Upcoming deadlines:

- Homework 1 is due now
- Warm-up quiz 2 (section 1.11) is due next Tuesday
- Homework 2 is due next Thursday

Everything will be posted tomorrow

Plan for today

- Talk about homework/office hours
- Discuss two versions of the principle of virtual work
- Virtual work example problem
- Discuss Lagrangians, Lagrange equation, equation of motion
- Work on activities 4 and 5

Principle of Virtual Work

If a particle is in equilibrium the total virtual work, the total virtual work of the forces acting on the particle for any virtual displacement is zero.

$$\delta W = \sum_{\alpha=1}^{3N} Q_\alpha \delta q_\alpha = 0$$

Virtual Work and Generalized Force

- Generalized force:

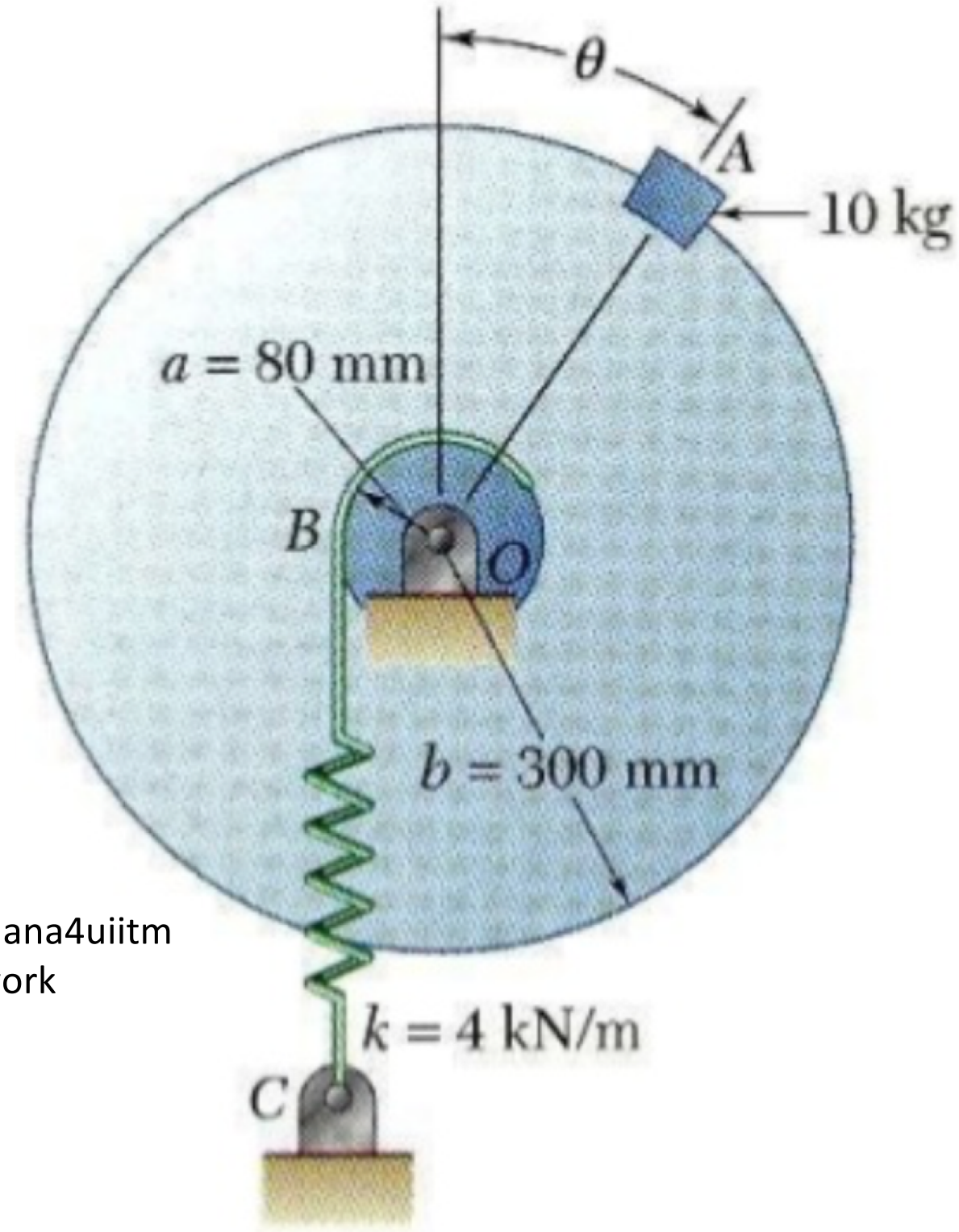
$$Q_\alpha = \sum_{i=1}^{3N} F_i \frac{\partial x_i}{\partial q_\alpha} = \sum_{i=1}^{3N} \left(-\frac{\partial V}{\partial x_i}\right) \frac{\partial x_i}{\partial q_\alpha} = -\frac{\partial V}{\partial q_\alpha}$$

