Exam #1

Hour exam 1, Wed September 27
In-class 50 minutes
Chapters 1 and 3-6
Scantron with 20 multiple choice questions
Bring #2 pencil and calculator
1 8.5” x 11” equation sheet, front only

- Today Exam Review

Aristotle Onward

- Inertia:
  A body subject to no external forces will
  - Stay at rest if it began at rest
  - Will continue motion in straight line at unchanging speed if it began in motion.
- Can explain some motions
  - Leaves out motions as simple at the moon orbiting around earth, etc.
  - Need more detail to quantify and understand motion

Quantifying motion

$$\text{Average speed} = \frac{\text{distance traveled}}{\text{traveling time}}$$

As an equation:

Distance traveled = d
Traveling time = t
Average speed = $\bar{s}$

$$\bar{s} = \frac{d}{t}$$

Acceleration is the rate at which velocity changes:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time to make the change}}$$

Instantaneous speed and acceleration = can be though of as average values over very short time interval.

Question: acceleration

You throw a ball directly upwards to the ceiling and let it hit to the floor.
Using g=9.81 m/s^2, the acceleration is smallest

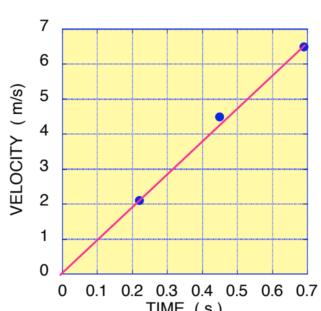
A. Near the ceiling
B. Just before it hits floor
C. None of the above

After it leaves your hand, acceleration is constant, and equals acceleration of gravity. Acceleration is different than velocity. The velocity is zero at the top of the arc, but it is still continuously changing, even when it is zero.

Falling object instantaneous speed vs time

- Instantaneous speed proportional to time.
- So instantaneous speed increases at a constant rate
- This means constant acceleration
- *s=at*

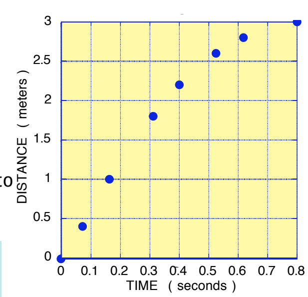
$$\text{accel} = \frac{\text{change in speed}}{\text{change in time}} = \frac{6.75\ m/s}{0.69\ s} = 9.8\ m/s/s = 9.8\ m/s^2$$



Distance vs time for falling ball

- Position vs time of a falling object
- This completely describes the motion
- Distance proportional to time squared.

$$d = \left(\frac{1}{2} 9.81\ m/s^2\right) t^2$$



Another Tool: Momentum

- Momentum = mass × velocity
- Momentum can be negative.
  - For objects moving in opposite directions, one will have positive momentum and one will have negative momentum
  - The total momentum could be zero, even though there is plenty of 'motion'.
- Amount of 'motion' in a body (but not always positive).

- Conservation of momentum: *Momentum is not created or destroyed, only transferred from one object to another.*

Conservation of momentum

- Useful in understanding result of collisions.
- Not concerned with details of collision, only before and after.
- Total amount of momentum before = total momentum after.
- Momentum is transferred from one object to another.

Momentum Question

A 5 kg ball moving at 1 m/s to the right collides with a stationary 10 kg ball.

After the collision, the 10 kg ball moves to the right at 0.25 m/s.

What is the final speed of the 5 kg ball?

A. 0 m/s.

B. 0.5 m/s

C. 1 m/s

Momentum before
= 5kg×1m/s + 10kg×0m/s =5 kg-m/s

Momentum after =
= 5kg× ?m/s + 10kg×0.25m/s =5 kg-m/s
= 5kg× ?m/s + 2.5 kg-m/s = 5 kg-m/s

v = 0.5 m/s moving to the right

Momentum example

before

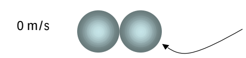
Two 5 kg balls move toward each other, each moving at 1 m/s, but in opposite directions.

After the collision, clay on them makes them stick together.

