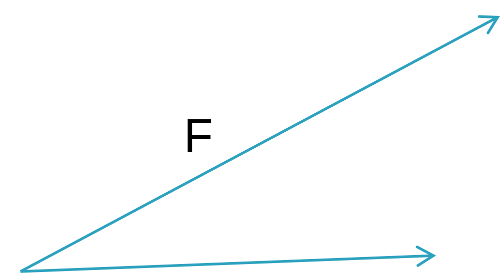
J is for Work

- When there is an angle between F and x

$$W = (F\cos\theta)\,\Delta x$$



- SI Unit

$$1 \text{ Joule (J)} = 1 \text{ N m} = 1 \text{ kg m}^2/\text{s}^2$$

Calorie

- 1 calorie = 4.186 J
- 1 Calorie = 1000 calorie

Kinetic Energy

- What's kinetic energy of a bullet?
- Mass = 50 g
- Velocity = 400 m/s

- $KE = \frac{1}{2} mv^2$

- SI Unit: $1J = 1 \text{ kg } m^2/s^2$

Energy in food

- Does a bag of snack contains more or less energy?

Work–Energy Theorem

- The net work done on an object is equal to the change in the object's kinetic energy.

$$W_{net} = \frac{1}{2} mv^2 - \frac{1}{2} mv_0^2$$

Friction does dissipative work

- When a car brakes, where did the kinetic energy go?

$$-f \, \Delta x = EK_f - EK_i$$

Road Accident Reconstruction

Plainsboro Police Sargent John Brensnon

Braking

- A 1000 kg car is moving at 11.17m/s. What is it's kinetic energy?

- If the car is brought to a full stop through friction. How much work is done by friction?

Gravitational Potential Energy

- Object near earth surface
- Mass: m
- Height: y

$$PE = mgy$$

- SI Units

$$1 \text{ Joule (J)} = 1 \text{ kg m}^2/\text{s}^2$$

Conservation of Mechanical Energy

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$\tfrac{1}{2} m v_1^2 + m g y_1$$

$$=$$

$$\tfrac{1}{2} m v_2^2 + m g y_2$$

What's wrong here?

- An object's kinetic energy is always conserved.

$$\frac{1}{2} mv_1 + mgy_1$$

$$=$$

$$\frac{1}{2} mv_2 + mgy_2$$

What's wrong here?

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$mv_1^2 + mgy_1$$

$$=$$

$$mv_2^2 + mgy_2$$

What is wrong here?

- (Condition) If an object has only gravitational force doing work, (Law) its mechanical energy is conserved.

$$\tfrac{1}{2} m v_1{}^2 + m g y_1{}^2$$

$$=$$

$$\tfrac{1}{2} m v_2{}^2 + m g y_2{}^2$$

Slide

Motion Studied

MOTION	MATH DESCRIPTION	
1-D Motion w CONSTANT velocity	v = const $\Delta x = vt$	
1-D Motion w. CONSTANT acceleration (Free Fall)	a = const $v = v_0 + at$; $\Delta x = v_0 t + ½ at^2$ $a = g$ =9.8 m/s^2 pointing down	
2-D motion	x	Y
Newton's Laws	Fnet = 0 Fnet= ma $F_{12} = -F_{21}$	
Conservation of Energy (ONLY gravity does work)	$KE_1 + mgy_1 = KE_2 + mgy_2$	

Two Objects

- Newton's Law applies to the center of mass

Collisions

1. Contact of two objects – m_1, m_2

2. during small time period – t

3. With large Force – F

Momentum and Impulse

- The Linear Momentum and Impulse

$$P = mv$$

$$I = F\,\Delta t$$

- SI Units

$$1\,\text{kg m/s} = 1\text{ N s}$$

Impulse Momentum Theorem

(Condition) for a collision process

$$I = P_f - P_i$$

$$F\,\Delta t = m\,(v_f - v_i)$$

Dynamics – how force change motion

Impulse – Momentum Theorem (short Δt)

$$F_{ave}\,\Delta t = P_f - P_i$$

Work – Energy Theorem (sizable time period)

$$F_{net}\,\Delta x = KE_f - KE_i$$

Newton's Second Law (instantaneous moment)

$$F = ma$$

Conservation of Momentum

- When no net external force acts on a system, the total momentum of the system remains constant in time.

