Uniform Circular Motion
- An object moves at uniform speed in a circle of constant radius.

Acceleration in Uniform Circular Motion
- Turns object, but does not speed it up or slow it down.
- The acceleration points toward the center of the circle.
- The acceleration responsible for uniform circular motion is referred to as ***centripetal acceleration***.

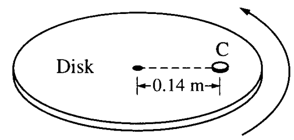
Centripetal Acceleration
- $a_c = v^2/r$

  a_c: centripetal acceleration in m/s^2
  v: tangential speed in m/s
  r: radius in meters

Force in Uniform Circular Motion
- When an object is moving in uniform circular motion we refer to the net force as a centripetal force.
- Centripetal force can arise from one force (IN), or from a combination of forces (IN-OUT).
- The centripetal force is not a type of force, just as the net force is not a type of force.
- You would never draw the centripetal force on a free body diagram, just as you would never draw the net force on a free body diagram.
- $F_c = ma_c$
- $F_c = m\,v^2/r$

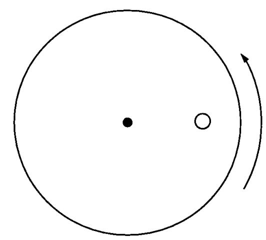
  Fc: centripetal force in N
  v: tangential speed in m/s
  r: radius in meters
- IN-OUT= $m\,v^2 / r$
- Since the centripetal forces always acts perpendicular to the velocity, the centripetal force does zero work.
- Therefore the KE and speed remains constant.

Problem: Centripetal Force (1999)



A coin C of mass 0.0050 kg is placed on a horizontal disk at a distance of 0.14 m from the center, as shown above. The disk rotates at a constant rate in a counterclockwise direction as seen from above. The coin does not slip, and the time it takes for the coin to make a complete revolution is 1.5 s.

a. The figure below shows the disk and coin as viewed from above. Draw and label vectors on the figure below to show the instantaneous acceleration and linear velocity vectors for the coin when it is at the position shown.



b. Determine the linear speed of the coin.

c. The rate of rotation of the disk is gradually increased. The coefficient of static friction between the coin and the disk is 0.50. Determine the linear speed of the coin when it just begins to slip.

Universal Law of Gravity

- $Fg = Gm_1m_2/r^2$
  - Fg: Force due to gravity (N)
  - G: Universal gravitational constant
  - 6.67 x 10-11N m^2/kg^2
  - m_1 and m_2: the two masses (kg)
  - r: the distance between the centers of the masses (m)
- Most orbit problems can be solved by setting the gravitational force equal to the centripetal force.
- $Gm_1m_2/r^2 = m_1v^2 / r$ (a good starting point for most problems!)
- Remember Newton's 3rd law!
- Weight is another word for force due to gravity. It is equal to mg, but also equal to the result calculated from the universal law of gravity.

Problem: Orbit (1998)

40. What is the kinetic energy of a satellite of mass m that orbits the Earth, of mass M, in a circular orbit of radius R ?

(A) Zero (B) $\frac{1}{2}\frac{GMm}{R}$ (C) $\frac{1}{4}\frac{GMm}{R}$

(D) $\frac{1}{2}\frac{GMm}{R^2}$ (E) $\frac{GMm}{R^2}$

Show your work:

Problem: Universal Law of Gravity and Weight (1998)

39. An object has a weight W when it is on the surface of a planet of radius R. What will be the gravitational force on the object after it has been moved to a distance of 4R from the center of the planet?

(A) $16W$
(B) $4W$
(C) W
(D) $\frac{1}{4}W$
(E) $\frac{1}{16}W$

Show your work:

Problem: Universal Law of Gravity and Acceleration due to Gravity (1993)

48. The planet Mars has mass 6.4 x 1023 kilograms and radius 3.4 x 106 meters. The acceleration of an object in free fall near the surface of Mars is most nearly

(A) zero (B) 1.0 m/s^2 (C) 1.9 m/s^2
(D) 3.7 m/s^2 (E) 9.8 m/s^2

Show your work:

Periodic Motion

- Repeats itself over a fixed and reproducible period of time.
- Mechanical devices that do this are known as oscillators.

Simple Harmonic Motion (SHM)

- Periodic motion which can be described by a sine or cosine function.
- Springs and pendulums are common examples of Simple Harmonic Oscillators (SHOs).
- All SHO's experience a "restoring force" that has the form: F = -kx (basic form of restoring force)
- Restoring force is greatest at maximum displacement and zero at equilibrium

Equilibrium

- The midpoint of the oscillation of a simple harmonic oscillator.
- Position of ***minimum potential energy and maximum kinetic energy***.

