

Newton's laws

- 2nd law and inertia
- 3rd law is condition-less, i.e. is always true

Free body diagram

- no contact, no force (if not gravity)!!!
- once you define the object of interest, find gravity and other contact force
- NO need to worry about other objects that are not touching your object of interest!!!
- if two or three separate objects exist, then need to consider free body diagram of each
- free body diagram of a compound object (e.g. two books pushed together) can be useful also
- no need to consider 3rd law forces between A,B if you are considering the f. b. diagram of C=A+B+...

Applying $F=ma$ to free body diagram

- In most cases, the RHS is known. Figure out forces from the knowledge of ma , not the other way around!! E.g. for an object at rest we know that the normal force = mg , because we see that the object is not moving (i.e. we are humans, not all-knowing God).

Normal force

- is NOT always equal to mg
- You should always deduce the normal force from acceleration (or lack thereof) and other forces!
- is NOT Newton's 3rd law pair with weight
- is always normal to the interface of the two objects
- always comes in pairs (if A is exerting normal force to B, then B does it to A also)
- Normal force of A to B, and that of B to A follow Newton's 3rd law
- Often if you are confused about the normal force, then you can imagine inserting a scale at the interface. The reading on the scale, whose mass we ignore, is identical to the normal force of the original interface. (e.g. in prob. 5.56)

Tension force

- usually is constant in magnitude along the string/rope
- and changes direction according to the string/rope shape
- can change if the string/rope is massive and accelerating or if the pulley that the string/rope wraps is massive and rotates
- always pulls on the object that is connected to it
- is the 3rd law pair with the force that that object exerts on the string

Spring force

- follows Hooke's law ($F = -kx$), where x is the length change of the spring relative to the length for no load
- is similar to tension force but it can push, as well as pull, the object that is connected to it

Circular Motion

- is important!!! (and so you need to be very familiar with it!!!)
- can give a "fake force" -- a centrifugal force (and two other "fake" forces, e.g. Coriolis force)
"fictitious force" is that official name for "fake force"
- can simulate gravity (fictitious but feels like it is real!)

Frictional Force

- is a non-conservative force.
- can be mysterious for wheels (but not if you really understood my blog posting).
- has magnitude μn , where n is normal force, not always equal to the weight!!
- The static friction is the *maximum* force that you need to apply to get an object to start moving. Then the friction becomes the kinetic friction, which is smaller than static friction.

Work (W)

- $\int \vec{F} \cdot d\vec{r}$
- $\int P dt$ where P is power.
- $\int \tau d\theta$ for a pure rotation, where τ is torque.

Power (P)

- is dW/dt where W is work
- is $\vec{F} \cdot \vec{v}$

Work-Energy Theorem

- Net work done on an object A = Kinetic energy change of object A
- is always applicable, including cases in which non-conservative forces are involved

Kinetic Energy (K)

- $K = m v^2 / 2$
- $K = I \omega^2 / 2$ for a pure rotation
- $K = M V^2 / 2 + K_{rot}$, where $K_{rot} = I \omega^2 / 2$ and V is the speed of the center of mass if a non-point object is moving as a whole (V) as well as rotating w.r.t. the center of mass (thus, in this case, I and ω should be defined w.r.t. the axis going through the center of mass)

Potential Energy (U)

- gives force $F(x) = -dU/dx$ (when U is dependent only on one coordinate x)
- $U(y) = mgy$ for gravity near earth surface
- $U(x) = kx^2/2$ for spring
- $dU/dx = 0$ means no force -- equilibrium at this point of x
 - stable equilibrium if U is minimum at that point
 - unstable equilibrium if U is maximum at that point

Mechanical Energy Conservation

- means that $K + U$ is a constant of time.
- is most useful in problems where time is not asked, or asked only qualitatively.
- is not applicable, if non-conservative forces are involved (like friction, drag).
- is applicable for rolling if rolling friction is zero (negligible wheel deformation).
- is applicable for a static friction of a non-deformed wheel, since that friction does not do any work!

Rotational Motion

- is analogous to the one-dimensional linear motion with the following simple substitution table

$$m \rightarrow I, x \rightarrow \theta, v \rightarrow \omega, a \rightarrow \alpha, F \rightarrow \tau$$
- The rotational inertia: $I = \sum m_i D_i^2$
- The torque, $\vec{\tau} = \vec{r} \times \vec{F}$
- The angular momentum, $\vec{L} = \vec{r} \times \vec{p}$
- The fundamental equation (Newton's law), $d\vec{L}/dt = \vec{\tau}$, where $\vec{\tau}$ is the net torque, applicable in an inertial reference frame or in the center of mass frame.
- The angular momentum is conserved for a spinning ice skater, or a diver, or for any isolated system.
- $\tau = I \alpha$ is also a useful, but less general equation (OK for this course).
- $\vec{L} = I \vec{\omega}$ is another such equation.
- When L is already very large (like for a gyroscope),
- a small τ causes \vec{L} to simply change its direction slightly according to $d\vec{L}/dt = \vec{\tau}$. The result may seem non-intuitive!

All homework problems are important to understand thoroughly, but *some* of the particularly important ones are

5.56, 5.70, 5.38, 5.47, 6.65, 7.59, "Potential Energy Graphs and Motion"

All practice Midterm problems are important to test your understanding of subject matters. In particular, make sure that you are capable of doing all the three write-up problems. There will be an actual midterm problem that is almost identical to one of them.

All homework problems are important to understand thoroughly, but these problems will not appear in this exam in any variation.

6.40, 6.62, 6.80, Parallel Axis Theorem, 10.65

(one more thing: in this exam, you will not need to know the cross product)