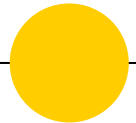


Physics 101H

General Physics 1 - Honors



Lecture 21 - 10/5/23

Momentum and Collisions



Summary

Topics

Friday: Energy conservation [[chapter 8](#)]

- Types of energy
- Energy transfer
- Energy conservation

Today: Momentum and collisions [[chapter 9](#)]

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

Announcements

Yesterday: Problem Set 4 assigned

Next week: No problem set assigned

No labs (PHYS 101L)

No class on Thursday or Friday



Two minute diagrams

Instructions: Write one “paragraph” on the following topic. You have two minutes. You may not use your notes and you should not consult with others around you. Your answer will not be graded; your answer is for your own learning and you don’t need to share your answer.

Question: Draw a mind map, or any other diagram, connecting the concepts we’ve been discussing: energy, work done, forces, energy conservation.



Practice in pairs

*Explaining your attempts and/or your solutions helps you clarify your own understanding, as well as helping others learn. You may also learn new tips and techniques from your peers.

Instructions: Solve the following question with a neighbour. Your answers will not be graded; your discussion is for your own learning*.

Question: Hydrogen fusion represents a relatively clean and almost limitless supply of energy that could be realised in the next century. There is enough hydrogen in the ocean to create 10^{34} J of energy via fusion. How many years of energy needs could be supplied by one millionth of the oceans' hydrogen fusion energy, assuming the future world uses ten times our current energy usage (which is approximately 4×10^{20} J each year)? What about 1 trillionth?

Newton's laws revisited



Newton II: In an inertial reference frame, acceleration is proportional to net force

Newton III: For every force there is an equal and opposite force

We can express in terms of the **momentum**

Systems with zero net force are **isolated systems**

Systems with nonzero net force are **not** isolated systems (**non-isolated?**)

Collisions



Momentum conservation plays a particularly important role in collisions

Two main types of collisions:

Elastic

Inelastic



Summary

Topics

Today: Momentum and collisions [[chapter 9](#)]

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

Tomorrow: Collisions and centre of mass [[chapter 9](#)]