Before the collision, the total momentum is

5 kg × (1 m/s) + 5 kg × (-1 m/s) = 0 kg-m/s

after



After the collision, the total momentum must also be zero. Since the balls are stuck together, this means that the velocity of each must be zero.

Inertia, Mass and Newton

- **Principle of inertia**:
  - object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.
- Defined **mass *m***:
  - amount of inertia of a body
  - Measured in kg
- Define **force *F***:
  - Something that changes a body's acceleration
- Related **force**, **mass**, and **acceleration**:
  - *F=ma*, or *a=F/m*
  - Subject to the same force, more massive objects accelerate more slowly.
- Weight:
  - Force of gravity on a body = *mg*
  - Measured in Newtons (*N*). 1 *N* = 1 kg-m/s^2

Newton: forces

- Newton changed the emphasis from 'before and after' to 'during'.
- To describe the interaction, he clearly defined forces and their affects:

A force changes the momentum of an object:
Change in momentum = Force × time

Question: force

A car weighs 9810 N.

It is moving at a speed of 30 m/s.

You apply the brakes with a force of 500 N. How many seconds will it take to stop?

A. 10 seconds
B. 30 seconds
C. 60 seconds

The force is 500N.
The mass = weight/g = 9810/9.81 m/s^2 = 1000 kg.
So the acceleration is 500 N /1000 kg = 0.5 m/s/s.
It takes 60 seconds for the speed to drop from 30m/s to zero.

Newton: 2nd law

- Second law is equivalent to
  Net Force = Mass x Acceleration

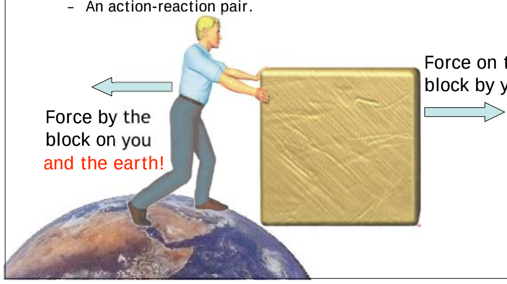
$$\text{Acceleration} = \frac{\text{Net Force}}{\text{Mass}}$$

$$a = \frac{F}{m}$$

- Constant force gives constant acceleration
  - ✓Velocity increases with time.

Newton: 3rd Law- Action/Reaction

- Every force is an interaction between two objects
- ***Each*** of the bodies exerts a force on the other.
- The forces are equal and opposite
  - An action-reaction pair.



Newton & mom. conservation

- The law of force pairs is the same as conservation of momentum.
- An applied force changes the momentum of an object.
- That momentum was transferred from the object applying the force.
- Hence an equal and opposite force had to change the momentum of the force-applying object.

Question

Two people are on roller chairs, and quickly push off of each other as hard as they can. They have masses of 100 kg and 50 kg. After the push, the 100 kg person is moving

A. Twice as fast as the 50 kg person
B. The same speed as the 50 kg person
C. Half as fast as the 50 kg person

Equal and opposite forces, but $a=F/m$.
so the accel of 100 kg person is half that of 50 kg person.
Accel is applied for same time, and $v=at$.

Or… by conservation of momentum

Newton's laws of motion

1st law: ***Law of inertia***
Every object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.

2nd law: ***F=ma, or a=F/m***
The acceleration of a body along a direction is
- proportional to the total force along that direction, and
- inversely the mass of the body

$F=ma$ or, $a = F/m$

3rd law: ***Action and reaction***
For every action there is an equal and opposite reaction.

Force question

A racer floors his dragster from a stop, so that a constant force is applied to it for the entire race. Which of the following statements is true?

