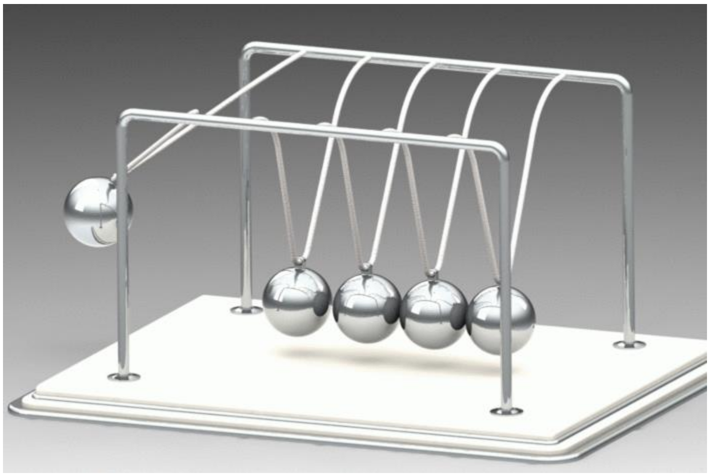
PHY131 F   Fall 2020
Class 17



Today:

- 6.3 Impulse
- 6.4 The Impulse-Momentum Principle

1

Warm-up Polls

1. Two carts collide, one of which was initially moving, and the other was initially at rest.

Is it possible for *both* carts to be at rest after the collision?

[Assume no external unbalanced forces act on the carts.]

A. Yes
B. No

2. Two carts collide, both of which were initially moving.

Is it possible for *both* carts to be at rest after the collision?

[Assume no external unbalanced forces act on the carts.]

A. Yes
B. No

3. Two carts collide, one of which was initially moving, and the other was initially at rest.

Is it possible for *one* cart to be at rest after the collision?

[Assume no external unbalanced forces act on the carts.]

A. Yes
B. No

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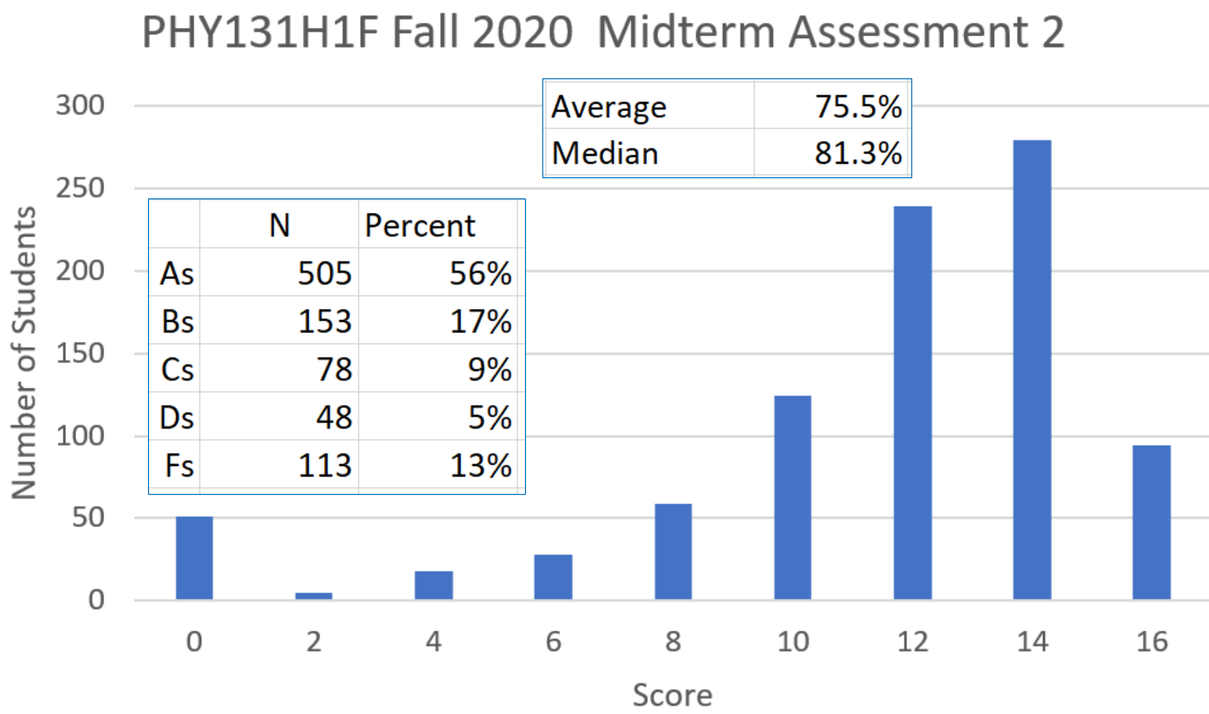
4