    - $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

Analyze Collision Problems

- (Draw a diagram)
- m_1 m_2 (kg)
- v_{1i} v_{2i} (+/–; 0 implied)
- v_{1f} v_{2f} ($v_{1f} = v_{2f}$)

Collisions

- Elastic

  Both momentum and kinetic energy are conserved.

- Inelastic

  Perfectly inelastic

  Momentum is conserved, but kinetic energy is not.

Rocket Propulsion

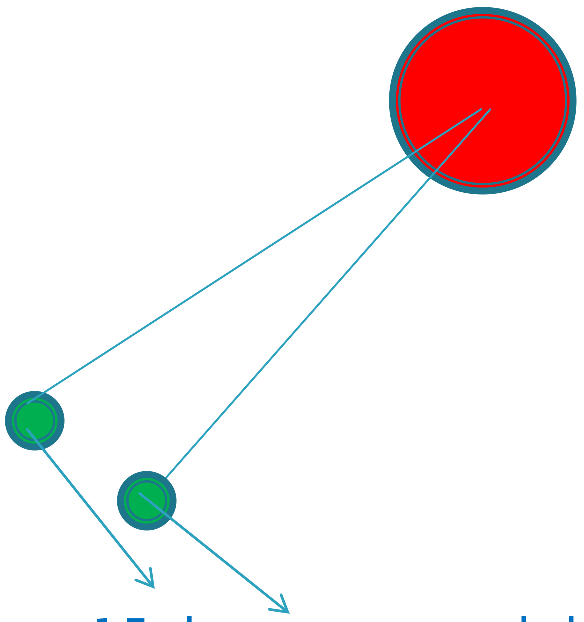
- What's being a rocket scientist is about?

- Newton's 3rd Law
- Conservation of Momentum
- Simplest Case:

  rocket (M) with one fuel pocket(Δm) with exhaust velocity of v_e.

Angular Motion

- Sun and earth



$\Delta\theta = +15$ degrees

How long does it take the earth to rotate 15 degrees around the sun?

How fast does the earth rotate around the sun?

Angular Motion

- Compare with Linear Motion

	Linear Motion	Angular Motion
displacement	Δx meters (m)	$\Delta\theta$ radian
velocity	$v = \Delta x/\Delta t$ m/s	$\omega = \Delta\theta/\Delta t$ $\omega = d\theta/dt$ rad/s
acceleration	$a = \Delta v/\Delta t$ m/s^2	$\alpha = \Delta\omega/\Delta t$ $\alpha = d\omega/dt$ rad/s^2

Relations between angular and linear quantities

- Linear distance

$$s = r\,\theta$$

- Linear velocity

$$v = r\omega$$

- Linear acceleration

$$a = r\,\alpha$$

Equations of Motion

Linear Motion	Angular Motion
Motion with const. velocity $\Delta x = vt$	Motion with const. angular velocity $\Delta\theta = \omega t$
Motion with const. acceleration $v = v_0 + at$ $\Delta x = v_0 t + 1/2 a t^2$ $v^2 = v_0^2 + 2a\Delta x$	Motion with const. acceleration $\omega = \omega_0 + at$ $\Delta\theta = \omega_0 t + 1/2 \alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$
Free Fall $a = g = 9.8\ m/s^2$	___________________________________

Rotational Motion

- Particles
  - moving in 3-D space

- Sizable objects
  - moving in 3-D space
  - rotation

Kinetic Energy

Motion	Energy
Translation	$KE = \frac{1}{2} mv^2$
Rotation	$KE = \frac{1}{2} I\omega^2$
Vibration	

Equilibrium

image source: shutter stock

Torque

- Is the door knob always at the far end from the hinge?

