P2211K

11 / 09 / 2010

- **The test is closed book & closed notes;**
- **No one is allowed to leave the room during the test, so sharpen all pencils, visit the rest room, etc., before it begins;**
- **Programmable calculators, graphics calculators, hand held computers and any type of cell phone are not allowed for tests and exams. For these, you need to have a simple “scientific” calculator that has roots and trig functions.**

Highlights of material in Chapters 10-12:

Work & energy relationships (from chapters 10 & 11, but also used in Ch. 12)

- Defined kinetic energy: **$K = \frac{1}{2}mv^2$**
- Defined work: Work done by a force **$W_F = Fd\cos\theta_{Fd}$**, where ***θ_{Fd}*** is the angle between the force and the displacement ***d***.
- Introduced the work-energy relation based on the definitions of K and W: **$\Delta K = W_{net}$**, where W_{net} is the net work done by ***all forces*** acting on the object whose kinetic energy is changed.
- Recognized that some forces can cause things to move (e.g., gravity and springs) while others only act against things moving (e.g., friction).
- On this basis, introduced the idea of conservative (e.g., gravity and springs) and nonconservative (e.g., friction) forces.
- Developed the idea of potential energy associated with the work done by conservative forces: **$\Delta U = -W_c$,** where **W_c** is the work done by a conservative force
- From the idea of potential energy, introduced the concept that mechanical energy is conserved when only conservative forces act:

$$\Delta K = W_{net} = -\Delta U \rightarrow \Delta K + \Delta U = 0, \text{ or } \Delta(K + U) = 0, \text{ or } \Delta E_T = 0 \text{ if } E_T = K + U$$

- When the object is acted on by a combination of conservative and nonconservative forces the work-energy relation can be restated using the potential energy concept:

$$\Delta K = W_{net} = W_c + W_{nc} = -\Delta U + W_{nc} \rightarrow \Delta K + \Delta U = W_{nc}$$

- Defined Power, the rate of doing work (or expending energy): **$P = \Delta W / \Delta t$**

Highlights of material in Chapters 10-12, cont'd:

Rigid bodies (Chapter 12)

- Basic description of rigid body motion = linear motion of the center of mass + rotation about the center of mass;
- Introduced and defined the idea of center of mass (or center of gravity)
- Introduced and defined the idea of rotational inertia (or moment of inertia)
- From the definition of kinetic energy, developed the expression for rotational kinetic energy:

$$\mathbf{K = \tfrac{1}{2}mv^2 \rightarrow K_{rot} = \tfrac{1}{2}I\omega^2}$$

- Recalled the useful descriptors for rotational motion: angular position = θ, angular speed = ω, and angular acceleration = α (where the angular measure is radians)
- Recalled that the tangential speed and acceleration of points in a rotating object are related to the rotational descriptors according to $\mathbf{s = R\theta}$; $\mathbf{v_t = R\omega}$, **and** $\mathbf{a_t = R\alpha}$, where R is the distance from the cneter of rotation to the point being described**.**
- Used work and energy methods to analyze situations involving rotational motion;
- Introduced the concept of torque $\boldsymbol{\tau} = \mathbf{RF\sin\theta_{RF}}$, where R is the distance between the point at which F is applied and θ_{RF} is the angle between F and R.
- For rigid bodies, $\boldsymbol{\tau} = \mathbf{I\alpha}$; used force and torque methods to analyze situations involving rotational motion;
- Examined the case of rolling without slipping & recognized that the angular speed is related to the speed of the center of mass by $\mathbf{v_{cm} = R\omega}$
- Analyzed rolling motion using energy methods and also using force + torque methods
- Introduced the concept of angular momentum: $\mathbf{L = I\omega}$ for a rigid body;
- Recognized that $\boldsymbol{\tau} = \mathbf{I\alpha}$ means that $\boldsymbol{\tau} = \mathbf{dL/dt}$ and that L is conserved when $\boldsymbol{\tau} = \mathbf{0}$.

CONSERVATION OF ANGULAR MOMENTUM:

The relation is like that for linear momentum:

$$\vec{L}_f = \vec{L}_i \;\Rightarrow\; I_f \vec{\omega}_f = I_i \vec{\omega}_i$$

Example: A 2.0 kg, 20-cm-diameter turntable rotates at 100 rpm on frictionless bearings. Two 500 g blocks fall from above, hit the turntable simultaneously at opposite ends of a diagonal, and stick.

- What is the turntable's angular velocity, in rpm, just after this event?

This event amounts to a completely inelastic "rotational collision."

Initially, the two blocks have no angular momentum. However, adding them to the rotating turntable (a disk) increases its Rotational Inertia.

$$\text{Initial } I = I_{disk} = \tfrac{1}{2} M_{disk} R_{disk}^2$$

Each block adds $I = M_{block} R_{disk}^2$ ***because they attach at the edge of the disk.***

$$\text{Final } I = I_{disk} + I_{blocks} = \tfrac{1}{2} M_{disk} R_{disk}^2 + 2M_{block} R_{disk}^2$$

Thus, conservation of angular momentum and this information lead to :

$$I_{initial}\,\omega_{initial} = \left(\tfrac{1}{2} M_{disk} R_{disk}^2\right)\omega_{initial} = \left(\tfrac{1}{2} M_{disk} R_{disk}^2 + 2M_{block} R_{disk}^2\right)\omega_{final} = I_{final}\,\omega_{final}$$

and

$$\omega_{final} = \omega_{initial}\left[\frac{\left(\tfrac{1}{2} M_{disk} R_{disk}^2\right)}{\left(\tfrac{1}{2} M_{disk} R_{disk}^2 + 2M_{block} R_{disk}^2\right)}\right] = \omega_{initial}\left[\frac{\left(\tfrac{1}{2} M_{disk}\right)}{\left(\tfrac{1}{2} M_{disk} + 2M_{block}\right)}\right] = 50 \text{ rpm}$$

Assignment:

- **Continue reading and working on Chapter 14;**