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Midterm Assessment 2 Marking is done

- Please have a look over the marking.
- I have posted a rubric detailing how the TAs determined your marks "Midterm Assessment 2 Detailed Marking Rubric".
- For each problem, one TA marked the entire class. This TA was consistent and stuck very strictly to the 2+2+2+2 rubric. Part marks were deducted in the same way for every student in the class.
- If there is a mistake in your marking or the computation of your mark, I would like to fix it. I will remark your test. Simply send an email to phy131fall@physics.utoronto.ca letting me know there was a mistake, and letting me know that you request a remark. You must do this by Monday Oct. 26 by 11:59pm at the latest.
- The TAs have worked there 32 hours each, as per their CUPE contract, and are not able to remark the tests. I will remark the tests as per your requests by correcting any marking mistakes I see.

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Midterm Assessment 2 Marking is done

- A few things to keep in mind:
- There are 857 tests, and only one me. Please be kind.
- I will **not** be changing the rubric at this time, as I don't think that is a good use of my time. My job this semester is to teach you Chapters 1-11 of Etkina to the best of my ability.
- If your answer was perfect, thorough, and followed all the instructions exactly as given, then you should get 8/8.
- I will **not** be overriding any partial-credit decisions that the marking TAs made that were consistently applied to the entire class. If they were consistent, then that was FAIR, and I will not change your mark. I do reserve the right to reduce your mark if I notice a mistake which was made in your favour.

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Midterm Assessment 2 Marking is done

- Here is an example of a situation in which I will **not** be increasing your mark:
- ISSUE: *"For the first question, I received 0.5-points off because my physical quantities and unknowns were not identified in the Sketch and Translate section, rather, I put them in the Represent Mathematically section as this helps me solve the mathematical steps more easily. I did the same for question 2 and received full marks."*
- RESULT: REDUCTION OF 0.5 MARKS. The instructions were clear, and it is possible that one marker followed the rubric more closely than the other. In this case you should have lost 0.5 points for both questions.

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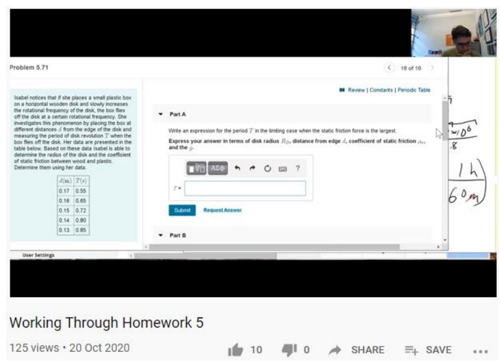
Midterm Assessment 2 Marking is done

- Here is another example of a situation in which I will **not** be increasing your mark:
- ISSUE: *"For the second question, I lost 0.5 marks for significant digits. I reported 2 sig digs because I used g = 9.8, but the marker said it should be 3 sig digs."*
- RESULT: NO CHANGE. I clearly stated during lectures that in this course, we are using 9.80 m/s^2 as the acceleration due to gravity, and that this has 3 significant digits. All other quantities in the problem were specified to at least 3 significant digits.

