{L} \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) dt \\ \int_{0}^{L} \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) dt \\ \int_{0}^{L} \int_{0}^{L} \int_{0}^{L} (EA \partial u) dx \delta u + \left[EA \partial u + ku \right] \delta u(l,t) dt$$

$$\int_{t_{1}}^{t_{2}} \int_{t_{1}}^{t_{2}} \int_{0}^{t_{2}} \int_{t_{1}}^{t_{2}} \int_{t_{1}}^{t_{1}} \int_{t_{1}}^{t_{2}} \int_{t_{1}}^{t_{$$

Hamilton Principle

$$t_{1}$$

$$\int_{t_{1}}^{t_{2}} (ST - SV) dt = 0$$

$$t_{1}$$

$$\Rightarrow \int_{t_{1}}^{t_{2}} \int_{0}^{L} \frac{\partial}{\partial t} (fA \frac{\partial u}{\partial t}) dx Su + M \frac{\partial^{2}u(t,t)}{\partial t^{2}} Su(t,t) dt$$

$$+ \int_{t_{1}}^{t_{2}} \int_{0}^{L} \frac{\partial}{\partial x} (EA \frac{\partial u}{\partial x}) dx Su - [EA \frac{\partial u}{\partial x} + Ru] Su(t,t) dt$$

$$+ \int_{t_{1}}^{t_{2}} \int_{0}^{L} (-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (EA \frac{\partial u}{\partial x}) dx Su \right) dx$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial t} (fA \frac{\partial u}{\partial t}) + \frac{\partial}{\partial x} (EA \frac{\partial u}{\partial x}) \right) dx Su dt$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial t} (fA \frac{\partial u}{\partial t}) + \frac{\partial}{\partial x} (EA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial t} (fA \frac{\partial u}{\partial t}) + \frac{\partial}{\partial x} (EA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

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$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

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$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

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$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) + \frac{\partial}{\partial x} (fA \frac{\partial u}{\partial x}) \right) dx Su(t,t) dt = 0$$

$$+ \int_{t_{1}}^{t_{2}} \left(-\frac{$$

Boundary condition at $\kappa = L$

$$\frac{M\partial^{2}u(L,t)}{\partial t^{2}} + EA\frac{\partial u(L,t)}{\partial t} + ku(L,t) = 0$$

Solution 5:-

$$\mathcal{L} = T - V$$
Ender Lagrange Equation
$$\frac{d}{dt} \left(\frac{\partial L}{\partial \mathring{\phi}_{i}} \right) - \frac{\partial L}{\partial \mathring{\phi}_{i}} = 0 \qquad \mathring{\lambda} = 1, 2$$

$$\mathcal{L} = \mathcal{L} m l^{2} (\mathring{\phi}_{2}^{2} + 4\mathring{\phi}_{i}^{2} + 3\mathring{\phi}_{i} \mathring{\phi}_{2}^{2} \cos(\mathring{\phi}_{i} - \mathring{\phi}_{2}))$$

$$- \frac{mgl}{2} (3\cos\mathring{\phi}_{i} + \cos\mathring{\phi}_{2})$$

$$- \frac{d}{dt} \left(\frac{\partial L}{\partial \mathring{\phi}_{i}} \right) - \frac{\partial L}{\partial \mathring{\phi}_{i}} = 0$$

$$m l^{2} \frac{d}{dt} \left(\frac{4xz}{83} \mathring{\phi}_{i} + \frac{1}{2} \mathring{\phi}_{2}^{2} \cos(\mathring{\phi}_{i} - \mathring{\phi}_{2}) \right) - \frac{3mgl}{2} \sin\mathring{\phi}_{i} = 0$$

$$+ \frac{1}{6} m l^{2} (3\mathring{\phi}_{i} \mathring{\phi}_{2} \sin(\mathring{\phi}_{i} - \mathring{\phi}_{2}))$$

$$+ \frac{1}{2} \pi l^{2} (\mathring{\phi}_{i} \mathring{\phi}_{2} \sin(\mathring{\phi}_{i} - \mathring{\phi}_{2})) - \frac{3mgl}{2} \sin\mathring{\phi}_{i} = 0$$

$$+ \frac{1}{2} \pi l^{2} (\mathring{\phi}_{i} \mathring{\phi}_{2} \sin(\mathring{\phi}_{i} - \mathring{\phi}_{2})) - \frac{3mgl}{2} \sin\mathring{\phi}_{i} = 0$$

$$\frac{4}{3} l \ddot{0}_{1} + \frac{1}{2} \left(\ddot{0}_{2} \cos(0_{1} - 0_{2}) - \ddot{0}_{2} \sin(0_{1} - 0_{2}) (\ddot{0}_{1} - \ddot{0}_{2}) - 3g \sin(0_{1} = 0) + \ddot{0}_{1} \cos(0_{1} - 0_{2}) \right) = 2g \sin(0_{1} = 0)$$

Jaking
$$i = 2$$

$$\frac{d}{dt} \left(\frac{\partial L}{\partial \hat{o}_{2}} \right) - \frac{\partial L}{\partial \hat{o}_{2}} = 0$$

$$ml^{\frac{1}{2}} \frac{d}{dt} \left(\frac{2}{6} \hat{o}_{2} + \frac{3 \hat{o}_{1}}{6} \cos(0_{1} - 0_{2}) \right) - \frac{mgl}{2} \sin(0_{2}) = 0$$

$$- \frac{1}{6} ml^{\frac{1}{2}} (3 \hat{o}_{1}, \hat{o}_{2} \sin(0_{1} - 0_{2}))$$

$$= \frac{1}{6} ml^{\frac{1}{2}} (3 \hat{o}_{1}, \hat{o}_{2} \sin(0_{1} - 0_{2}))$$

$$\Rightarrow \frac{1}{3} \stackrel{\circ}{\mathcal{O}_{2}} + \frac{1}{2} \stackrel{\circ}{\mathcal{O}_{1}} cos(\mathcal{O}_{1} - \mathcal{O}_{2}) + \stackrel{\circ}{\mathcal{O}_{1}} sin(\mathcal{O}_{1} - \mathcal{O}_{2}) (\stackrel{\circ}{\mathcal{O}_{1}} - \stackrel{\circ}{\mathcal{O}_{2}}) - \stackrel{\circ}{\mathcal{O}_{1}} sin(\mathcal{O}_{1} - \mathcal{O}_{2}) - g sin(\mathcal{O}_{2}) = 0$$

$$\frac{1}{3} \stackrel{\circ}{\mathcal{O}}_{2} + \frac{1}{2} \stackrel{\circ}{\mathcal{O}}_{1} cos(\mathcal{O}_{1} - \mathcal{O}_{2}) + \stackrel{\circ}{\mathcal{O}}_{1} sin(\mathcal{O}_{1} - \mathcal{O}_{2})(\mathring{\mathcal{O}}_{1} - \mathring{\mathcal{O}}_{2})) - \frac{9}{2} sin\mathcal{O}_{2} = 0$$

$$- \stackrel{\circ}{\mathcal{O}}_{1} \stackrel{\circ}{\mathcal{O}}_{2} sin(\mathcal{O}_{1} - \mathcal{O}_{2})$$