## Announcements

- Homework 11 due Monday!
- Final Chapter write-ups due on Monday morning
  - Email me a pdf copy of your paper without your name on it
  - We will meet on Discord for some initial instructions, and then I'll temporarily co-op the HW Solutions website for it to become the Papers and Peer Evaluations site
- Final will be going out a week from Saturday.
- Responses: rembold-class.ddns.net





## Today's Objectives

- Build up ideas of how to linearize equations of motion
- Reinforce ideas of how all these normal frequencies and modes come together to form a general solution





Last class, we had found that for a pendulum attached to a mass attached via spring to a wall, we got equations of motions that looked like:

$$-kx = 2m\ddot{x} + m\ell\cos(\phi)\ddot{\phi} - m\ell\dot{\phi}^2\sin(\phi)$$
$$-mg\ell\sin(\phi) = m\ell^2\ddot{\phi} + m\ell\cos(\phi)\ddot{x}$$

Where does this system have equilibrium points?

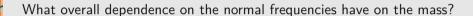
A) 
$$x = 0$$
 and  $\phi = 0$ 

B) 
$$x = \ell$$
 and  $\phi = 0$ 

C) 
$$x = \ell$$
 and  $\phi = \ell/x$ 

D) 
$$x = k/m$$
 and  $\phi = 0$ 





- A) Zero dependence, it all cancels out
- B) As the mass increases, both normal frequencies increase
- C) As the mass increases, both normal frequencies decrease
- D) None of the above



$$\omega_1=1.95, \quad ec{\mathbf{e}}_1=egin{bmatrix} 1.58 \ 1 \end{bmatrix} \quad ext{and} \quad \omega_2=5.08, \quad ec{\mathbf{e}}_2=egin{bmatrix} -0.62 \ 1 \end{bmatrix}$$

What can you conclude about the motion of the pendulum when the upper mass is traveling to the right?

- A) It is stationary
- B) It is moving right
- C) It is moving left
- It is impossible to sav



Suppose we knew that the system started with both masses at their equilibrium point. The pendulum mass is is stationary, but the upper mass is traveling to the right at  $20 \,\mathrm{cm/s}$ . Take both  $m=\ell=1$ . What is the position of the top mass after 2 seconds?

$$\omega_1=1.95, \quad ec{\mathbf{e}}_1=egin{bmatrix} 1.58 \ 1 \end{bmatrix} \quad ext{and} \quad \omega_2=5.08, \quad ec{\mathbf{e}}_2=egin{bmatrix} -0.62 \ 1 \end{bmatrix}$$

- A) 4.3 cm
- B) 0 cm
- (-1.95 cm)
- D) -5.7 cm