Working Through Homework 5

- I've been getting a lot of questions about the Homework #5 on MasteringPhysics, which was quite a long one. The class average was 57% on this homework.
- There were 16 problems, and I have carefully worked through all of them on a **Bonus YouTube video** at:
- https://youtu.be/B2G44hfJgsQ
- In the description of the video you will see links where you can click right to the beginning of any problem.
- All 16 problems took me 77 minutes to explain, so that's a pretty long homework. But this is tricky stuff and I think it's good to get enough practice.



Example

- Laura, whose mass is 35 kg, is stranded without a paddle in a 65 kg canoe in a still lake, 5 m from shore.
- She has 10 kg of rocks on board the canoe.
- If she throws all these rocks away from shore, and can throw rocks at 10 m/s, what is the maximum speed she can give herself and the canoe toward the shore?

SKETCH & TRANSLATE.

SIMPLIFY & DIAGRAM

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Example

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REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

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6.2 Linear Momentum

- In the canoe example, we were able to determine the velocity by using the principle of momentum constancy.
  - **We did not need any information about the forces involved.**
  - This is a very powerful result, because in all likelihood the forces exerted by throwing those rocks were not constant.
- The kinematics equations from Ch.2 assume constant acceleration of the system (and thus constant forces).

6.2 Linear Momentum

Momentum constancy of an isolated system

The momentum of an isolated system is constant. For an isolated two-object system:

$$m_1\vec{v}_{1\mathrm{i}} + m_2\vec{v}_{2\mathrm{i}} = m_1\vec{v}_{1\mathrm{f}} + m_2\vec{v}_{2\mathrm{f}} \qquad (6.2)$$

Because momentum is a vector quantity and Eq. (6.2) is a vector equation, we will work with its *x*- and *y*-component forms:

$$m_1 v_{1\mathrm{i}x} + m_2 v_{2\mathrm{i}x} = m_1 v_{1\mathrm{f}x} + m_2 v_{2\mathrm{f}x} \qquad (6.3x)$$

$$m_1 v_{1\mathrm{i}y} + m_2 v_{2\mathrm{i}y} = m_1 v_{1\mathrm{f}y} + m_2 v_{2\mathrm{f}y} \qquad (6.3y)$$

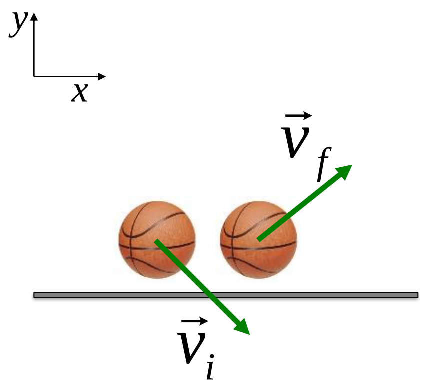
Poll

A basketball with mass 0.1 kg is traveling down and to the right with v_{xi} = +5 m/s, and v_{yi} = –5 m/s.

It hits the horizontal ground, and then is traveling up and to the right with v_{xf} = +5 m/s, and v_{yf} = +4 m/s.

What is the **change** in the *x*-component of its momentum?

A. +0.5 kg m/s
B. –0.5 kg m/s
C. +0.1 kg m/s
D. +0.9 kg m/s
E. zero



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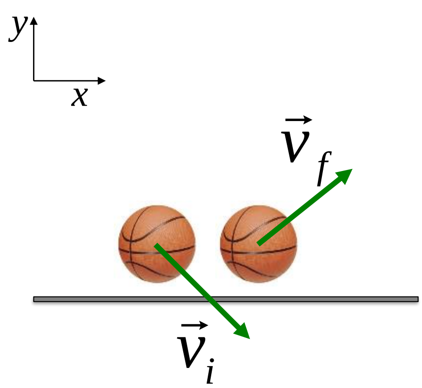
Poll

A basketball with mass 0.1 kg is traveling down and to the right with v_{xi} = +5 m/s, and v_{yi} = –5 m/s.

