Announcements   March 16, 2010 Tues (16th)

- Midterm grades are posted : they're more of a guide … you can do better (or worse…)
- HW #7 is due Wed. night.
- HW #8 WebAssign AND Supplemental has been posted (due on Monday) : NOTE - START NOW
- *There will be a quiz over Supplemental #7 on Thurs… Any questions??*
- *Remember that TEST #3 will be next Wed. covering primarily Chapt. 10 - 13.4*

Physics gone awry ??

Example of:

1) *Equilibrium*
2) *Impulse/Collision*
3) *Conservation of angular momentum*
4) *Impulse/Collision*

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Class material

- *Today: FINISH Chapt. 12 … Start Chapt. 13*
- *Thurs: Finish Chapt. 13 (Gravitation) ….. Oh an quiz, too…. !!*

Chapt 12:
Equilibrium (and Elasticity*)

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

** will not cover*

Again: Requirement of Equilibrium

$$\vec{F}_{net} = \frac{d\vec{P}}{dt} = 0$$

$$\vec{\tau}_{net} = \frac{d\vec{L}}{dt} = 0$$

1) *Vector sum of all external forces that act on the body must be zero*
2) *Vector sum of all external torques that act on the body, measured about **any** possible point, must also be zero.*

For motion only in x-y plane

Balance of forces	Balance of torques
$F_{net,x} = 0$	$\tau_{net,x} = 0$
$F_{net,y} = 0$	$\tau_{net,y} = 0$
$F_{net,z} = 0$	$\tau_{net,z} = 0$

Not rotating - Stable for 200+ yrs

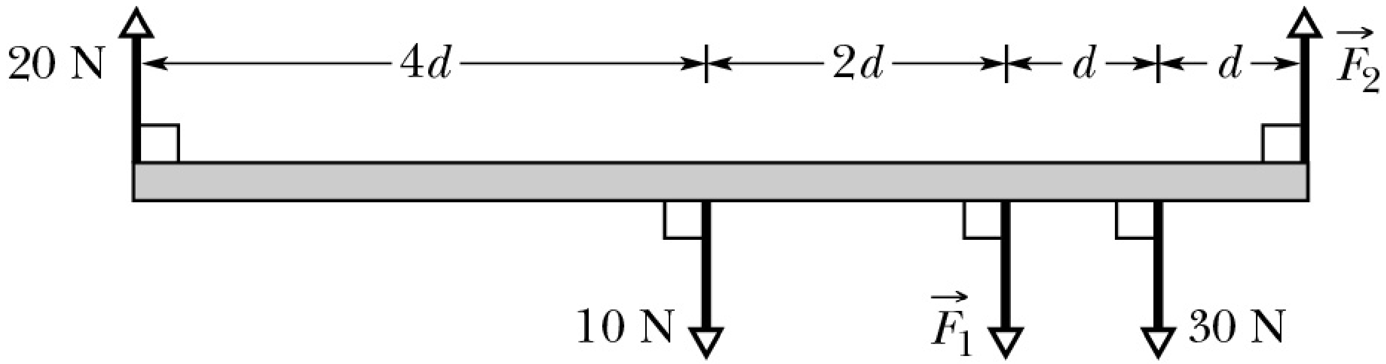
4□ : 3m /56m

Checkpoint 12-1

The figure gives an <u>overhead</u> view of a uniform rod in static equilibrium.

a) *Can you find the magnitudes of F_1 and F_2 by balancing the forces?*

b) *If you wish to find the magnitude of F_2 by using a single equation, where should you place a rotational axis?*



1) Draw a free-body diagram showing all forces acting on body and the points at which these forces act.

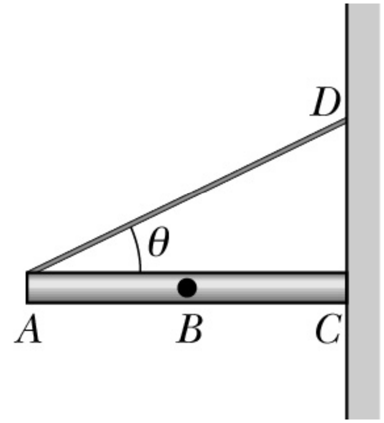
2) Draw a convenient coordinate system and resolve forces into components.

3) Using letters to represent unknowns, write down equations for:
$\sum F_x=0$, $\sum F_y=0$, *and* $\sum F_z=0$

4) For $\sum \tau = 0$ *equation, choose any axis perpendicular to the xy plane. But choose judiciously! Pay careful attention to determining lever arm and sign! [for xy-plane, ccw is positive & cw is negative]*

5) Solve equations for unknowns.