- Torque

$$\tau = rF\sin\theta$$

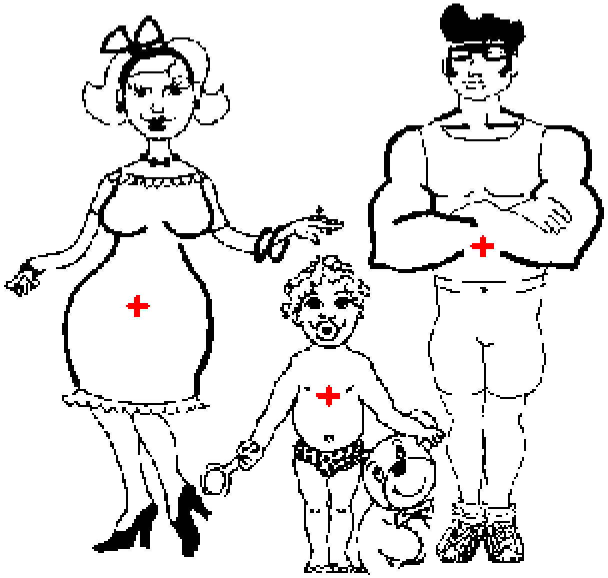
- SI Units:

Newton meter (N m)

Is this crib safe?

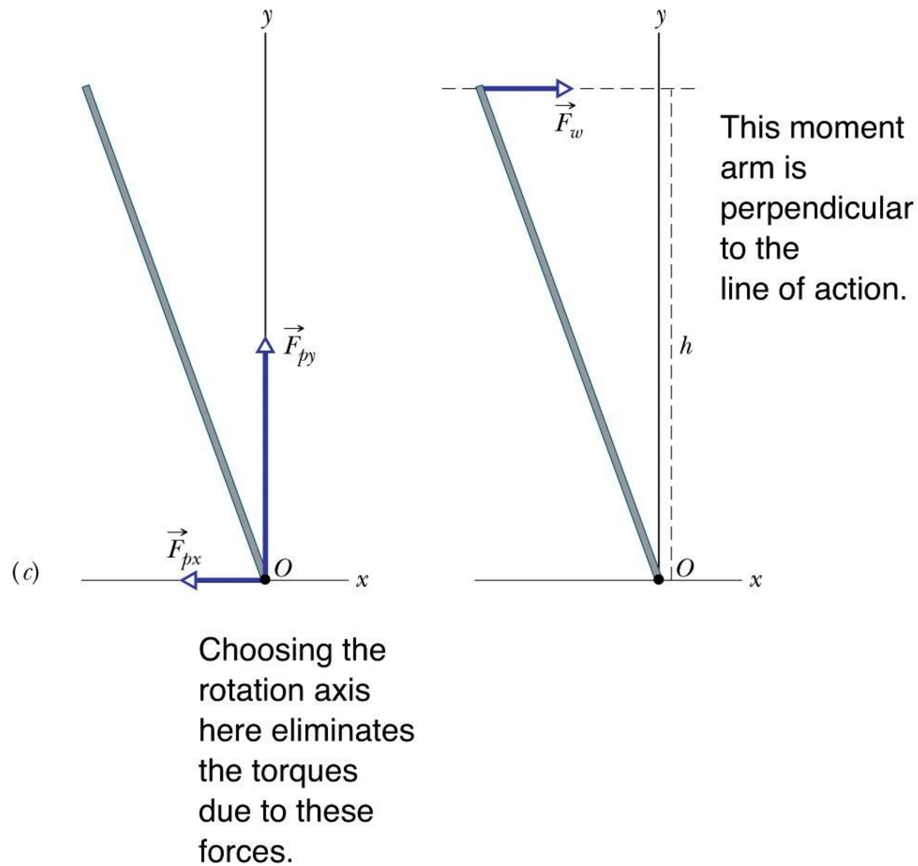
Center of Gravity

- The gravitational force on a body effectively act on a single point.



http://spot.pcc.edu/

O is for rotational axis



 halliday_9e_fig_12_05c

I is for Moment of Inertia

$$I = \sum mr^2$$

$$\tau = I\alpha$$

$$KE_r = \frac{1}{2} I\omega^2$$

$$L = I\omega$$

Dynamics

Translation	Rotation
$F = ma$	$\tau = I \alpha$