It hits the horizontal ground, and then is traveling up and to the right with v_{xf} = +5 m/s, and v_{yf} = +4 m/s.

What is the **change** in the *y*-component of its momentum?

A. +0.5 kg m/s
B. –0.5 kg m/s
C. +0.1 kg m/s
D. +0.9 kg m/s
E. zero



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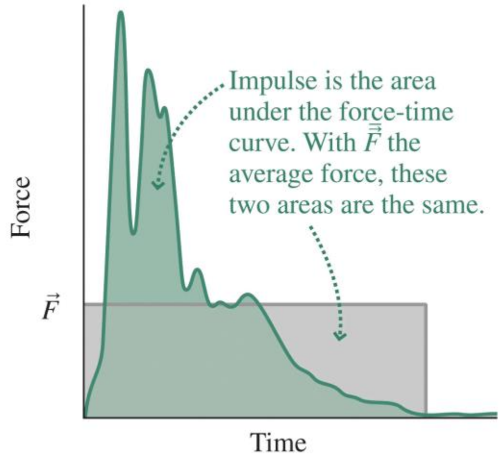
Impulse

The *impulse* upon a particle is:

$$J_x = \int_{t_1}^{t_2} F_x dt$$

$$J_y = \int_{t_1}^{t_2} F_y dt$$



- Impulse has units of N s, but you should be able to show that N s are equivalent to kg m/s.
- The **impulse-momentum theorem** states that the change in a particle's momentum is equal to the impulse on it:

$$\Delta p_x = J_x \qquad \Delta p_y = J_y$$

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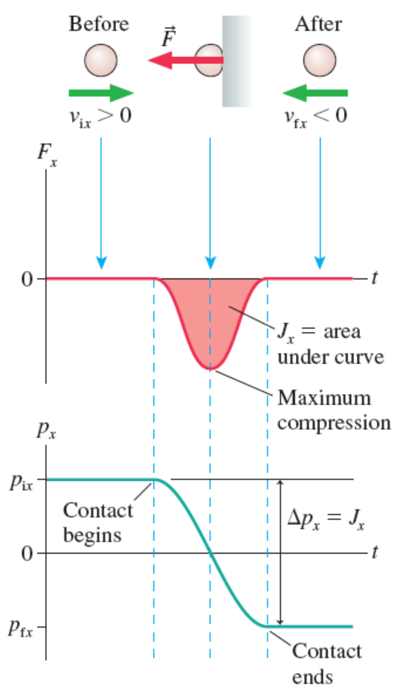

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Image from http://images.thecarconnection.com/med/25-years-of-the-airbag_100223157_m.jpg

- Consider a car accident in which a car, initially traveling at 50 km/hr, collides with a large, massive bridge support.
- The car comes to an abrupt stop.
- Why is it better to hit the airbag as opposed to the hard plastic steering wheel or dashboard?
- ANSWER:
- The people must reduce their momentum from mv to zero. This requires a force applied over some amount of time. If the time is very short, the force must be very large (ie hitting steering wheel).
- If the person hits the airbag, this squishes during impact, lengthening the time of the stop. If the stopping process **takes longer**, then the average force is **less**.

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Poll Question

A 100 g rubber ball and a 100 g damp cloth are dropped on the floor from the same height.
They both are traveling at the same speed just before they hit the floor.
The rubber ball bounces, the damp cloth does not.
Which object receives a larger upward impulse from the floor?

A. They receive equal impulses.
B. The damp cloth receives a larger impulse.
C. The rubber ball receives a larger impulse.