Checkpoint 1+2-4 *A stationary 5 kg rod AC is held against a wall by a rope and friction between the rod and the wall. The uniform rod is 1 m long and $\theta = 30°$.*



(a) *If you are to find the magnitude of the force T on the rod from the rope with a single equation, at what labeled point should a rotational axis be placed?*

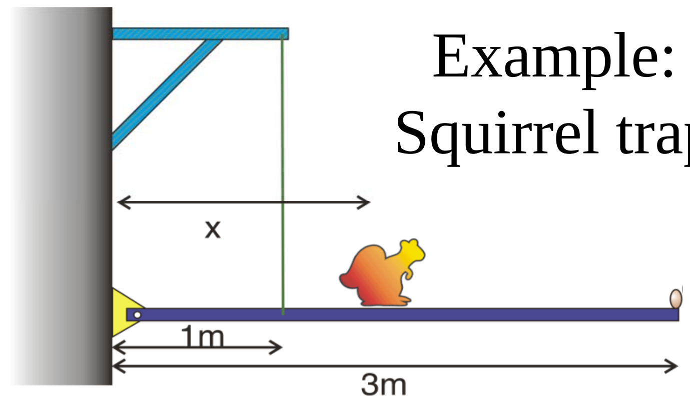
(b) *About this axis, what is the sign of the torque due to the rod's weight and the tension?*

[redacted]

A small aluminum bar is attached to the side of a building with a hinge. The bar is held in the horizontal via a fish line with 14 lb test. The bar has a mass of 3.2 kg.

a) Will the 14 lb (62.4 N) hold the bar?

b) A nut is placed on the end and a squirrel of mass 0.6 kg is tries to climb out and get the nut. Does the squirrel get to the nut before the string breaks? If not, how far does he get?



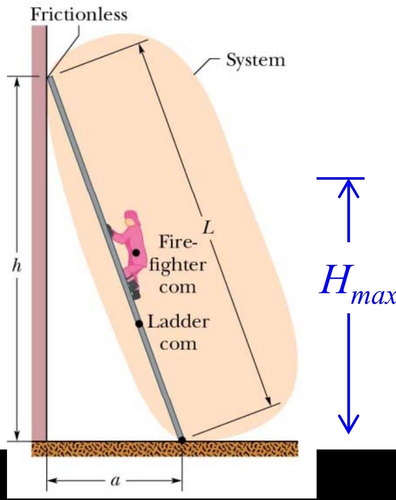
Example:
Squirrel trap

WHAT HAPPENS AFTER STRING BREAKS?

Sample Problem *A ladder of length* ***L*** *and mass* ***m*** *leans against a slick (frictionless) wall. Its upper end is at a height* ***h*** *above the payment on which the lower end rests (the payment is not fricionless). The ladder's center of mass is* ***L/3*** *from the lower end. A firefighter of mass* ***M*** *climbs the ladder until her center of mass is* ***L/2*** *from the lower end.*

a) What are the magnitudes of the forces exerted on the ladder?

b) Now assume that the wall is again frictionless and the pavement has a coefficient of friction μ_s *. What is the maximum height the firefighter climbs (*H_{max}*)*



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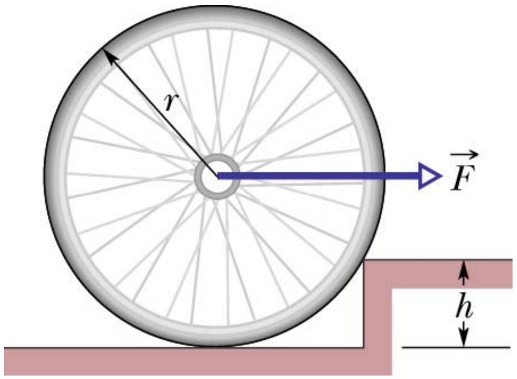
Problem 12-37

What magnitude of force **F** *applied horizontally at the axle of the wheel is necessary to raise the wheel over an obstacle of height* **h**? *The wheel's radius is* **r** *and its mass is* **m**.



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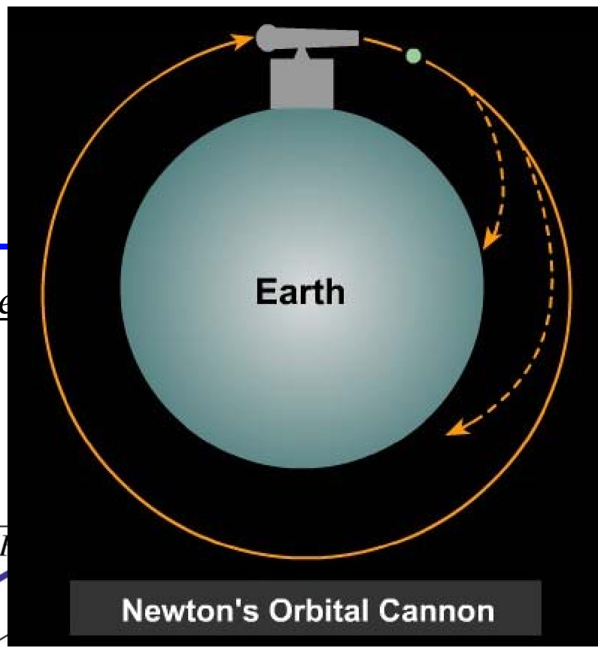
Chapt. 13: Gravitation

Isaac Newton (1687) : What keeps the moon in a nearly circular orbit about the earth?

