Straight Up Physics V5

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Circular Motion and Universal Gravitation

[Flipping Physics- Circular Motion/Rotational Kinematics]

[Flipping Physics- Universal Gravitation]

https://tinyurl.com/straightupguidescircles

Circular Motion/Rotational Kinematics

Formulæ

Angular Velocity- $\omega = \frac{V}{r} = \frac{\Delta\theta}{\Delta t}$ (radians/sec OR rev/min)

1 rev = 360° = 2π radians

Angular Acceleration- $\alpha = \frac{a}{r} = \frac{\Delta\omega}{\Delta t}$ (radians per second squared)

Centripetal Acceleration- $a_c = \frac{v^2}{r}$

Centripetal Force- $F_c = ma_c = m\frac{v^2}{r}$

Period (T)- $\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi\mathrm{rad}}{\mathrm{T}} \Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi \mathrm{r}}{\mathrm{v}}$ the time for one cycle(sec OR sec per cycle)

Frequency- $f = \frac{1}{T}$ is the cycles completed every second (cycle per second OR Hertz-Hz)

Concepts:

Centripetal Acceleration - "center seeking"

- **NOT A DISTINCT FORCE**
- A force (normal, friction, tension) that **causes** circular motion
- Never in FBD
- Convention: "in" is positive

"Centrifugal" - apparent force

- Essentially inertia

- As the object moves in a circle, it wants to keep going straight (tangent). The constant change in velocity feels as if you are being pushed away, when in fact you are being pulled towards

Uniform Circular Motion

- **Velocity** is always changing because direction always changes
- **Speed** is constant
- Tangential velocity is linear velocity, changes as r increases/decreases

Rotational Kinematics

- Replace linear variables with angular variables (x to θ)
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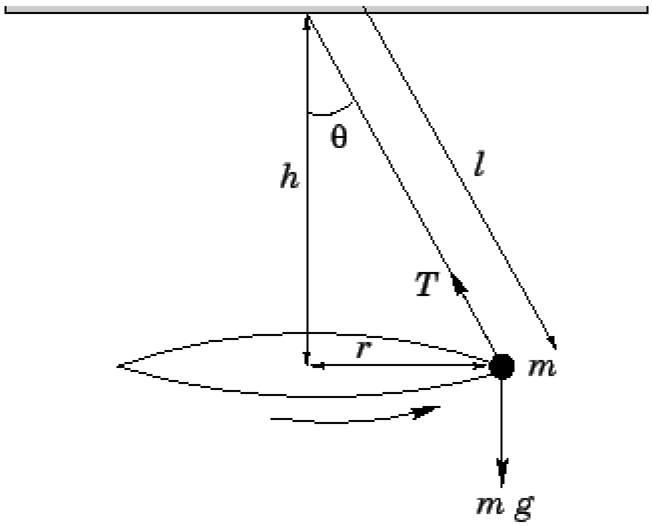
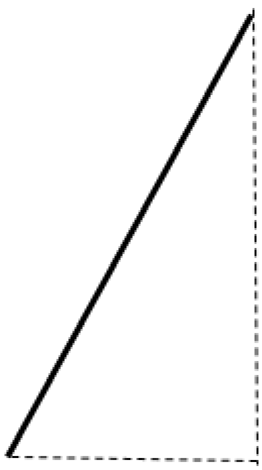
Uniformly Accelerated Motion, UAM	Uniformly Angularly Accelerated Motion, UαM
$v_x = v_{x0} + a_x t$	$\omega = \omega_0 + \alpha t$
$x = x_0 + v_{xo} t + \frac{1}{2} a_x t^2$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$
$v_x^2 = v_{x0}^2 + 2a_x \left(x - x_0\right)$	$\omega_f^2 = \omega_i^2 + 2\alpha \Delta\theta$
$\Delta x = \frac{1}{2}\left(v_f + v_i\right)\Delta t$	$\Delta\theta = \frac{1}{2}\left(\omega_f + \omega_i\right)\Delta t$