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6.4 The Generalized Impulse Momentum Theorem

Initial Momentum + External Impulse on System = Final Momentum

$$\left(m_1 v_{1x} + m_2 v_{2ix} + \cdots\right) + \sum F_{\text{on Sys } x}\left(t_f - t_i\right) = \left(m_1 v_{1fx} + m_2 v_{2fx} + \cdots\right) \qquad (6.9x)$$

$$\left(m_1 v_{1y} + m_2 v_{2iy} + \cdots\right) + \sum F_{\text{on Sys } y}\left(t_f - t_i\right) = \left(m_1 v_{1fy} + m_2 v_{2fy} + \cdots\right) \qquad (6.9y)$$

Note: If the net impulse exerted in a particular direction is zero, then the component of the momentum of the system in that direction is constant.

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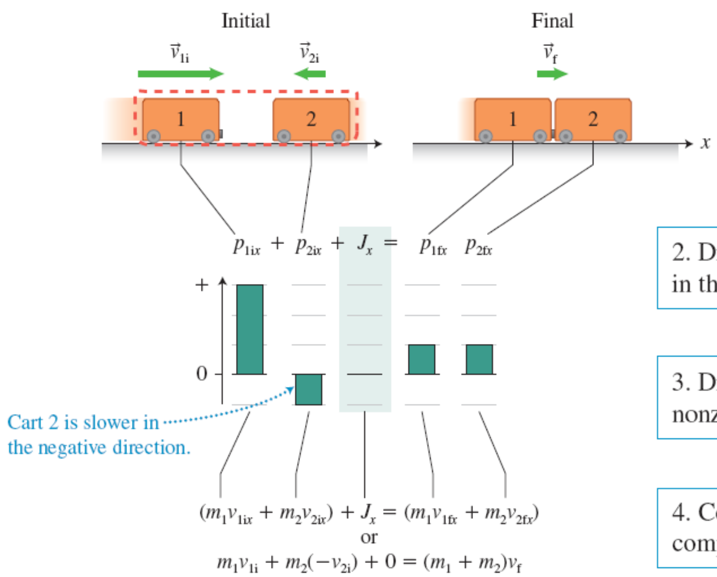
PHYSICS TOOL BOX 6.1 Constructing a qualitative impulse-momentum bar chart



1. Sketch the process, choose the initial and final states, and choose a system.

2. Draw initial and final momentum bars for each object in the system. (Note cart directions and bar directions.)

3. Draw an impulse (J) bar if there is an external nonzero impulse.

4. Convert each bar in the chart into a term in the component form of the impulse-momentum principle.

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6.4 The Generalized Impulse Momentum Theorem

Impulse-momentum bar chart

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2. Draw initial and final momentum bars for each object in the system.
3. Draw an impulse bar if there is an external nonzero impulse.
4. Convert each bar in the chart into a term in the component form of the impulse-momentum equation.

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6.4 The Generalized Impulse Momentum Theorem

Impulse-momentum bar chart

- The lengths of the bars are qualitative indicators of the relative magnitudes of the momenta.
- The middle shaded column in the bar chart represents the net external impulse exerted on the system objects during the time interval.
- The sum of the heights of the bars on the left plus the height of the shaded impulse bar should equal the sum of the heights of the bars on the right.
- This “conservation of bar heights” reflects the conservation of momentum.

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Example: Problem 6.71

A record rainstorm produced 304.8 mm (approximately 1 ft) of rain in 42 min. Estimate the average force that the rain exerted on the roof of a house that measures 10 m× 16 m. Assume the (terminal) speed of the rain to be 10 m/s.

SKETCH & TRANSLATE.

SIMPLIFY & DIAGRAM

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REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

Before Class 18 on Friday

- Please finish reading Chapter 6.
- Plan to meet up with your Practical Pod during Friday's class – you should be able to turn on your microphone in order to participate in the TeamUp Quiz Module 3 Ch.6.
- If you cannot do the TeamUp quiz during class, it can be done either with your pod or on your own at any time over the weekend.

- As usual, I'll be around until 12:30, then a TA will be in the PHY131 Help Centre:
- Zoom Meeting ID: 938 0964 2256
- Passcode: 723874