If falling objects accelerate, they must experience a force.

Force = Gravity

No contact !

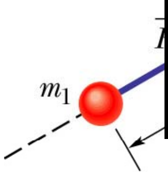


...cts every other body

Example... *...f the attractive force between them is*

$$...m_1 m_2 / r^2$$

...are masses and r is distance between them and...

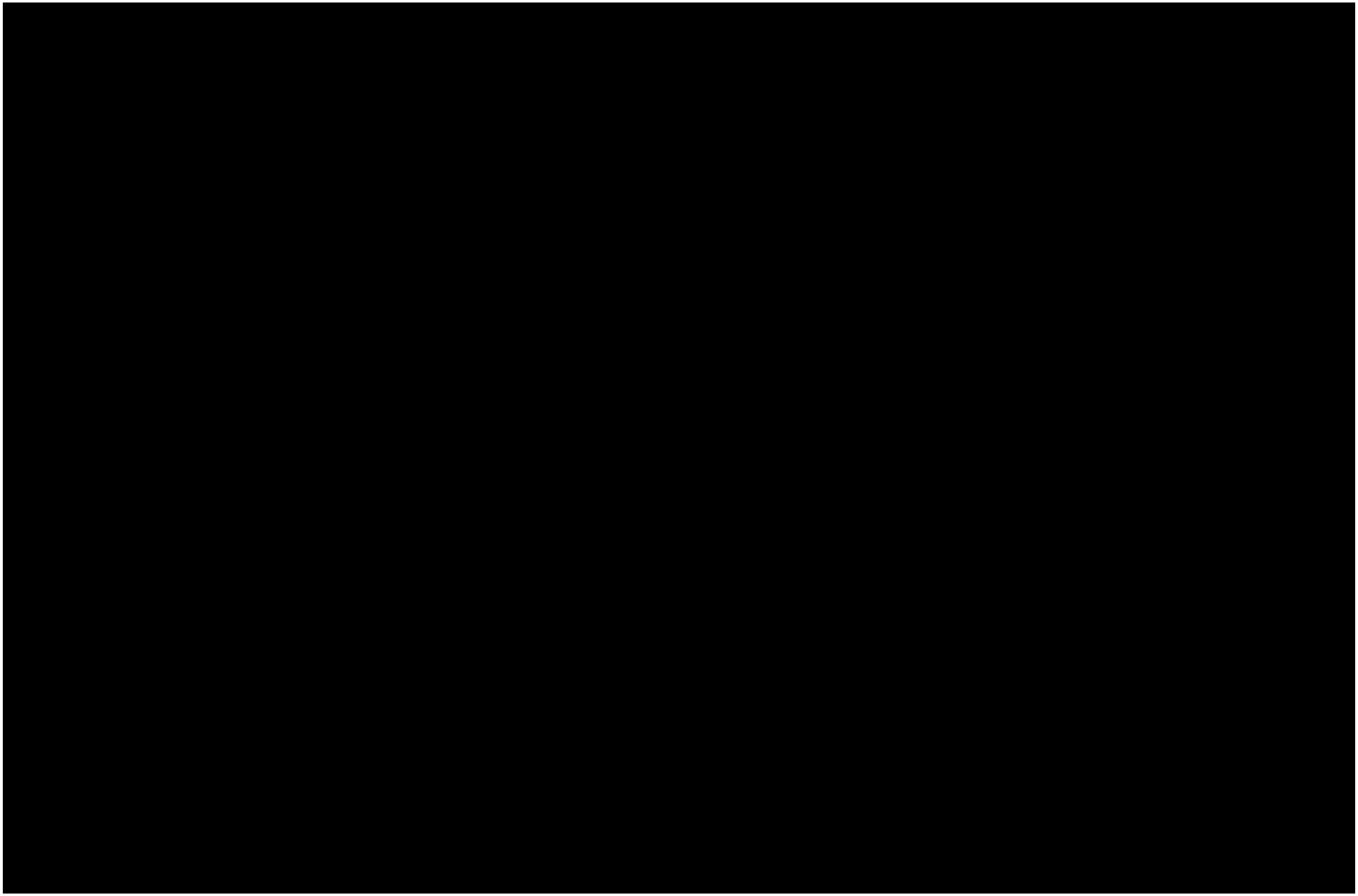


$$G = 6.67 \times 10^{-11}\, N \cdot m^2 / kg^2$$
$$= 6.67 \times 10^{-11}\, m^3 / kg \cdot s^2$$

$\vec{F}_{12} = -\vec{F}_{21}$ *Newton's third law*

Gravitational Constant *($\neq$ g, $\neq$ 9.8 m/s^2)*

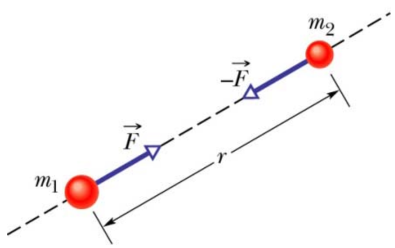
Gravitation: Notes



Gravitation: Notes

1) *Three objects -- independent of each other*
Newton's 3rd Law

2) *Gravitational Force is a VECTOR - unit vector notation*



$$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$ *Force on m_1 due to m_2* $$\hat{r}_{12} = \frac{\vec{r}_{12}}{|r_{12}|}$$

$$\vec{F}_{21} = G\frac{m_1 m_2}{r_{21}^2}\hat{r}_{21}$$ *Force on m_2 due to m_1* $$\hat{r}_{21} = \frac{\vec{r}_{21}}{|r_{21}|} = -\hat{r}_{12}$$

$\longrightarrow$ $$\left|\vec{F}_{21}\right| = \left|\vec{F}_{12}\right| \qquad \vec{F}_{21} = -\vec{F}_{12}$$

3) *Principle of* *<u>superposition</u>*

$$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots + \vec{F}_{1n} = \sum_{i=1}^{n}\vec{F}_{1i}$$ *VECTOR ADDITION!!*

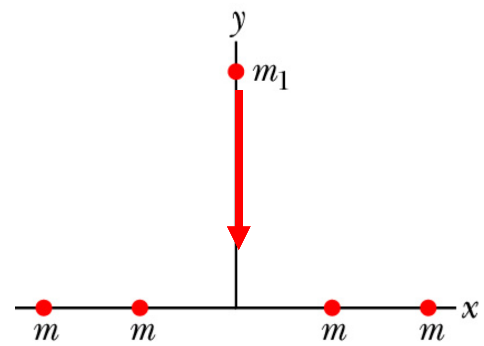
4) *A uniform spherical shell of matter attracts an object on the outside as if all the shell's mass were concentrated at its center (note: this defines the position)*

height = $R_E + h$

Checkpoint

What are the gravitational forces on the particle of mass m_1 due to the other particles of mass m.

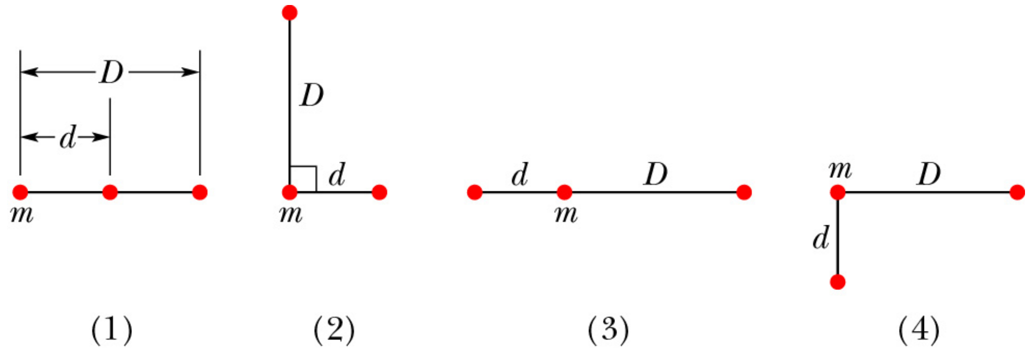
What is the direction of the **net** *gravitational force on the particle of mass m_1 due to the other particles.*



The figure shows four arrangements of three particles of equal mass.

Checkpoint

Rank the arrangements according to the magnitude of the net gravitational force on the particle labeled m, greatest first.



