Physics 1A Week 3 Reading Quiz Spring 2001

1. If both the speed and the mass of an object are doubled, its momentum is now:

a) 4 times larger.

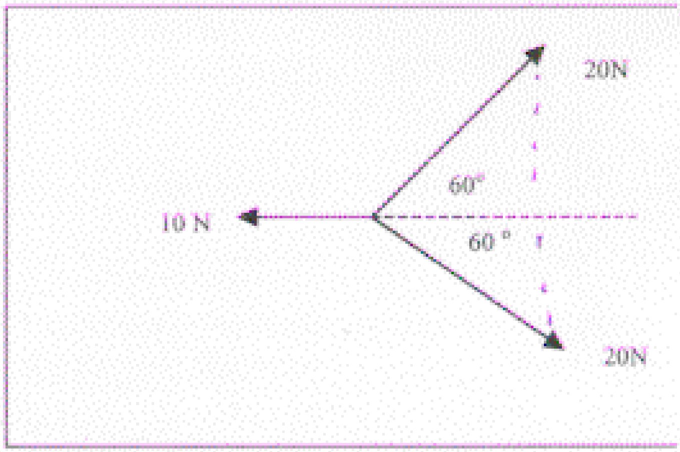
b) 2 times larger.

c) unchanged.

d) 8 times larger.

e) 16 times larger.

2. What is the sum of these three forces?



a) 40 N to right

b) 20 N to right

c) 10 N to right

d) 10 N to left

e) 0 N.

3. A small car crashes into a stationary garbage truck and both come to rest.

The small car is now a wreck, and the garbage truck has a scratched bumper. Which experienced the greater force of impact?

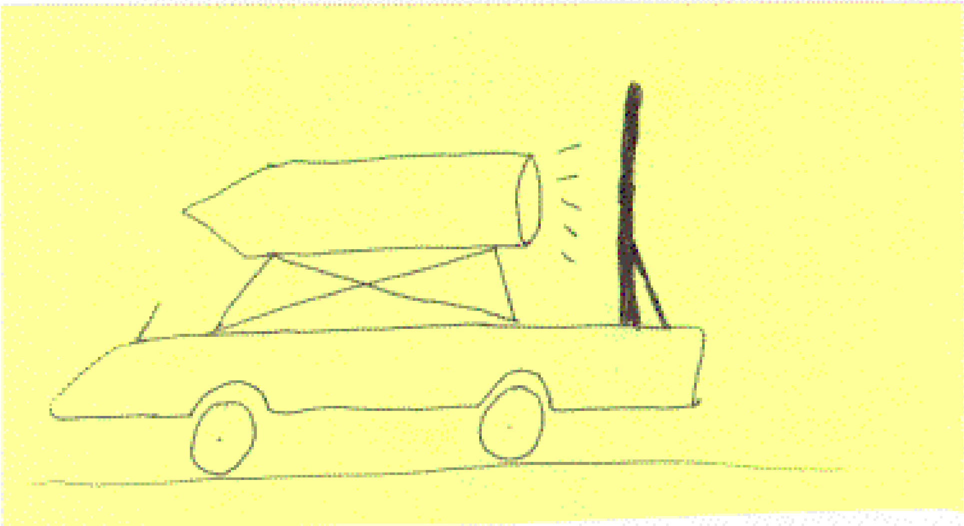
a) the small car.

b) the garbage truck.

c) depends on the speed of the car and its mass relative to the truck.

d) both the same.

4. An inventor builds a rocket-powered race car which can beat any competitor.
Just before a race, however, safety officials insist that he install a "blast shield" behind the rocket to protect spectators, as shown:



When the rocket is ignited....

a) the rocket will accelerate the car to the left.

b) the car will move to the left as long as the air friction is less than the wheel friction.

c) the car will not move.

d) the blast shield will act as a "sail" and the rocket's exhaust will accelerate the car to the right.

Questions, Questions .... Let the Physics Begin!

Q. How do we measure "motion"? What causes things to move? To stop moving?

Q. How do we compare effort needed to bring to a stop (with one hand):

- baseball with v = 60 mph?
- quarterback " 8 mph?
- train " 0.2 mph?

(Is there more to motion than just speed?)

Q. In "weightless" space .....

- can astronaut tell a full box of bolts from an empty box? (Answer: shake it! But why...?)
- On the moon (or underwater), does a weight belt add "extra gravity" without side-effects? (No)
- If astronaut hits thumb with "weightless" hammer, does it hurt? (Yes!)
- If astronaut is "stranded" floating in space, how can he return to ship? (Hint: use the hammer + box of bolts!)

Newton's Laws of Motion - Dynamics (ch. 4)

Aristotle : Bodies tend to move towards their "natural" place, then stay there. Any motion requires continuous "disturbance" or force. ✗

Galileo's experimental Law of Inertia ~ Newton's 1st Law:

1. "An object continues in a state of rest or uniform motion in a straight line unless acted upon by an external force"

i.e. $\frac{d\vec{v}}{dt} = 0$ or $\vec{v}$ = constant

e.g. Wear your seat-belt! (Note: crash victims are not "thrown" from car - they leave car behind)

∴ If object has changing $\vec{v}$ (e.g. slows down), we must look for a force causing it (usually friction)

So what is "Force"?

1st law says: "that which alters motion"

e.g. force of gravity changes $\vec{v}$ of falling body

friction changes $\vec{v}$ to zero

Force is a Vector: has magnitude and direction

Direction – must be same as change in $\vec{v}$

i.e. same direction as accel. $\vec{a} = \frac{d\vec{v}}{dt}$

Magnitude? "Effort" changes with both

mass and change in $\vec{v}$....

e.g. baseball 0.2kg at 60mph

quarterback 100kg at 8mph

train 2×10^4kg at 0.2mph

($|\vec{F}|$ increasing ↓)

First need to quantify "motion" of these objects.....