A. Its speed is constant after a short time.

B. Its speed increases proportional to time.

C. Its speed increases proportional to time squared.

D. Its speed increases proportional to the square root of time.

Some equations

- Constant speed (no forces)
  - *distance=(velocity)x(time), d=vt*
  - *v*=constant
- Constant acceleration (constant force)
  - d=(1/2)x(*accel*)x(*time*)^2, d=(1/2)at^2
  - $v=at$,
  - a=constant

Gravity

- **Centripetal acceleration**: body in circular orbit at constant speed has an acceleration directly inward.
  - magnitude is v^2/r. r=orbital radius

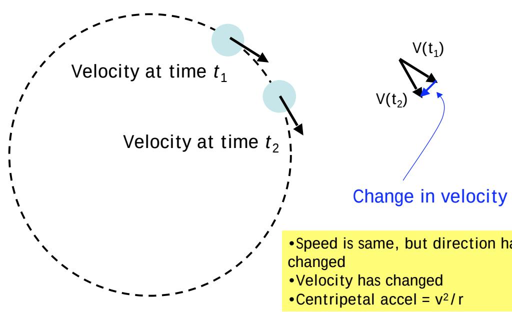
$$a_c = \frac{v^2}{r} \quad m/s^2$$

- **Gravitational force**:
  - Force between any two bodies with mass
  - r = separation between centers

$$F = 6.7 \times 10^{-11} \frac{m_1 \times m_2}{r^2}$$

- Free-fall
  - Accelerating at acceleration of gravity

Acceleration = $\frac{\text{change in velocity}}{\text{change in time}}$



- Speed is same, but direction has changed
- Velocity has changed
- Centripetal accel = v^2/r

Circular orbits

A geosynchronous satellite is one that orbits the Earth once every 24 hours. It orbits at some particular distance from the Earth's center.

In order for it to orbit **twice** every 24 hours, it must be

A. Closer to the Earth

B. Farther from the Earth.

C. Same distance but moving twice as fast.

Centripetal acceleration is v^2/r. This acceleration is due to the gravitational force, so equals g, and is constant for all orbits.
The speed v is (circumference / period) = $2\pi r/T$

Then the centripetal acceleration is proportional to r/T^2
So if the orbital time is shorter, the orbital radius must be smaller.

Properties of gravity

- Gravitational force between two objects proportional to product of masses
- Gravitational force drops with the square of the distance between centers of objects.
- On Earth's surface, gravitational force produces constant acceleration, g=9.81 m/s^2

Question

Halfway to the moon, what is the acceleration of an apple due to the Earth's gravity? The Moon is 60 Earth radii from Earth)

A. $g/2$
B. $g/4$
C. $g/900$

Moon is 60 Earth radii from the Earth.
Halfway is 30 Earth radii.
So apple is 30 times farther than when on surface.
Gravitational force is $(30)^2$ times smaller = $g/900$

Work, Energy and Power

- Work = Force x Distance
- Energy = an object's ability to do work
- Kinetic energy of motion: $E_{kinetic}=(1/2)mv^2$
- Power - rate of done work $P = W/t$

Work-energy relation

- The acceleration of the body is related to the net force by $F=ma$

$$Work = F_{net} \times d = (ma) \times d = m \times (ad)$$

For a body initially at rest, constant accel. says

$$\left\{ \begin{array}{l} d = \frac{1}{2}at^2, \ so \ t = \sqrt{\frac{2d}{a}} \\ v_{final} = at = a\sqrt{\frac{2d}{a}} = \sqrt{2ad} \\ ad = \frac{1}{2}v_{final}^2 \end{array} \right\}$$

$$Work = F_{net} \times d = \frac{1}{2}mv_{final}^2$$

$\frac{1}{2}mv^2$ is called Kinetic Energy, or energy of motion

Energy conservation

- In Newtonian mechanics, it is found that the total energy defined as the sum of kinetic (visible) and potential (invisible) energies is conserved.
- E = K + U = constant
- Many situations become much clearer from an energy perspective.

Question: work

You push on a car with a constant force of 10 N for 1 second.
How much work did you do on the car?

A. 10 J
B. 50 J
C. Need more information

Work = (Force)x(Distance). But don't know distance!
Could find distance from $d=(1/2)at^2$, and a=Force / mass.
But need to know the mass.

Question: Power

An electrical plant produces power from falling bowling balls.
The balls weigh 100 N each,
fall a distance of 100 m,
and 10 balls fall each second.
How much power does the plant produce?

A. 100 kW
B. 10 kW
C. 1 kW

Potential energy converted to kinetic. Kinetic energy converted to electrical power.

Pot. E = mgh = (100 N) × (100 m)=10,000 J

10,000 J × 10 ball/sec = 100,000 J/s = 100,000 W