For conservative forces

- Virtual work: $\delta W = \sum_{\alpha=1}^{3N} Q_\alpha \delta q_\alpha$
- Principle of virtual work: $\delta W = 0$ in equilibrium $\Rightarrow Q_\alpha = -\partial V / \partial q_\alpha = 0$

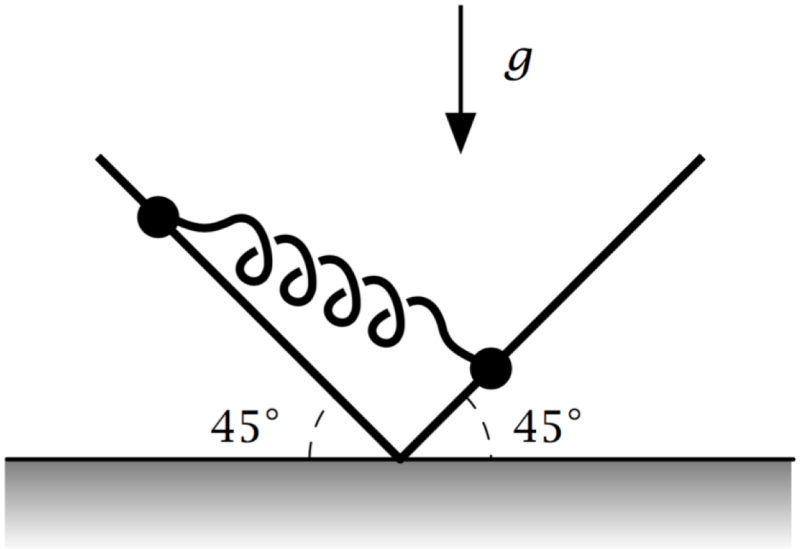
Example problem for virtual work in the form

$$\frac{\partial V}{\partial q_\alpha} = 0$$



I took this from
https://www.slideshare.net/ramana4uiitm/chapter-8-principle-of-virtual-work

Activity 4:



Potential energy

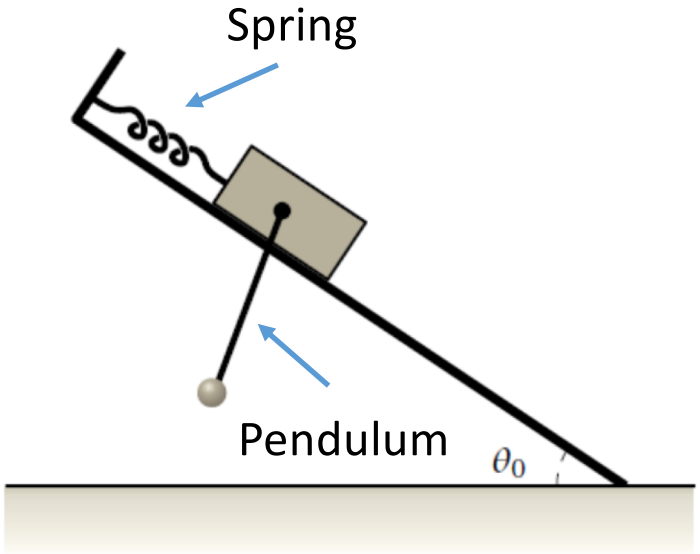
Has gravitational and spring components

Principle of virtual work: $\frac{\partial V}{\partial q_\alpha} = 0$

Generalized coordinate(s)

- How many are required?
- Which one(s) make the problem simple?
- How many equations?

Activity 5:



- How many degrees of freedom?
- How many independent variables required?
- Which ones make the problem simple?
- What are the equations of constraint?
- Lagrangian $L = T - V$, same strategy as for total energy
- Equations of motion by plugging the Lagrangian into Lagrange's equation $\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_i} = \frac{\partial L}{\partial q_i}$
- One equation for each generalized coordinate