Physics 101H

General Physics 1 – Honors

Lecture 21 – 10/10/22

Collisions

Summary

Topics

Friday: Momentum and collisions [chapter 9]

- Newton's third law and momentum
- Momentum and impulse
- Isolated systems
- Collisions

Today: Collisions [chapter 9]

- Elastic collisions
- Inelastic collisions
- Collisions in two dimensions

Announcements

This week: **No class on Thursday or Friday**
No homework this week!

Next week: **Class on Monday is pre-recorded**
No office hours on Monday

Snooker

Quick quiz

*Quick quizzes incorporate *retrieval practice* and *interleaving*, in which we revisit older material to reinforce your understanding. By keeping track of answers that you can and can't write down without reference to your notes, these quizzes help you identify which topics and concepts you understand best and which you may need to keep reinforcing.

Instructions: This quiz is for your own learning. There are three questions and each question has two columns. Write your own solution, without reference to your notes, the textbook, or your neighbour, **in the first column**. Once you have tried to answer all the questions, discuss the questions with a neighbour and fill in any incomplete answers **in the second column**. Keep your sheet for future reference.

Example: Find the final velocities in terms of the initial velocities in an elastic collision

Example: Find the final velocity in terms of the initial velocities in a perfectly inelastic collision in one dimension.

Example: Find the final velocity of a tennis ball when a tennis ball and basketball are dropped simultaneously from a height h? Assume that the tennis ball is vertically above the basketball and has a mass one tenth of the basketball, that both balls are initially stationary, and that all collisions are perfectly elastic.

Summary

Topics

Today: Collisions [chapter 9]

- Elastic collisions
- Inelastic collisions
- Collisions in two dimensions

Wednesday: Centre of mass [chapter 9]

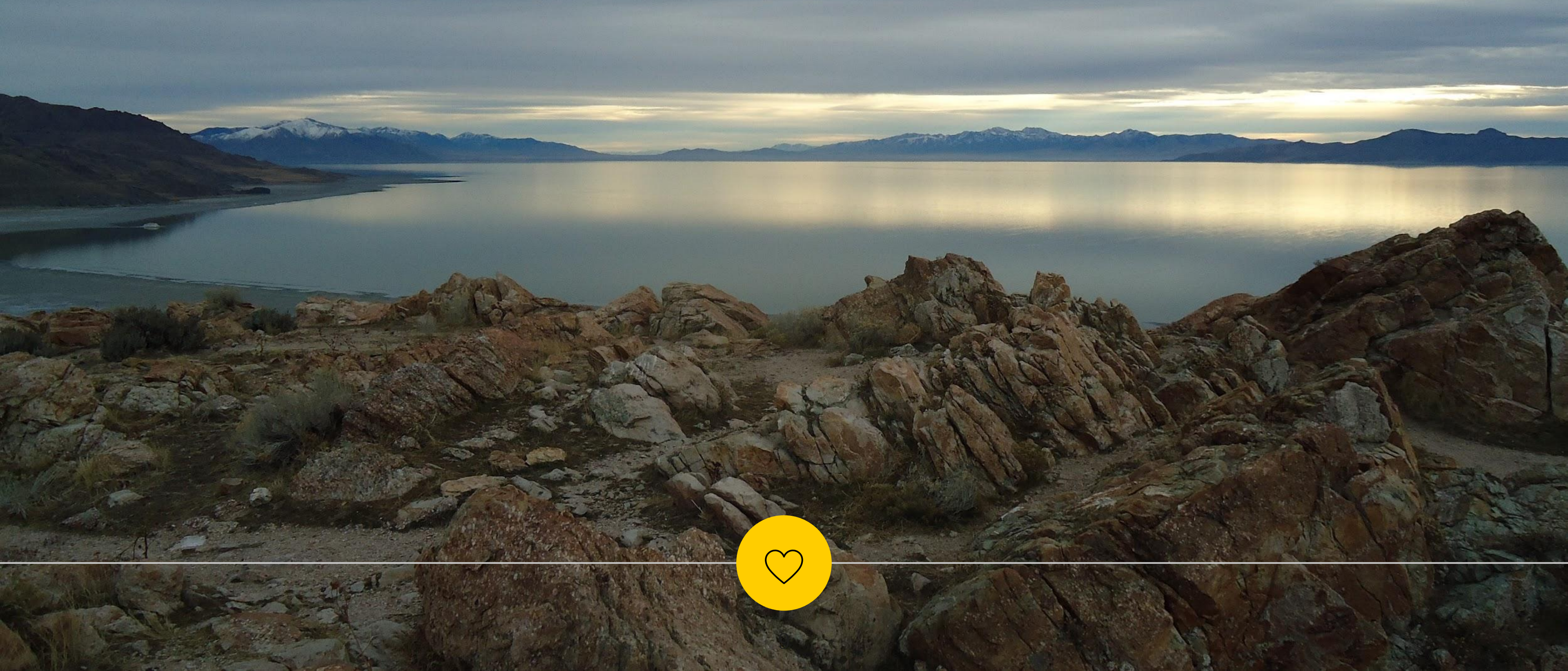
- Centre of mass
- Calculating the centre of mass
- Centre of mass motion

Announcements

This week: **No class on Thursday or Friday**
No homework this week!