- Collisions
- Centre of mass

Announcements

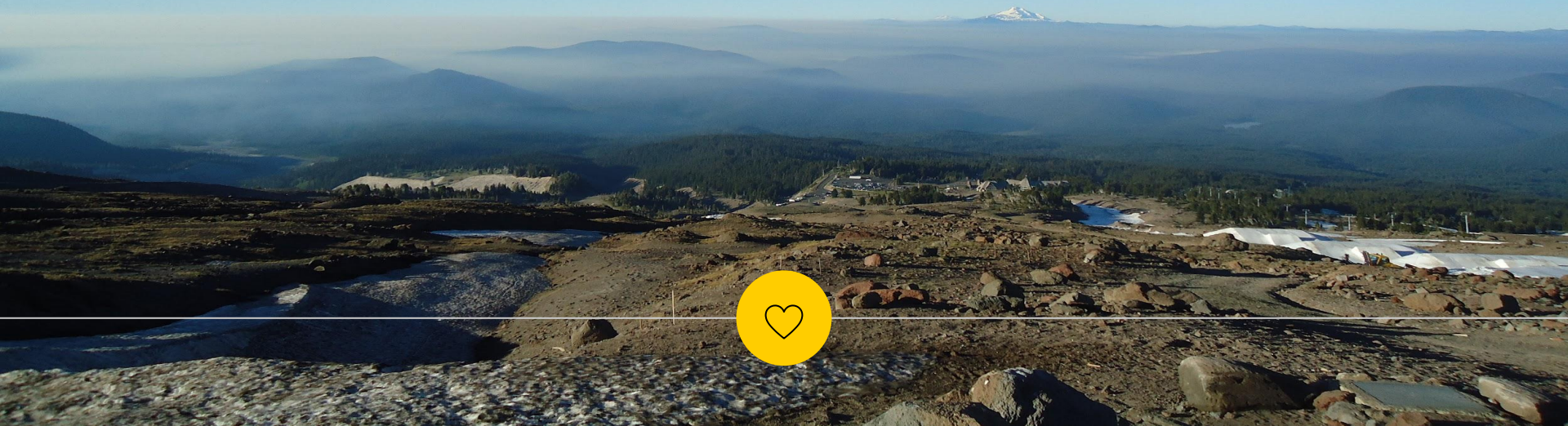
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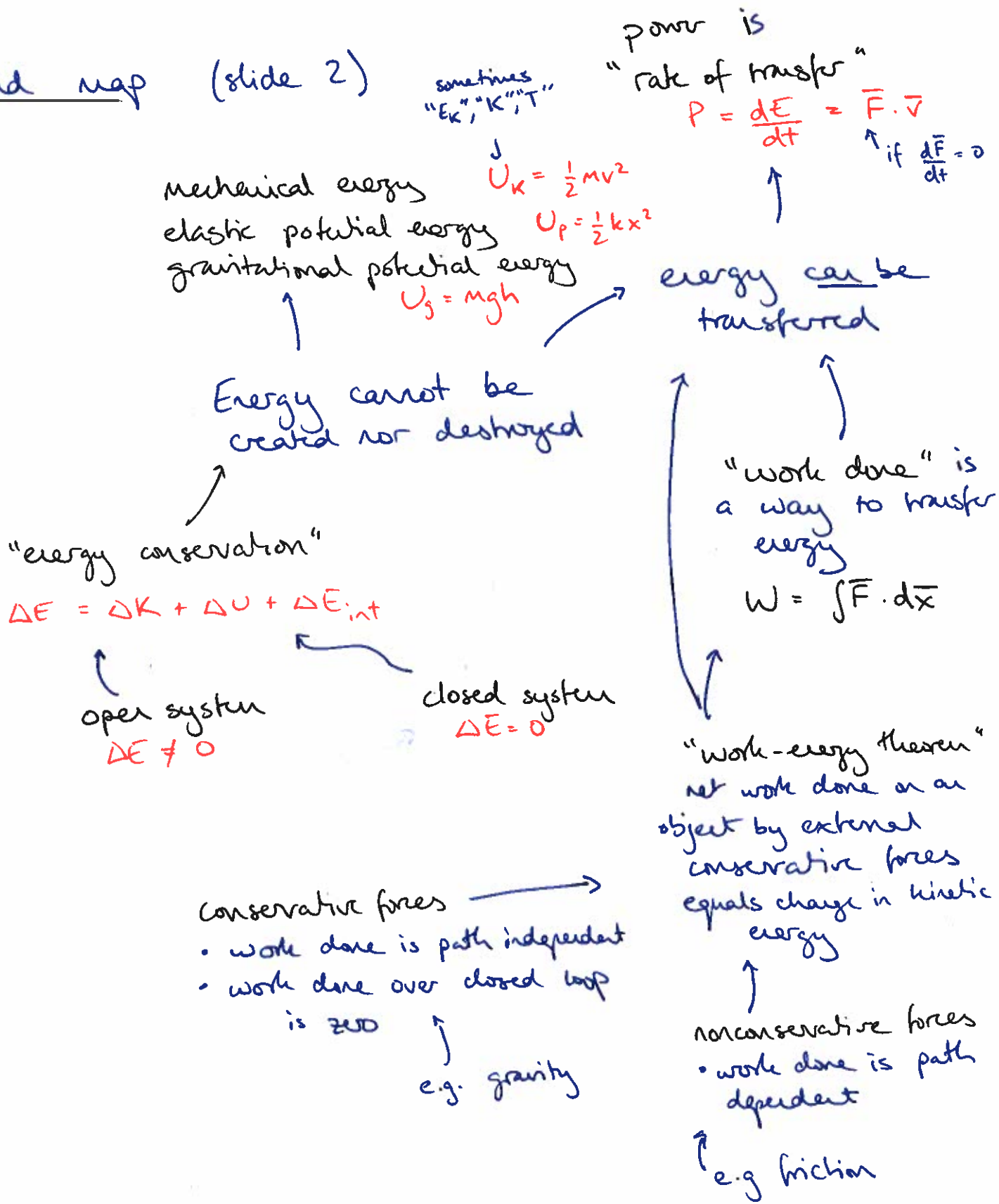
**NEXT WEEK:
NO CLASSES ON THURSDAY OR FRIDAY
NO LABS**



PHYSICS 101 - HONORS

Lecture 21 10/5/23

Mind map (slide 2)