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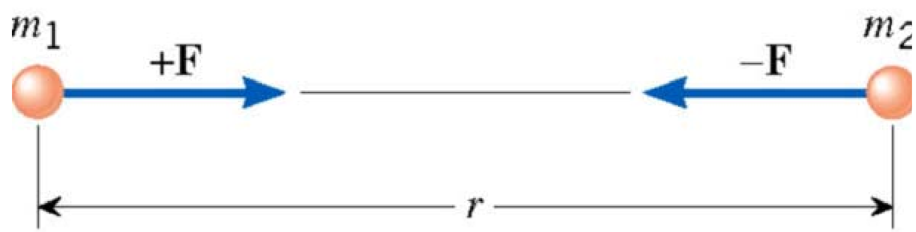
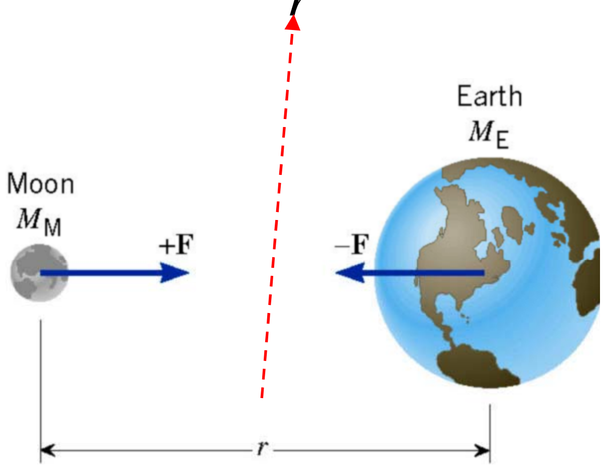
Newton's Law of Gravitation

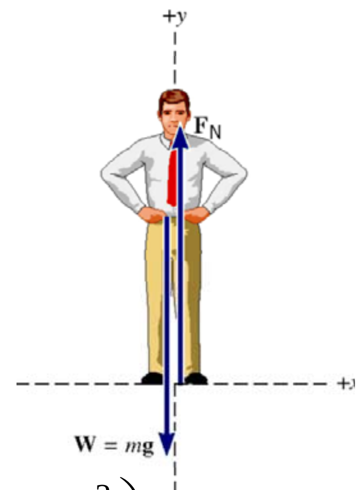


$$F = G\frac{m_1 m_2}{r^2}$$ This is always attractive. $$G = 6.67\times10^{-11}\,\frac{N\cdot m^2}{kg^2}$$



$$F = m_1 g = G\frac{m_1 m_2}{r^2}$$

$$= m_1\left(G\frac{m_{EARTH}}{r_{EARTH}^2}\right)$$



$$= m_1\left(6.67\times10^{-11}\,\frac{N\cdot m^2}{kg^2}\right)\frac{5.98\times10^{24}\,kg}{\left(6.38\times10^{6}\,m\right)^2}$$

Where does "g" come from?

What is force of gravity at surface of earth?

$$= m_1\left(9.8\,\frac{m}{s^2}\right) = m_1 g$$

Acceleration of Gravity at Hubble

What is the acceleration due to gravity at the Hubble Space Telescope? It orbits at an altitude of 600 km.

$$g_{HST} = G\frac{m_E}{r^2}$$

$$= \left(6.67\times10^{-11}\frac{N\cdot m^2}{kg^2}\right)\frac{5.98\times10^{24}\,kg}{\left(6.38\times10^6\,m + 6\times10^5\,m\right)^2}$$

$$= 8.19\frac{m}{s^2}$$

Why do astronauts float? => *they are in* ***free-fall*** *How fast are they going ?*

We know from before that $\frac{v^2}{r} = g_{HST}$

so

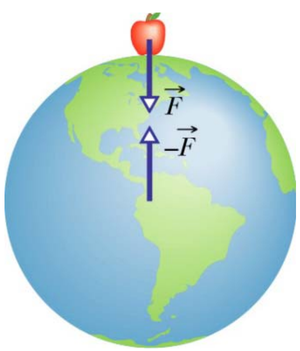
$$v = \sqrt{g_{HST}r} = 7550\frac{m}{s}\left(\frac{1mph}{0.447m/s}\right) = 17{,}000mph$$

What is the time for one orbit? $T = \frac{2\pi r_{ORBIT}}{v} = \left(\frac{2\pi\left(6.98\times10^6\,m\right)}{7550m/s}\right) = 5800s = 1.6hours$

Gravitational Force

Force on 1 due to 2: $\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$ $G = 6.67\times10^{-11}\,N\cdot m^2/kg^2$

Force on 1 due to many: $\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots + \vec{F}_{1n} = \sum_{i=1}^{n}\vec{F}_{1i}$ *VECTOR ADDITION!!*