Amplitude (A)

- How far the oscillating mass is from equilibrium at its maximum displacement.
- Position of ***minimum kinetic and maximum potential energy***.

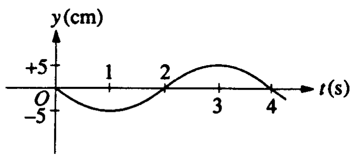
Period (T)

- The length of time it takes for one cycle of periodic motion to complete itself.

Frequency (f):

- Number of cycles per second
- Frequency is inversely related to period.
  - f = 1/T
- The units of frequency is the Herz (Hz) where 1 Hz = 1 s^{-1}.

Problem: Simple Harmonic Motion (1993)



43. A particle oscillates up and down in simple harmonic motion. Its height y as a function of time t is shown in the diagram above. At what time t does the particle achieve its maximum positive acceleration?
(A) 1s
(B) 2s
(C) 3s
(D) 4s
(E) None of the above, because the acceleration is constant

Explain your reasoning:

Period of a spring

- $T = 2\pi\sqrt{\frac{m}{k}}$

T: period (s)
m: mass (kg)
k: spring constant (N/m)

Period of a pendulum

$T = 2\pi\sqrt{\frac{l}{g}}$

T: period (s)
l: length of string (m)
g: gravitational acceleration (m/s2)

Problem: Period of Pendulum (1988)

8. The length of a simple pendulum with a period on Earth of one second is most nearly
(A) 0.12 m
(B) 0.25 m
(C) 0.50 m
(D) 1.0 m
(E) 10.0 m

Show your work:

Problem: Period of Spring and of Pendulum (1988)

44. An object swings on the end of a cord as a simple pendulum with period T. Another object oscillates up and down on the end of a vertical spring, also with period T. If the masses of both objects are doubled, what are the new values for the periods?

	Pendulum	Mass on Spring
(A)	$\frac{T}{\sqrt{2}}$	$\sqrt{2}T$
(B)	T	$\sqrt{2}T$
(C)	$\sqrt{2}T$	T
(D)	$\sqrt{2}T$	T
(E)	$\sqrt{2}T$	T$\sqrt{2}$

Explain your reasoning:

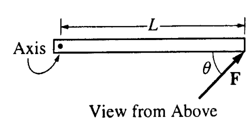
Torque

- Torque is a "twist" (whereas force is a push or pull).
- $\tau = Fr\sin\theta$

τ is torque (Nm)
F is force (N)
r is distance between point of rotation and point of application of force (m)
θ is angle between F and r (often 90 degrees)

- If θ is 90… $\tau = Fr$
- Torque Units: Nm (NOT a Joule)
- We typically identify a torque as clockwise (+) or counterclockwise (-).

Problem: Torque (1998)



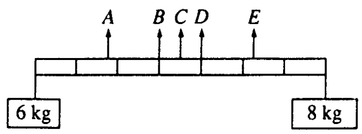
68. A rod on a horizontal tabletop is pivoted at one end and is free to rotate without friction about a vertical axis, as shown above. A force **F** is applied at the other end, at an angle θ to the rod. If **F** were to be applied perpendicular to the rod, at what distance from the axis should it be applied in order to produce the same torque?

(A $L\sin\theta$
(B) $L\cos\theta$
(C) L
(D) $L\tan\theta$
(E) $\sqrt{2}L$

Rotational Equilibrium

- If counterclockwise torques equal the clockwise torques, the system is balanced and no rotation occurs.
- $\tau_{cw} = \tau_{ccw}$

Problem: Rotational Equilibrium (1993)

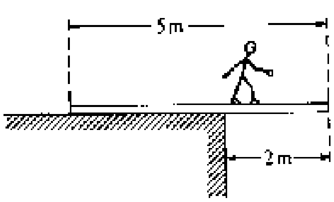


57. Two objects, of masses 6 and 8 kilograms, are hung from the ends of a stick that is 70 centimeters long and has marks every l0 centimeters, as shown above. If the mass of the stick is negligible, at which of the points indicated should a cord be attached if the stick is to remain horizontal when suspended from the cord?

(A) A (B) B (C) C (D) D (E) E

Show your work:

Problem: Rotational Equilibrium (1984)



13. A 5-meter uniform plank of mass 100 kilograms rests on the top of a building with 2 meters extended over the edge as shown above. How far can a 50-kilogram person venture past the edge of the building on the plank before the plank just begins to tip?

A) $\frac{1}{2}m$ B) 1 m

C) $\frac{2}{3}m$ D) 2 m

E) It is impossible to make the plank tip since the person would have to he more than 2 meters from the edge of the building.

Show your work: