Physics 121.
Lecture 14.

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February 1 (my father's birthday): the flood of 1953.

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In 1953, my father was in the army and was sent to rescue people and rebuild dikes.


OORKONDE
AANGEBODEN AAN
M.H. Wolfs
ALS·UITING·VAN·ONZE·BIJZONDERE
DANK·EN·WAARDERING·VOOR·DE
KRACHTIGE·MEDEWERKING·EN·ONVER
DROTEN·IJVER, BETOOND·BIJ·DE
HULPVERLENING, TIJDENS·DE
WATERSNOOD·VAN·FEBRUARI 1953.

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20 days after the flood: plans were developed. **De Delta Werken** were completed in 1997.

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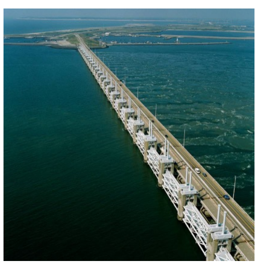
An example: Oosterscheldekering, 9 km long.



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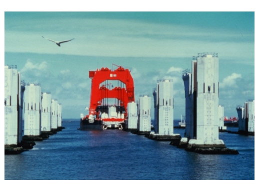
After constructing the pillars, flood the construction area and pick up the pillars.



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Laying a carpet.
Putting down pillars.

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The project was completed in 1997, 44 years after the flood of 1953.

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Physics 121.
Lecture 14.

- Course Information
- Quiz
- Topics to be discussed today:
  - Conservation of linear momentum and one-dimensional collisions (a brief review)
  - Two-dimensional collisions (elastic and inelastic)

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Course Information.

- Homework set # 5 is due on Saturday morning, March 21, at 8.30 am.
- Exam # 2 will take place on Tuesday March 24 between 8 am and 9.20 am in Hubble. Extra office hours on Sunday and Monday will be announced via email.

Quiz.

- Let's practice what we learned (and read).

Linear momentum (a quick review).

- The product of the mass and velocity of an object is called the **linear momentum p** of that object.
- In the case of an extended object, we find the total linear momentum by adding the linear momenta of all of its components:

$$\vec{P}_{tot} = \sum_i \vec{p}_i = \sum_i m_i \vec{v}_i = M\vec{v}_{CM}$$

Linear momentum (a quick review).

- The change in the linear momentum of the system can now be calculated:

$$\frac{d\vec{P}_{cm}}{dt} = M\frac{d\vec{v}_{cm}}{dt} = M\vec{a}_{cm} = \sum_i m_i\vec{a}_i = \sum_i \vec{F}_i = \vec{F}_{net,ext}$$

- This relations shows us that if there are no external forces, the total linear momentum of the system will be constant (independent of time).

Linear momentum (a quick review). Systems with variable mass.

- The first Rocket equation:

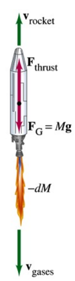
$$RU_0 = Ma_{rocket}$$

where
- $R = -dM/dt$ is the rate of fuel consumption.
- $U_0 = -u$ where u is the (positive) velocity of the exhaust gasses relative to the rocket.

This equation can be used to determine the rate of fuel consumption required for a specific acceleration.

- The **second rocket equation**:

$$v_f = v_i + u\ln\frac{M_i}{M_f}$$

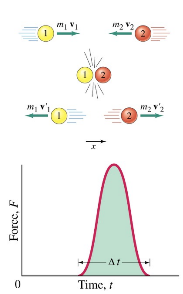


Collisions (a quick review). The collision force.

- During a collision, a strong force is exerted on the colliding objects for a short period of time.
- The collision force is usually much stronger then any external force.
- The result of the collision force is a change in the linear momentum of the colliding objects.
- The change in the momentum of one of the objects is equal to

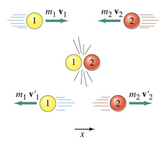
$$\vec{p}_f - \vec{p}_i = \int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}(t)dt$$

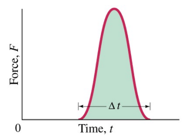
- This change is the **collision impulse**.



Elastic and inelastic collisions (a quick review).

- If we consider both colliding object, then the collision force becomes an internal force, and the total linear momentum of the system must be conserved if there are no external forces acting on the system.
- Collisions are usually divided into two groups:
  - **Elastic collisions**: kinetic energy is conserved.
  - **Inelastic collisions**: kinetic energy is NOT conserved.





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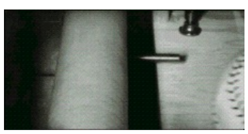
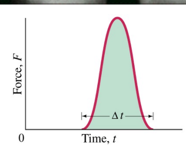
Collisions (a quick review).

- Kinetic energy does not need to be conserved during the time period that the collision force is acting on the system. The kinetic energy may even become 0 for a short period of time.
- During the time period that the collision force is non-zero, some or all of the initial kinetic energy may be converted into potential energy (for example, the potential energy associated with deformation).





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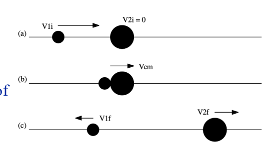
Elastic collisions in one dimension.

- The solution for the final velocity of mass m_1 is:

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

- The solution for the final velocity of mass m_2 is:

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



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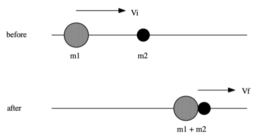
Inelastic collisions in one dimension (a quick review).