On Earth

$$\left|F_g\right| = \left(G\frac{M_E}{R_E^2}\right)m_{apple} = m_{apple}\,g$$

Net force points towards center of earth

Check

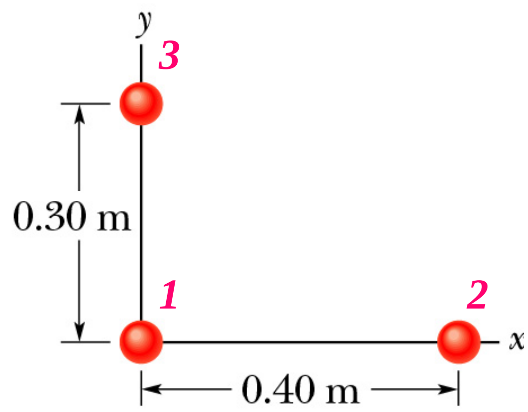
$GM_E \cong 4\times10^{14}\cdot m^3/s^2$

$R_E = 6{,}380\cdot km$

$\Rightarrow \frac{GM_E}{R_E^2} \cong 9.8\cdot m/s^2 = g$

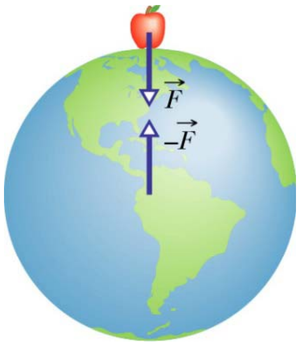
Problem 12-6

Three 5 kg spheres are located in the xy-plane. What is the magnitude and direction of the net gravitational force on the sphere at the origin due to the other two spheres?



Symmetry?

Gravitation and the earth



$$\left|F_g\right| = \left(G\frac{M_E}{R_E^2}\right)m_{apple} = m_{apple}g$$

Net force points towards center of earth

<u>*g differs around the earth*</u> *(equator-9.780 & north pole-9.832 m/s^2)*

1) <u>*Earth is not a perfect sphere - height*</u> *(R_E is not constant):*
   - *On Mount Everest (8.8 km) g=9.77 m/s^2 (0.2% smaller)*
   - *At Equator earth bulges by 21 km*

2) <u>*Earth is not uniform density*</u>*: "gravity irregularities" (10^{-6}-10^{-7})g*
   gravimeters can measure down to 10^{-9}g

2) <u>*Earth is rotating*</u>*: centripetal force makes apparent weight change*

At poles:

$$W - mg = 0$$
$$W = mg$$

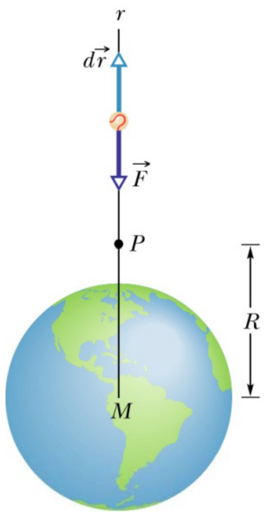
At equator:

$$W - mg = -m\left(\frac{v^2}{R_E}\right)$$
$$W = m\left(g - \frac{v^2}{R_E}\right)$$

Weight is less (0.3%)

Gravitational potential energy

From Section 8.3 $\Rightarrow$ $-\Delta U = W_{\text{done by force}}$ $\Rightarrow$ *Conservative force-path independent*



$$\Delta U_g = -W_{\text{done}} = -\int_{x_i}^{x_f} \vec{F}_g \bullet d\vec{x}$$

At Earth's surface, F_g~const.

$$\Delta U_g = -W_{\text{done}} = -m(-g)\int_{y_i}^{y_f} dy = mg\Delta y$$

$$W = \int_{r_i}^{r_f} \left(-G\frac{mM}{r^2}\right)dr = -GmM\int_{r_i}^{r_f}\left(\frac{1}{r^2}\right)dr$$

If we define U = 0 at ∞, then the work done by taking mass m from R to ∞

$$U_\infty - U(r) = -W = -GmM\left[0 - \left(-\frac{1}{R}\right)\right]$$

$$U(r) = -\frac{GmM}{r}$$

$$F(r) = -\frac{dU(r)}{dr}$$

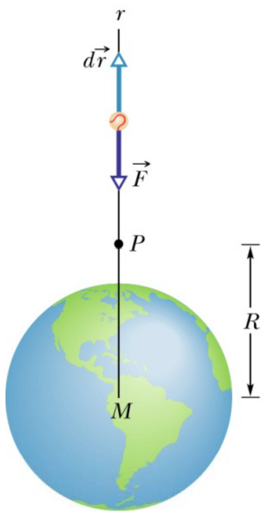
$$-\frac{d}{dr}\left(-\frac{GmM}{r}\right) = -\frac{GmM}{r^2}$$

Note:

1) *As before, Grav. Pot. Energy decreases as separation decreases (more negative)*
2) *Path independent*
3) *MUST HAVE AT LEAST TWO PARTICLES TO POTENTIAL ENERGY (& force)*
4) *Knowing potential, you can get force….*