Figure 4.1

Ball rolling down an incline plane illustrating the laws of inertia

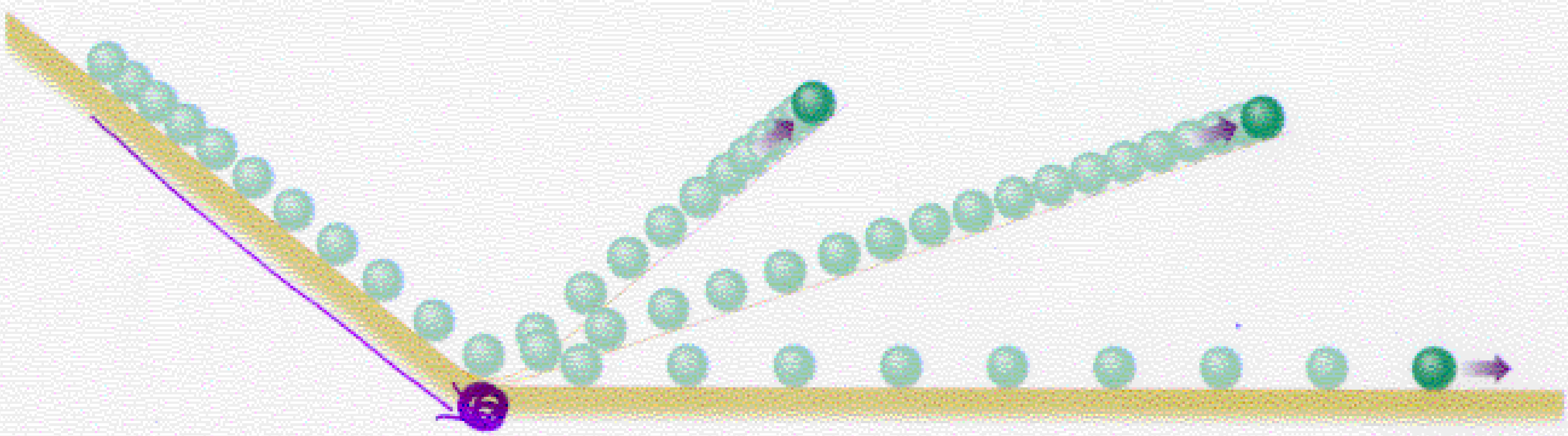


Figure 4.5
Experiment performed in a moving train, as seen from inside and out

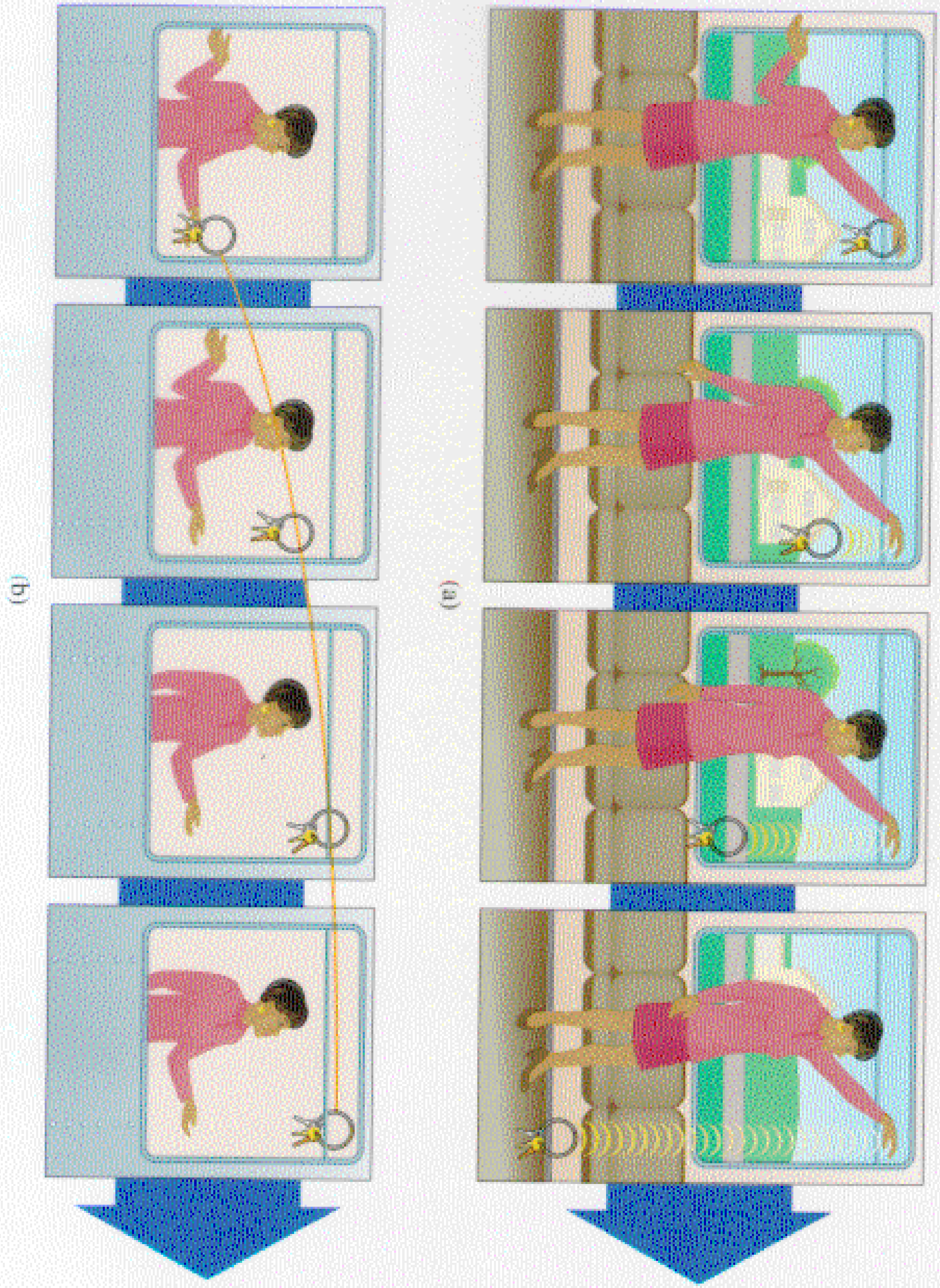
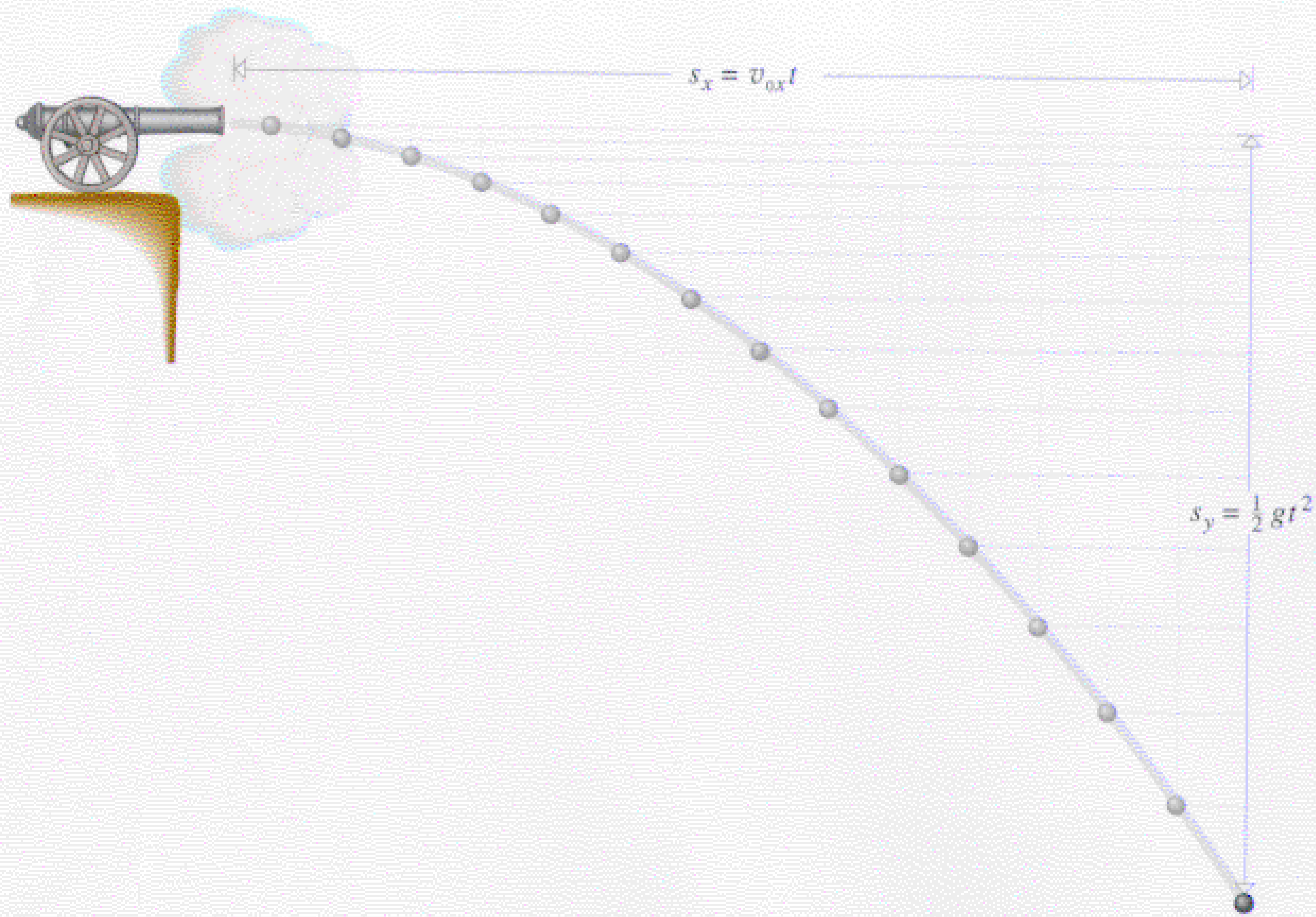


