Physics 101H

General Physics 1 – Honors

Lecture 20 – 10/7/22

Momentum and Collisions


TODAY:
OFFICE HOURS AT 2:30-3PM

Two minute essay

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?

Summary

Topics

Wednesday: Computational physics & drag

Yesterday: Energy conservation [chapter 8]

- Types of energy
- Energy transfer
- Energy conservation
- Power

Today: Momentum and collisions [chapter 9]

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

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

Elastic collisions

Inelastic collisions

Summary

Topics

Today: Momentum and collisions [chapter 9]

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

Next week: Collisions and centre of mass [chapter 9]

- Collisions
- Centre of mass

Announcements

Next week: **No class on Thursday or Friday**


NEXT WEEK:
NO CLASSES ON THURSDAY OR FRIDAY

PHYSICS 101 - HONORS

Lecture 20

Mind map (slide 2)

power is "rate of transfer"

$P = \frac{dE}{dt} = \bar{F} \cdot \bar{v}$ if $\frac{d\bar{F}}{dt} = 0$

sometimes "E_K", "K", "T"

mechanical energy $U_K = \frac{1}{2}mv^2$

elastic potential energy $U_p = \frac{1}{2}kx^2$

gravitational potential energy $U_g = mgh$

energy can be transferred

Energy cannot be created nor destroyed

"work done" is a way to transfer energy

$W = \int \bar{F} \cdot d\bar{x}$

"energy conservation"

$\Delta E = \Delta K + \Delta U + \Delta E_{int}$

open system $\Delta E \neq 0$

closed system $\Delta E = 0$

"work-energy theorem" net work done on an object by external conservative forces equals change in kinetic energy

conservative forces

- work done is path independent
- work done over closed loop is zero

e.g. gravity

nonconservative forces

- work done is path dependent

e.g friction

Fusion example

1 millionth $= \frac{1}{10^6} = 10^{-6}$ $\Rightarrow$ time $= \frac{10^{-6} \cdot 10^{34}}{4 \cdot 10^{21}} \simeq \boxed{2.5 \times 10^6 \text{ years}}$

or 2.5 million years

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

Momentum and Newton's laws (slide 5)

Define momentum $\bar{p} = m\bar{v}$ $\leftarrow$ units kg m/s

a vector! $p_x = mv_x,\ p_y = mv_y,\ p_z = mv_z$

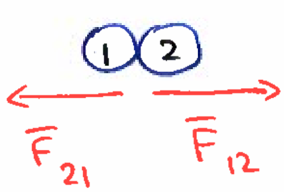
Recall Newton II $\bar{F}_{net} = m\bar{a} = m\frac{d\bar{v}}{dt}$

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

$\Rightarrow \boxed{\bar{F}_{net} = \frac{d\bar{p}}{dt}}$ $\leftarrow$ 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 $\bar{F}_{12} = -\bar{F}_{21}$



$\Rightarrow \bar{F}_{21} = m_1\bar{a}_1$ and $\bar{F}_{12} = m_2\bar{a}_2$ if there are no other forces

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

$\Rightarrow m_1\bar{a}_1 + m_2\bar{a}_2 = 0$

cont.

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

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

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

$\bar{p}_{tot} = \bar{p}_1 + \bar{p}_2$

Newton III says that the total momentum of a system is <u>conserved</u> in the absence of external net forces!

Another example of a <u>conservation law</u>, like conservation of energy.

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

Non-isolated systems – net force
– change in momentum given by the <u>impulse</u>

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

– force a constant net force
$$\bar{I} = \bar{F}\Delta t$$

because
$$\bar{I} = \int \bar{F}\,dt = \bar{F}\int dt = \bar{F}\Delta t$$

to see this

$$\bar{F}_{net} = \frac{d\bar{p}_{tot}}{dt}$$
$$\int_{p_i}^{p_f} d\bar{p}_{tot} = \int \bar{F}_{net}\,dt$$
$$\Delta\bar{p} = \bar{p}_f - \bar{p}_i = \bar{I} \quad \text{where } \bar{I} \equiv \int \bar{F}_{net}\,dt$$

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