Gravitational potential energy

$$\Delta U_g = -W_{\text{done}} = -\int_{x_i}^{x_f} \vec{F}_g \bullet d\vec{x}$$ $\Rightarrow$ *Conservative force-path independent*



If we define U = 0 at ∞, then the work done by taking mass m from R to ∞

$$U(r) = -G\frac{m_1 m_2}{|r_{12}|}$$

$$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$

Note: Potential energy increases as you the separation gets larger:

If $r\uparrow$ then $\left(\frac{GmM}{r}\right)\downarrow$ and U gets less negative (larger)

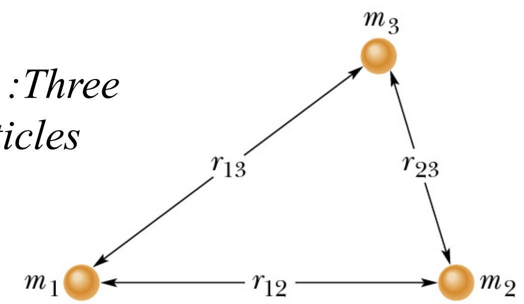
Gravitational Potential Energy of SYSTEM

Scalar - just add up total potential energy
(BE CAREFUL: don't double count)

Work?

$$U_{tot} = -G\left(\frac{m_1 m_2}{r_{12}} + \frac{m_1 m_3}{r_{13}} + \frac{m_2 m_3}{r_{23}}\right)$$

System :Three particles



Note: don't need direction, just distance

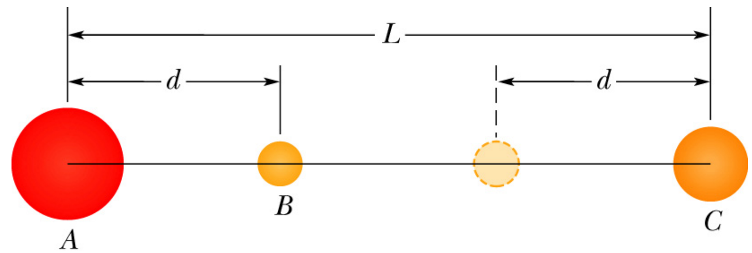
Gravitational Potential Energy

Problem 12-35

Three spheres with mass m_A, m_B, and m_C. You move sphere B from left to right.

How much work do you do on sphere B ?

How much work is done by the gravitational force?



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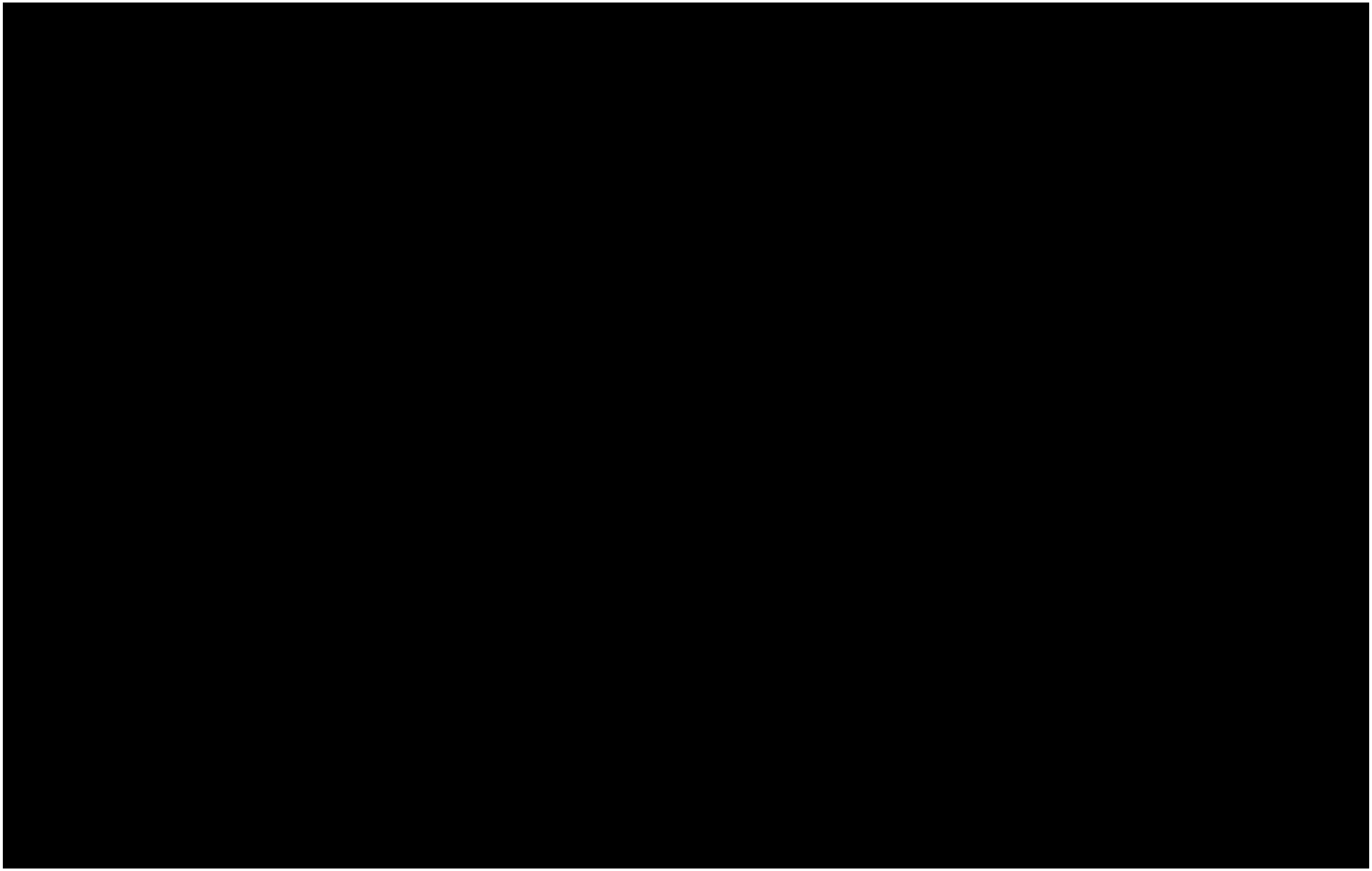
Escape speed: *Conservation of Mechanical Energy*