NEXT TWO WEEKS: THERE ARE NO CLASSES ON THURSDAY OCTOBER 13 AND FRIDAY OCTOBER 14

MONDAY OCTOBER 17: PRE-RECORDED CLASS AND NO OFFICE HOURS



PHYSICS 101 - HONORS

Lecture 21 10/10/22

Quick Quiz

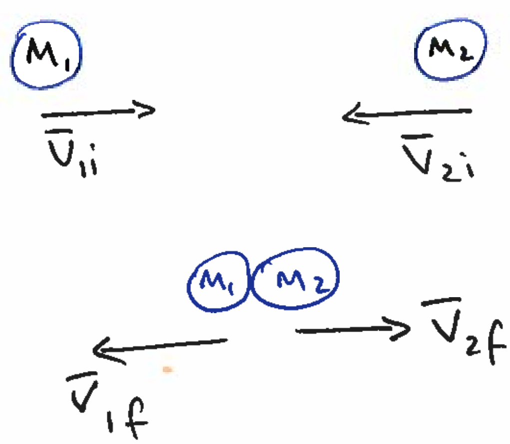
Question 2 - they <u>all</u> can do work (f)

- gravity does work on a falling object
- static friction does work on a stationary object on a table when you accelerate the table
- kinetic friction likewise
- tension does work when you pull on a rope
- normal force does work on a block sliding down a moving plane (!)

Velocities in elastic collisions (slide 3)

initial

final



elastic collision => momentum is conserved
kinetic energy is conserved

Momentum conservation $\Rightarrow \bar{p}_i = \bar{p}_f$ or $\bar{p}_i - \bar{p}_f = 0$

$\bar{p}_i = \bar{p}_{1i} + \bar{p}_{2i}$

$= m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i}$

$\bar{p}_f = \bar{p}_{1f} + \bar{p}_{2f}$

$= m_1 \bar{v}_{1f} + m_2 \bar{v}_{2f}$

$\Rightarrow m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i} = m_1 \bar{v}_{1f} + m_2 \bar{v}_{2f}$

or $m_1 \bar{v}_{1i} - m_1 \bar{v}_{1f} = m_2 \bar{v}_{2f} - m_2 \bar{v}_{2i}$

$\Rightarrow m_1 (\bar{v}_{1i} - \bar{v}_{1f}) = m_2 (\bar{v}_{2f} - \bar{v}_{2i})$

in 1D $m_1 (v_{1i} - v_{1f}) = m_2 (v_{2f} - v_{2i})$ (*)

kinetic energy conservation $\Rightarrow E_{Ki} = E_{Kf}$ or $E_{Ki} - E_{Kf} = 0$

$E_{Ki} = E_{K1i} + E_{K2i}$

$= \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2$

$E_{Kf} = E_{K1f} + E_{K2f}$

$= \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$

$\Rightarrow \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$) × 2 and rearrange

$\Rightarrow m_1 (v_{1i}^2 - v_{1f}^2) = m_2 (v_{2f}^2 - v_{1f}^2)$ (**)

We now have two equations for two unknowns, $\bar{v}_{1f}, \bar{v}_{2f}$

It helps to use a trick $(a^2 - b^2) = (a-b)(a+b)$ and notice that the combinations $(v_{1i} - v_{1f})$ and $(v_{2f} - v_{2i})$ appear in both (*) and (**) once you apply this trick to (**)

The results are

$$v_{1f} = \frac{(m_1 - m_2)\, v_{1i} + 2 m_2 v_{2i}}{m_1 + m_2}$$

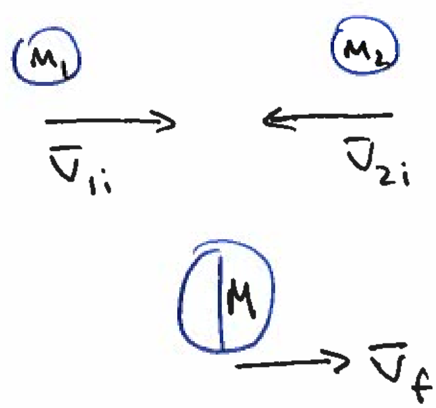
$$v_{2f} = \frac{2 m_1 v_{1i} + (m_2 - m_1)\, v_{2i}}{m_1 + m_2}$$

You will study a simpler derivation (when one of the masses is initially stationary) in PS5.

