

**18.5.2 Double pendulum, Again.** For the double pendulum in problem ??,  $\ddot{\phi}_1$  and  $\ddot{\phi}_2$  are also known at the instant shown. For the instant shown, answer the following questions in terms of  $\ell$ ,  $\phi_1$ ,  $\dot{\phi}_1$ ,  $\ddot{\phi}_1$ ,  $\phi_2$ ,  $\dot{\phi}_2$ , and  $\ddot{\phi}_2$ .

- What is the absolute acceleration of point A?
- What is the acceleration of point B relative to point A?
- What is the absolute acceleration of point B?

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known:  $\ell$ ,  $\phi_1$ ,  $\dot{\phi}_1$ ,  $\ddot{\phi}_1$ ,  $\phi_2$ ,  $\dot{\phi}_2$ ,  $\ddot{\phi}_2$

c) find  $\underline{a}_A$ .

$$\underline{a}_A = \underline{\omega}_{O1} \times \underline{r}_{A/O} + \underline{\omega}_{O1} \times (\underline{\omega}_{O1} \times \underline{r}_{A/O})$$

note  $\underline{\omega}_{O1} = \dot{\phi}_1 \hat{k}$   
 $\underline{\dot{\omega}}_{O1} = \ddot{\phi}_1 \hat{k}$

$$\Rightarrow \underline{a}_A = \ddot{\phi}_1 \hat{k} \times (\ell \sin \phi_1 \hat{i} - \ell \cos \phi_1 \hat{j}) - \dot{\phi}_1^2 (\ell \sin \phi_1 \hat{i} - \ell \cos \phi_1 \hat{j})$$

$$\underline{a}_A = \ell [(-\dot{\phi}_1^2 \sin \phi_1 + \ddot{\phi}_1 \cos \phi_1) \hat{i} + (\dot{\phi}_1^2 \cos \phi_1 + \ddot{\phi}_1 \sin \phi_1) \hat{j}]$$

b)  $\underline{a}_{B/A} = \underline{\omega}_{AB} \times \underline{r}_{B/A} + \underline{\omega}_{AB} \times (\underline{\omega}_{AB} \times \underline{r}_{B/A})$

$$\underline{a}_{B/A} = \dot{\phi}_2 \hat{k} \times (\ell \sin \phi_2 \hat{i} - \ell \cos \phi_2 \hat{j}) - \dot{\phi}_2^2 (\ell \sin \phi_2 \hat{i} - \ell \cos \phi_2 \hat{j})$$

$$\underline{a}_{B/A} = \ell [(\dot{\phi}_2 \cos \phi_2 - \dot{\phi}_2^2 \sin \phi_2) \hat{i} + (\dot{\phi}_2^2 \sin \phi_2 + \ddot{\phi}_2 \cos \phi_2) \hat{j}]$$

c)  $\underline{a}_B = \underline{a}_A + \underline{a}_{B/A}$  (add the answers to parts a & b to get the absolute accel.)