Fusion example

$$1 \text{ millionth} = \frac{1}{10^6} = 10^{-6} \Rightarrow \text{time} = \frac{10^{-6} \cdot 10^{34}}{4 \cdot 10^{24}} \approx \boxed{2.5 \times 10^6 \text{ years}}$$

or 2.5 million years

$$1 \text{ trillionth} = 10^{-12} \Rightarrow \text{time} \approx 2.5 \text{ years}$$

Momentum and Newton's laws (slide 5)

Define momentum $\vec{p} = m\vec{v}$ ← units kg m/s
a vector! $\vec{p}_x = mv_x, \vec{p}_y = mv_y, \vec{p}_z = mv_z$

Recall Newton II $\vec{F}_{\text{net}} = m\vec{a} = m \frac{d\vec{v}}{dt}$

If $\frac{dm}{dt} = 0$ then $\vec{F}_{\text{net}} = m \frac{d\vec{v}}{dt} = \frac{d(m\vec{v})}{dt} = \left(\frac{dm}{dt}\right)\vec{v} + m \frac{d\vec{v}}{dt}$

$\Rightarrow \boxed{\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt}}$ ← Newton II says that the net force on an object is the time rate of change of momentum.

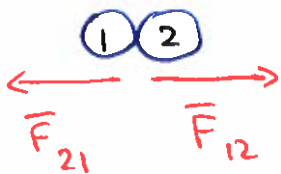
In fact this holds even if the mass is changing!

Recall Newton III tells us that $\vec{F}_{12} = -\vec{F}_{21}$

$\Rightarrow \vec{F}_{21} = M_1 \vec{a}_1$ and $\vec{F}_{12} = M_2 \vec{a}_2$ if there are no other forces

$$\vec{F}_{21} = -\vec{F}_{12} \Rightarrow \vec{F}_{21} + \vec{F}_{12} = 0$$

$$\Rightarrow M_1 \vec{a}_1 + M_2 \vec{a}_2 = 0$$



cont.

$$\begin{aligned}
m_1 \bar{a}_1 + m_2 \bar{a}_2 &= m_1 \frac{d\bar{v}_1}{dt} + m_2 \frac{d\bar{v}_2}{dt} \\
&= \frac{d}{dt} (m_1 \bar{v}_1) + \frac{d}{dt} (m_2 \bar{v}_2) \\
&= \frac{d}{dt} \bar{p}_1 + \frac{d}{dt} \bar{p}_2 \\
&= \frac{d}{dt} (\bar{p}_1 + \bar{p}_2)
\end{aligned}$$

But we know this is zero in the absence of other forces!

$$\Rightarrow \frac{d}{dt} (\bar{p}_1 + \bar{p}_2) = \frac{d}{dt} \bar{p}_{\text{tot}} = 0 \quad \Rightarrow \boxed{\bar{p}_{\text{tot}} = \text{constant}}$$

$\nwarrow \bar{p}_{\text{tot}} = \bar{p}_1 + \bar{p}_2 \quad \nearrow$

Another example of a conservation law, like conservation of energy.

Newton III says that the total momentum of a system is conserved in the absence of external forces!

Isolated systems - no net force
 - $\frac{d\bar{p}_{\text{tot}}}{dt} = 0$ or $\bar{p}_{\text{tot}} = \text{constant}$

Non-isolated systems - net force
 - change in momentum given by the impulse

to see this \rightarrow

$$\bar{F}_{\text{net}} = \frac{d\bar{p}_{\text{tot}}}{dt}$$

$$\int_{P_i}^{P_f} d\bar{p}_{\text{tot}} = \int \bar{F}_{\text{net}} dt$$

$$P_f - P_i = \Delta \bar{p} = \bar{p}_f - \bar{p}_i = \bar{I} \quad \text{where} \quad \bar{I} \equiv \int \bar{F}_{\text{net}} dt$$

$$\boxed{\Delta \bar{p}_{\text{tot}} = \bar{I} = \int \bar{F} dt}$$

- force a constant net force

$$\bar{I} = \bar{F} \Delta t$$

$$\begin{aligned}
\bar{I} &= \int \bar{F} dt = \bar{F} \int dt \\
&= \bar{F} \Delta t
\end{aligned}$$

because \nearrow

Collisions (slide 6)

Elastic collisions

"Snooker (pool) balls bouncing off each other"

- momentum conserved
- kinetic energy conserved

Inelastic collisions

"Throwing gum at a wall"

↑ perfectly inelastic = stick together

- momentum conserved
- kinetic energy not conserved