Escape speed: *Conservation of Mechanical Energy*

Escape speed: *minimum speed (v_{escape}) required to send a mass m, from mass M and position R, to infinity, while coming to rest at infinity.*

At infinity: E_{mech}=0 because U=0 and KE = 0
Thus any other place we have:

$$E_{mech} = (KE + U_g) = 0 \quad \Rightarrow \quad E_{mech} = \left(\frac{1}{2}mv^2 - \frac{GmM}{R}\right) = 0 \quad \Rightarrow \quad v_{escape} = \sqrt{\frac{2GM}{R}}$$

<u>*Escape speed:*</u>

Earth = 11.2 km/s (25,000 mi/hr)
Moon = 2.38 km/s
Sun = 618 km/s

Problem 10-39

A projectile is fired vertically from the Earth's surface with an initial speed of 10 km/s (22,500 mi/hr)

Neglecting air drag, how far above the surface of Earth will it go?

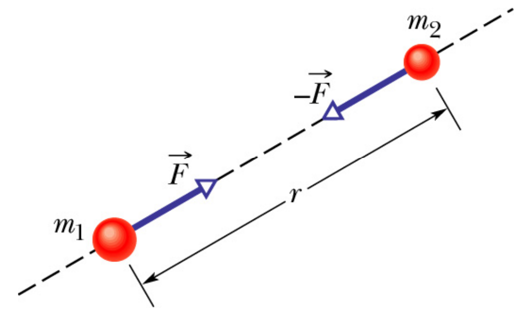
$$(KE_i + U_i) = (KE_f + U_f)$$

$$\left(\frac{1}{2}mv_i^2 - G\frac{mM_E}{r_i}\right) = \left(0 - G\frac{mM_E}{r_f}\right)$$

$$R_E = 6380 \cdot km$$

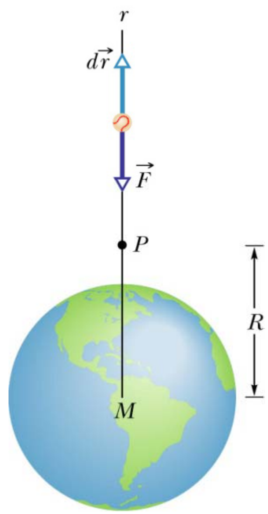
$$GM_E = 4 \times 10^{14} \cdot m^3/s^2$$

Chapt. 13: review



Force on 1 due to 2: $$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$ $$G = 6.67\times10^{-11}\, N\cdot m^2/kg^2$$

Force on 1 due to many: $$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots + \vec{F}_{1n} = \sum_{i=1}^{n}\vec{F}_{1i}$$ *VECTOR ADDITION!!*



Gravitational potential energy

If we define U = 0 at ∞, then the work done by taking mass m from R to ∞

$$U(r) = -G\frac{m_1 m_2}{|r_{12}|}$$ $$\vec{F}_{12} = G\frac{m_1 m_2}{r_{12}^2}\hat{r}_{12}$$