<table>
<thead>
<tr>
<th>Today</th>
<th>2.1-.3, (.9, .10) Momentum Principle &amp; Simple Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tues.</td>
<td>2.4 – .5 Momentum with Changing Force, Quiz 1</td>
</tr>
<tr>
<td>Wed.</td>
<td>L2 Measuring &amp; Modeling 1-D Motion</td>
</tr>
<tr>
<td>Lab</td>
<td>2.6 – .8 Constant Force, time estimates, Models</td>
</tr>
<tr>
<td>Fri.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RE 2.a</td>
</tr>
<tr>
<td></td>
<td>EP1, HW1: Ch 1 Pr.98</td>
</tr>
<tr>
<td></td>
<td>RE 2.b, bring smart device</td>
</tr>
<tr>
<td></td>
<td>Could bring headphones</td>
</tr>
<tr>
<td></td>
<td>RE 2.c</td>
</tr>
</tbody>
</table>

Motion is neither created nor destroyed, but transferred via interactions.

\[
\mathbf{Momentum} = \mathbf{p} \equiv \frac{m\mathbf{v}}{\sqrt{1 - \left(\frac{|\mathbf{v}|}{c}\right)^2}} \approx m\mathbf{v} \quad \text{for} \quad |\mathbf{v}| << c
\]
Q 1.8 a

Three protons travel through space at three different speeds.

Proton A: 290 m/s
Proton B: $2.9 \times 10^6$ m/s
Proton C: $2.9 \times 10^8$ m/s

For which proton(s) is it reasonable to use the approximation when calculating its momentum?

1. A only
2. A and B
3. A and B and C
4. none of the protons
Q1.9.c: Suppose you are driving a 1000 kg car at 20 m/s in the +x direction. After making a 180 degree turn, you drive the car at 20 m/s in the –x (opposite) direction. What is the magnitude of the change of the momentum $|\Delta \vec{p}|$ of the car?

a) 0 kg· m/s

b) 2.0e4 kg· m/s

c) 4.0e4 kg· m/s

d) 6.0e4 kg· m/s

e) 8.0e4 kg· m/s
Q1.9.c: Suppose you are driving a 1000 kg car at 20 m/s in the +x direction. After making a 180 degree turn, you drive the car at 20 m/s in the –x (opposite) direction. What is the change of the magnitude of the momentum $\Delta |\vec{p}|$ of the car?

a) 0 kg· m/s
b) 2.0e4 kg· m/s
c) 4.0e4 kg· m/s
d) 6.0e4 kg· m/s
e) 8.0e4 kg· m/s
motion is neither created nor destroyed, but transferred via interactions.

\[
\vec{p} \equiv \frac{m\vec{v}}{\sqrt{1 - \left(\frac{\vec{v}}{c}\right)^2}} \approx m\vec{v} \quad \text{for} \quad |\vec{v}| << c
\]
2.1 Systems & Surroundings

Bookkeeping motion
2.2 Momentum Principle

\[ \Delta \text{Motion}_{\text{system}} = \sum_{\text{all. external}} \text{Interactions} \]

\[ \Delta \text{Momentum}_{\text{system}} = \sum_{\text{all. external}} \text{Impulse} \]

\[ \Delta \vec{p}_{\text{system}} = \sum_{\text{all. external}} \vec{I} \]

\[ \vec{I} = \vec{F} \Delta t \quad \text{Force} \]

\[ \Delta \vec{p}_{\text{system}} = \sum_{\text{all. external}} \vec{F}_{\rightarrow \text{system}} \Delta t \]

\[ \Delta \vec{p}_{\text{system}} = \vec{F}_{\text{net} \rightarrow \text{system}} \Delta t \]

Units:
An object is moving in the +x direction.

Which of the following statements about the net force acting on the object could be true?

A. The net force is in the +x direction
B. The net force is in the –x direction
C. The net force is zero
D. A and B
E. B and C
F. A and C
G. A, B and C
Q 2.2 b
Which cart(s) experience a net force to the left?

A. Green Cart which moves to the left at nearly constant speed.
B. Red Cart which moves to the left, gradually speeding up.
C. Blue Cart which moves to the left, gradually slowing down.
D. Both Green and Red carts
E. Both Blue and Red carts
F. Both Green and Blue carts
Problem-Solving Style Example
A hockey puck is sliding along the ice with nearly constant momentum
< 10, 0, 5 > kg m/s when it is suddenly struck by a hockey stick with a force < 0, 0, 2000 > N
that lasts for only 3 milliseconds (3e-3 s). What is the new (vector) momentum of the puck?
Inside a spaceship in outer space there is a small steel ball. At a particular instant, the ball has momentum \( < -8, 3, 0 > \) kg· m/s and is pulled by a string, which exerts a force \( < 20, -10, 0 > \) N on the ball. What is the ball’s (vector) momentum 2 seconds later?

A. \( < -28, 23, 0 > \) kg· m/s
B. \( < 12, -7, 0 > \) kg· m/s
C. 36.2 kg· m/s
D. \( < 32, -17, 0 > \) kg· m/s
E. \( < 40, -20, 0 > \) kg· m/s
Position Update (ch 1)

\[ \vec{r}_{object_{new}} = \vec{r}_{object_{old}} + \vec{v}_{object_{ave}} \Delta t \]

\[ \vec{v}_{object_{ave}} \approx \frac{\vec{p}_{object_{ave}}}{m_{object}} \Delta t \]

Momentum Update (ch 2)

\[ \vec{p}_{object_{new}} = \vec{p}_{object_{old}} + \vec{F}_{net\rightarrow object_{ave}} \Delta t \]

Note: If \( \Delta t \) is small enough, old speed is close enough to average, old force is close enough to average to approximate in simulation.

A “while loop”

```
while t < t_{\text{max}}
    t \leftarrow t + \Delta t
    \vec{p}_{object} \leftarrow \vec{p}_{object} + \vec{F}_{net\rightarrow object} \Delta t
    \vec{r}_{object} \leftarrow \vec{r}_{object} + \frac{\vec{p}_{object}}{m_{object}} \Delta t
```
1-D Motion fan cart (1-D). Suppose you have a fan cart whose mass is 400 gram and it’s on a huge, 8m long track. Initially you set the cart moving down the track in the x-direction at location <0.5,0,0>m with velocity <1.2,0,0>m/s. The force due to the fan is <0.2,0,0>N; comparatively, friction is negligible. What are the momentum and position of the cart 3 seconds later?
<table>
<thead>
<tr>
<th>Today</th>
<th>Tues.</th>
<th>2.1-.3, (.9, .10) Momentum Principle &amp; Simple Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wed.</td>
<td></td>
<td>2.4 – .5 Momentum with Changing Force, <strong>Quiz 1</strong></td>
</tr>
<tr>
<td>Lab</td>
<td></td>
<td>L2 Measuring &amp; Modeling 1-D Motion</td>
</tr>
<tr>
<td>Fri.</td>
<td></td>
<td>2.6 – .8 Constant Force, time estimates, Models</td>
</tr>
</tbody>
</table>

**RE 2.a**
EP1, HW1: Ch 1 Pr.98

**RE 2.b**, bring smart device
Could bring headphones

**RE 2.c**