# Exam 2 Outline

## Torque and Equlibrium

- Torque
  - Every force has a corresponding torque around any given axis (or pivot)
  - Lever arm $\vec{r}$ from the pivot to the point where the force is applied
  - The torque is $\tau = rF\sin\theta = r_\perp F = rF_\perp$
  - Force has a larger torque if applied farther from pivot, and perpendicular to lever arm
  - Torque can be positive or negative depending on if it causes a counterclockwise or clockwise spin
- Equilibrium
  - If an object is not moving, then net force and net torque are both zero
  - You can calculate torque around any pivot (in this case, since object is not moving)
  - Gravity acts at the center of mass of the object
  - Variable forces act along point or surface of contact, to create equilibrium if they can
  - Stable/unstable equilibrium: give the object a small push and it returns/does not return to equilibrium
  - Remember the basic forces:
    - Weight (force of gravity): $mg$
    - Normal: perpendicular to surface of contact, adjustable
    - Tension: in direction of rope, adjustable
    - Kinetic Friction: $\mu_K N$, opposite direction of motion
    - Static Friction: adjustable, parallel to surface of contact

## Angular Motion

- Angular displacement $\Delta\theta$, equivalent to position
- Angular velocity $\omega = \Delta\theta/\Delta t$
  - normally measured in radians per second
  - $f = \dfrac{\omega}{2\pi}$ is the number of revolutions per second: "frequency"
  - $T = 1/f = 2\pi/\omega$ is the period of rotation
- Angular acceleration $\alpha = \Delta\omega/\Delta t$
- constant angular-acceleration equations:
  - $\omega = \omega_0 + \alpha t$
  - $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
  - $\theta = \theta_0 + \omega t - \frac{1}{2}\alpha t^2$
  - $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$
  - $\theta = \theta_0 + \frac{1}{2}(\omega + \omega_0)t$
- A point on a wheel has linear velocity $v = r\omega$
- A wheel rolling down a hill has speed $v = r\omega$ as well
- Acceleration of a point on the wheel: $\vec{a} = \vec{a}_c + \vec{a}_t$:
  - centripetal acceleration $\vec{a}_c = r\omega^2$ towards center
  - tangential acceleration $\vec{a}_t = r\alpha$ tangent to circle
- Newton's Second Law: $\tau = I\alpha$
- Rotational Inertia $I$
  - Larger when mass is farther from the axis
  - For disk: $\frac{1}{2}mr^2$
  - For ring: $mr^2$
- Angular Momentum
  - $L = I\omega$
  - conserved if net torque is zero

## Momentum and Impulse

- Momentum: $\vec{p} = m\vec{v}$ (vector quantity)
- Impulse: $\Delta\vec{p} = \vec{J} \equiv \vec{F}_{\text{avg}}\Delta t$: area under $F$–$t$ curve
- Systems of objects
  - Can consider a group of objects as a single system
  - Total momentum of the system is $\vec{p}_{\text{tot}} = \vec{p}_1 + \vec{p}_2 + \ldots$
  - Total momentum is $\vec{p}_{\text{tot}} = m_{\text{tot}}\vec{v}_{\text{com}}$
  - If no net external force, then momentum $\vec{p}_{\text{tot}}$ is conserved
- Some cases where momentum is conserved
  - Explosions
  - Recoil of a gun
  - Rocket thrust: exhaust goes one way, rocket goes the other
  - Maximally Inelastic Collisions: Objects stick together after the collision, move with same velocity
- Center of Mass
  - For particles: $\vec{r}_{\text{com}} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots}{m_1 + m_2 + \ldots}$
  - Average of all positions, closer to more massive particles
  - Velocity of center of mass is $\vec{v}_{\text{com}} = \vec{p}_{\text{tot}}/m_{\text{tot}}$