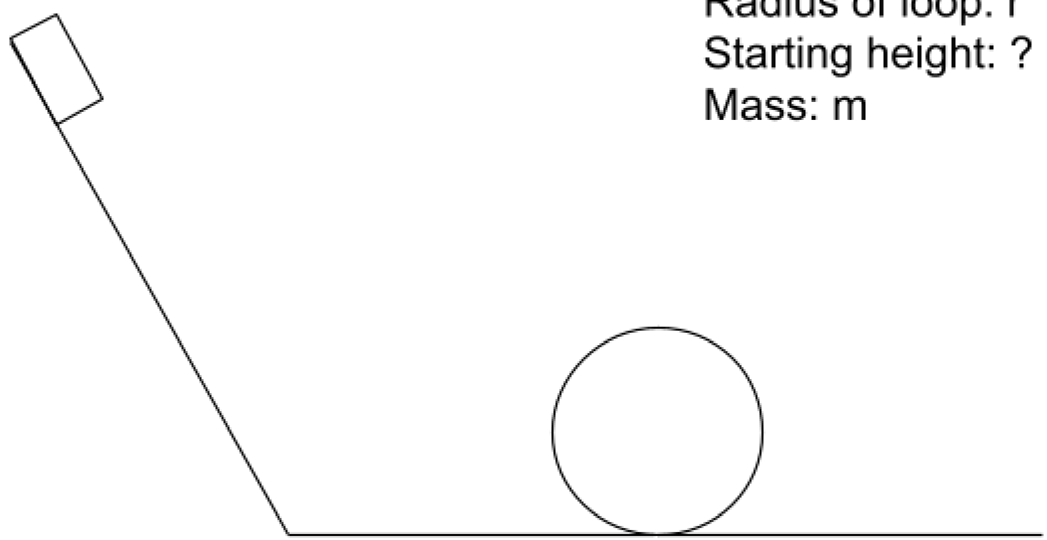
Problems

Conical Pendulum-solve for Tension, then velocity





Roller Coaster-find the minimum height at which the roller coaster can go around the loop



Radius of loop: r
Starting height: ?
Mass: m

Universal Gravitation

Formulæ

Gravitational Force- $F_g = G\frac{m_1 m_2}{r^2}$

Gravitational Potential Energy- $U_g = -G\frac{m_1 m_2}{r}$

Concepts

Non uniform fields

- Fields are properties of objects that affect other objects and permeate through space
- Gravitational fields cause objects to be attracted by the host
  - Grav fields lessen in magnitude the farther away the part of the field is
  - Close to the field, we can assume that the magnitude of the field is constant despite any height differences
  - Farther away, we must take into account the change in the magnitude of a field
- If you look carefully, the 'g' we use for uniform fields is nothing but $(Gm_{earth})/r$
  - This 'g' represents the strength of the gravitational field

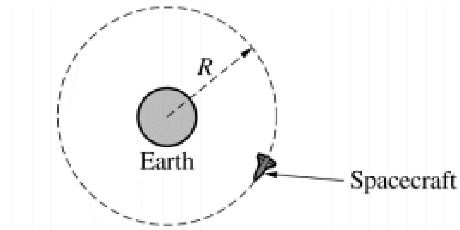
Gravitational Potential Energy

- Now when we talk about gravitational potential energy, we set the 'zero line' at infinitely far away from the object
  - This is why potential energy anywhere is negative

Problems

Speed of satellite in orbit

Escape velocity using energy (just enough to not be moving at the end)

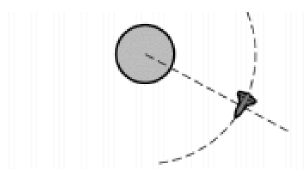


Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

   A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.

   (a) In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.

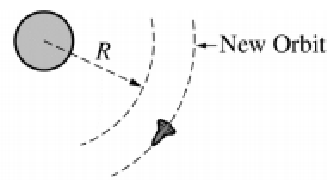


   ii. A second spacecraft of mass $2m$ is placed in a circular orbit with the same radius R. Is the orbital period of the second spacecraft greater than, less than, or equal to the orbital period of the first spacecraft?

   ____ Greater than ____ Less than ____ Equal to

   Briefly explain your reasoning.

   (c) The first spacecraft is moved into a new circular orbit that has a radius greater than R, as shown in the figure below.



Note: Figure not drawn to scale.

   Is the speed of the spacecraft in the new orbit greater than, less than, or equal to the original speed?

   ____ Greater than ____ Less than ____ Equal to