Outline for May 8, 2019

1. Survivor Outer Space Activity (**GOAL**: get students to think about center of mass)
2. Define the center-of-mass

$$\vec{R}_{CM} = \frac{m_i \vec{r}_1 + m_2 \vec{r}_2}{m_1 + m_2} \tag{1}$$

3. Small White Board Question: Draw the center of mass for 2 particles
4. Big White Board Question: Show that $\vec{R}_{CM}$ lies on the line spanned by $\vec{r} = \vec{r}_2 - \vec{r}_1$. **HINT**: consider the cross product $(\vec{R}_{CM} - \vec{r}_1) \times (\vec{r}_2 - \vec{r}_1)$
5. Define $\vec{F}_1$ and $\vec{F}_2$ to be the net external forces acting on particle 1 and 2. Define $\vec{F}_{12}$ and $\vec{F}_{21}$ to be the internal forces
6. Small White Board Question: Write down Newton's second law for the 2 masses

$$m_1 \ddot{\vec{r}}_1 = \vec{F}_{12} + \vec{F}_1 \tag{2}$$

$$m_2 \ddot{\vec{r}}_2 = \vec{F}_{21} + \vec{F}_2 \tag{3}$$

7. Small White Board Question: What is the relationship between $\vec{F}_{21}$ and $\vec{F}_{12}$?

$$\vec{F}_{12} = -\vec{F}_{21} \qquad \text{Newton's Third Law} \tag{4}$$

8. Write down some examples of "internal forces"
   - gravitaitonal
   - Coulomb
   - Hooke's law
9. Derive Newton's second law for the center of mass

$$(m_1 + m_2)(\ddot{\vec{r}}_1 + \ddot{\vec{r}}_2) = M \ddot{\vec{R}}_{CM} = \vec{F}_{\text{total}} \tag{5}$$

10. What happens when $\vec{F}_{\text{total}} = 0$?
11. Assume $\vec{F}_{\text{tot}} = 0$, write $\vec{F}_{21} = -\vec{F}_{12} = f(r)\hat{r} = -\vec{\nabla} U(r)$ so that we consider a "Central Force"
12. Find Newton's second law for $\vec{r} = \vec{r}_2 - \vec{r}_1$

$$\frac{m_1 m_2}{m_1 + m_2}(\vec{r}_2 - \vec{r}_1) = \mu \vec{r} = f(r)\hat{r} \tag{6}$$