Figure 4.3
Projectile fired horizontally



Momentum as measure of Motion

DEFINE: Momentum $\vec{p}$ = mass × velocity

i.e. $\vec{p} = m\vec{v}$

- $\vec{p}$ is a vector. Like $\vec{v}$, measured wrt some inertial reference frame ("local standard of rest")

- Units of $|\vec{p}|$ = mass × speed : kg m/s

  e.g. baseball $m = 0.2$ kg, $v = 28$ m/s (60mph)

  has $p = |\vec{p}| = 0.2 \times 28$ = 5.6 kg m/s

  quarterback $m = 100$kg, $v = 4.4$ m/s

  has $p = 100 \times 4.4$ = 440 kg m/s

- Change in $\vec{p}$, $\Delta\vec{p} = m\Delta\vec{v}$ is not relative to reference frame i.e. all observers agree on effect $\Delta\vec{p}$. (So they should also agree on cause of $\Delta\vec{p}$).

Newton's 2nd Law: Force and Momentum

When object changes motion over time interval Δt, need to define force (effort) required to cause that change.

~~We want~~:
We want:

Force $\propto$ mass

$\propto \Delta v$ in direction of $\Delta \vec{v}$

$\propto \frac{1}{\Delta t}$ ("gentle" vs. "harsh")

We can define $\vec{F} = m \frac{\Delta \vec{v}}{\Delta t} = \frac{\Delta \vec{p}}{\Delta t}$ from before

Let $\Delta t \rightarrow 0 \Rightarrow$ Newton's 2nd Law:

"The rate of change of an object's momentum is proportional to the force applied in the direction of that change."

i.e. $$\vec{F} = \frac{d\vec{p}}{dt}$$ SI Units: $kg\,m s^{-2}$ or Newton

$\vec{F} = m\vec{a}$: Mass as "inertial resistance" to motion

We have $\vec{F} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\vec{a}$

So for given force : accel $\vec{a} = \frac{F}{m}$: depends on <u>mass</u> not weight.

E.g. On moon ($g_M \approx 1/6\, g$), massive objects are still difficult to get moving (or slow down).

∴ Weight belt increases force of gravity (downwards) but also increases your inertia.

Or : In "weightless" environment, shake box of bolts or throw hand-to-hand. Effort required ∝ mass.

Decelerate moving hammer with thumb. "Weightless" hammer still has mass and so $F = ma$ = ouch!