<u>Velocities in inelastic collisions</u> (slide 5)

initial

final



inelastic ⇒ momentum is conserved
but kinetic energy is <u>not</u> conserved

<u>perfectly</u> inelastic ⇒ objects stick together

so $M = m_1 + m_2$

and $\bar{v}_{1f} = \bar{v}_{2f} = \bar{v}_f$

Momentum conservation $\Rightarrow$ $\bar{P}_i = \bar{P}_f$ or $\bar{P}_i - \bar{P}_f = 0$

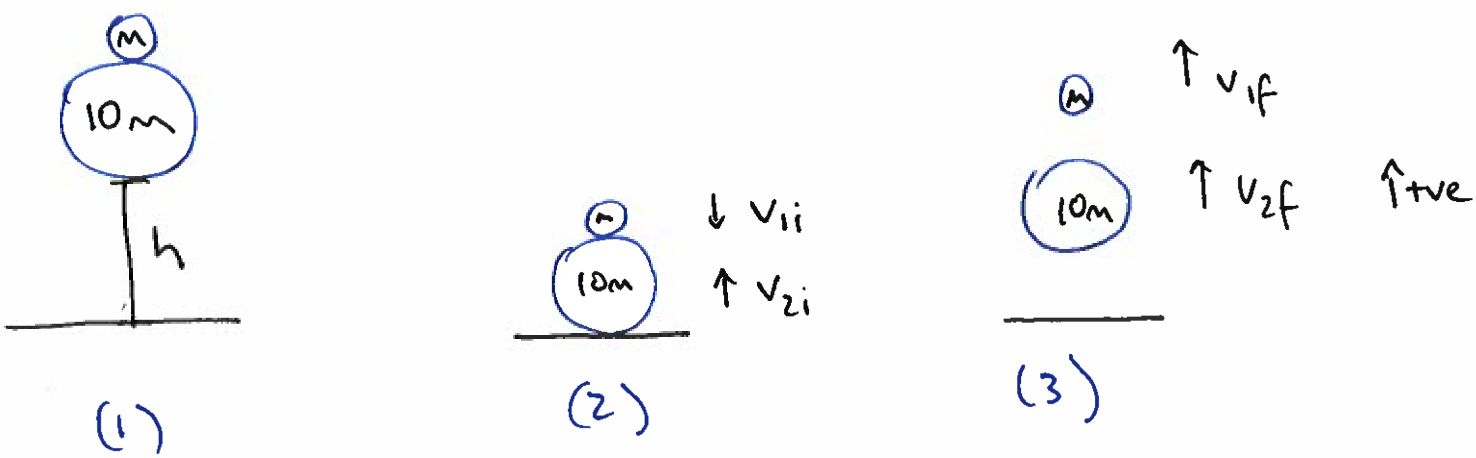
$$\bar{P}_i = m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i}$$

$$\bar{P}_f = M \bar{v}_f$$

$$\Rightarrow m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i} = M \bar{v}_f$$

$$\Rightarrow \boxed{\bar{v}_f = \frac{m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i}}{M} = \frac{m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i}}{m_1 + m_2}}$$

<u>Basketball and tennis ball example</u> (slide 6)



Two steps: first apply conservation of energy to determine speeds just before collision

$$E_{(1)} = E_{(2)}$$

$$\cancel{E_K^{(1)}}^{\,0} + E_p^{(1)} = E_K^{(2)} + \cancel{E_p^{(2)}}^{\,0}$$

$$10mgh = \frac{10}{2} m v_B^2$$

$$\Rightarrow v_B^2 = 2gh$$

$$v_B = \sqrt{2gh}$$ right as it hits the ground

Assuming the Earth is infinitely massive, the basketball bounces upward with the same kinetic energy (speed!)

$\Rightarrow v_{2i} = \sqrt{2gh}$ in diagram (2)

Assuming $h \gg$ diameter of the tennis ball and the basketball

$\Rightarrow v_{1i} \simeq \sqrt{2gh}$ downwards (in diagram (2))

Then use our result from earlier

$$v_{1f} = \frac{2m_2 v_{2i} + (m_1 - m_2) v_{1i}}{m_1 + m_2}$$

$$= \frac{2 \cdot 10m \sqrt{2gh} + (m - 10m)(-\sqrt{2gh})}{m + 10m}$$

$$= \frac{(20m + 9m)}{11m} \sqrt{2gh}$$

$$= \frac{29}{11} \sqrt{2gh} \quad \leftarrow \text{note } |v_{1i}| = \sqrt{2gh}$$

$$\simeq 2.6 \cdot |v_{1i}| \quad \Rightarrow \quad 2.6 \text{ times faster!}$$