- In inelastic collisions, kinetic energy is not conserved.
- A special type of inelastic collisions are the completely inelastic collisions, where the two objects stick together after the collision.
- Conservation of linear momentum in a completely inelastic collision requires that

$$m_1 v_{1i} = (m_1+m_2) v_f \rightarrow$$

$$v_f = \frac{m_1}{m_1+m_2} v_i$$



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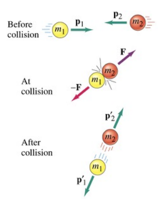
Collisions in two or three dimensions.

- Collisions in two or three dimensions are approached in the same way as collisions in one dimension.
- The *x*, *y*, and *z* components of the linear momentum must be conserved if there are no external forces acting on the system.
- The collisions can be elastic or inelastic.



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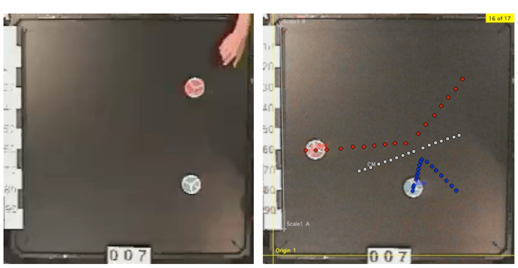
Collisions in two dimensions. Elastic Collisions.



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3 Minute 39 Second Intermission.

- Since paying attention for 1 hour and 15 minutes is hard when the topic is physics, let's take a 3 minute 39 second intermission.
- You can:
  - Stretch out.
  - Talk to your neighbors.
  - Ask me a quick question.
  - Enjoy the fantastic music.

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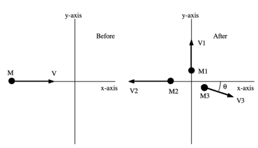
Collisions in two or three dimensions. Example problem.

- A 20-kg body is moving in the direction of the positive x-axis with a speed of 200 m/s when, owing to an internal explosion, it breaks into three parts. One part, whose mass is 10 kg, moves away from the point of explosion with a speed of 100 m/s along the positive y-axis. A second fragment, with a mass of 4 kg, moves along the negative x-axis with a speed of 500 m/s.
  - What is the speed of the third (6 kg) fragment ?
  - How much energy was released in the explosion (ignore gravity)?



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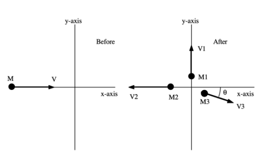
Collisions in two or three dimensions. Example problem.

- Since there are no external forces, linear momentum must thus be conserved.
- Conservation of linear momentum along the x axis requires

$$MV = m_3 v_3 \cos\theta_3 - m_2 v_2$$

- Conservation of linear momentum along the y axis requires

$$0 = m_1 v_1 - m_3 v_3 \sin\theta_3$$



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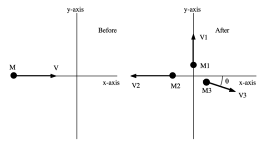
Collisions in two or three dimensions. Example problem.

- What do we know:
  - Speed and direction of mass M
  - Speed and direction of mass 1
  - Speed and direction of mass 2
- What do we need to know:
  - Speed and direction of mass 3
- Since we have two equations with two unknown, we can find the speed and direction of mass 3.
- Once we know the speed of mass 3, we can calculate the amount of energy released.



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Collisions in two or three dimensions. Example problem.

- Our two equations can be rewritten as

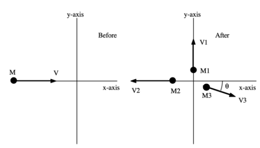
$$m_3 v_3 \cos\theta_3 = MV + m_2 v_2$$

$$m_3 v_3 \sin\theta_3 = m_1 v_1$$

- We can solve this equation by squaring each equation and adding them:

$$(m_3 v_3)^2 = (MV + m_2 v_2)^2 + (m_1 v_1)^2$$

- This equation tells us that v_3 = 1,014 m/s.
- The energy release is 3.23 MJ.



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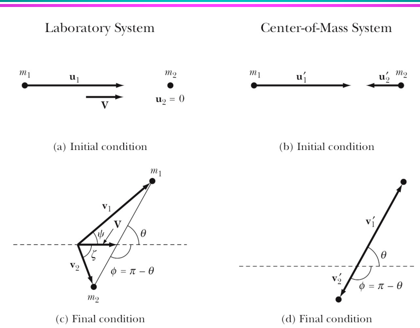
Collisions. Laboratory and Center-of-Mass Frames.



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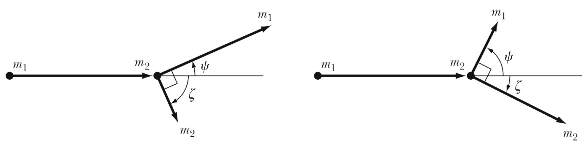
Outcome of collisions not uniquely defined.



If the mass of particle 1 is equal to the mass of particle 2, the two masses will always move at right angles with respect to each other after the scattering.

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Conceptual Questions.

- Let's practice what we learned (and read).

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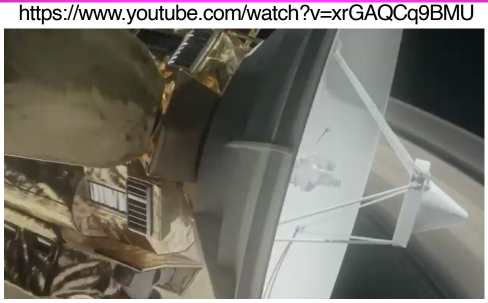
Done for today!
Next week: rotational motion.

https://www.youtube.com/watch?v=xrGAQCq9BMU



Cassini Closes in on Saturn Credit: NASA

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