Take-Home Version of Midterm 3

Dr. Jordan Hanson - Whittier College Dept. of Physics and Astronomy

November 27, 2019

1 Memory Bank

- Unit conversions: 1 km = 1000 m, 1 m = 100 cm, 1 hr = 3600 s, 1 year = $\pi \times 10^7$ s, 1 g/cm^3 = 1000 kg/m^3.
- $\vec{x} = a\hat{i} + b\hat{j}$ ... Component form of a two-dimensional vector.
- $|\vec{x}| = \sqrt{a^2 + b^2}$ ... Pythagorean theorem for obtaining vector magnitude.
- $\theta = \tan^{-1}(b/a)$ ... Obtaining the angle between vector and x-axis.
- $x(t) = x_i + vt$ ... Velocity is the slope of position versus time.
- $x(t) = \frac{1}{2}at^2 + v_i t + x_i$ ... With constant acceleration, position is quadratic. If $a = 0$ this becomes the prior function.
- $v(t) = v_i + at$ ... With constant acceleration, acceleration is the slope of velocity.
- $v^2 = v_i^2 + 2a\Delta x$ ... The kinematic equation without time, assuming constant acceleration.
- $\vec{F}_{net} = 0$ ... Newton's First Law, an object with no net force stays at constant velocity, or zero velocity.
- $\vec{F}_{net} = m\vec{a}$ ... Newton's Second Law.
- $\vec{F}_{AB} = -\vec{F}_{BA}$ ... Newton's Third Law.
- $f = \mu N$, $F_D = \frac{1}{2}C\rho A v^2$, $F_D = 6\pi r \eta v$ ... friction, drag in air, drag in viscous fluids.
- $stress = Y \times strain$, or $F/A = Y(\Delta x/L)$ ... Young's Modulus and elasticity.
- $s = r\theta$ ... Definition of a *radian*, with arc length s and angle θ.
- $v = r\omega$, $a = r\alpha$ ... Angular velocity, angular acceleration.
- $a_C = v^2/r = r\omega^2$ ... Centripetal acceleration.
- $F_C = ma_C = mv^2/r = mr\omega^2$ ... Centripetal force.
- $\vec{F}_G = Gm_1m_2/r^2 \;\; \hat{r}$ ... Newton's Law of Gravity.
- $W = \vec{F} \cdot \vec{d}$ ... Definition of Work, energy.
- $KE = \frac{1}{2}mv^2$ ... Definition of kinetic energy.
- $W = \Delta KE$ ... Work-Energy theorem.
- $U = mgh$ ... Gravitational potential energy.
- $U = \frac{1}{2}kx^2$ ... Spring potential energy.
- $P = W/t$ ... Power is work divided by time.
- 1 kilocalorie, or kcal, is 4184 Joules.
- $\vec{p} = m\vec{v}$ ... Definition of momentum.
- $\vec{p}_{i,tot} = \vec{p}_{f,tot}$ ... Momentum conservation for $\vec{F}_{net} = 0$. Also, $\vec{F}_{net} = \Delta\vec{p}/\Delta t$.
- $\vec{\tau} = \vec{r} \times \vec{F}$, $|\vec{\tau}| = I\alpha$, with $I = Nmr^2$. N depends on the shape.
- $\vec{L} = \vec{r} \times \vec{p}$, and $L = I\omega$, so $\Delta L/\Delta t = \tau$.

2 Chapter 7: Work, Energy, and Energy Resources

1. Suppose you push a large piece of furniture with mass 60.0 kg across a floor with frictional coefficient $\mu_k = 0.1$ a distance of 6.0 m at constant speed. a) What is the force of friction? b) What is the work done by friction on the object? c) Suppose you are pushing at a 10 degree angle with respect to the horizontal What work do you perform? (d) With what force are you pushing?

2. Vehicles are designed to cruch linearly to protect the passengers inside. (a) Use the work-energy theorem to calculate the force exerted on a 1400 kg vehicle, if the vehicle is compressed by 1.5 meters when it hits a solid object, decelerating from 10.0 m/s. (b) Compare this to the force exerted on the vehicle in the same situation, but the vehicle is made of older materials that only compress 0.25 meters. (Think about this when people tell you "bigger cars are safer." Depends on the materials.).

3. A big flatscreen TV can consume 200 Watts of power. What is the cost of operating this television for 2 hours per day, 5 days per week, for one year? (Assume $0.15 per kW h).

3 Chapter 8: Linear Momentum and Collisions

1. A proton with mass m collides with a helium ion of mass $4m$ and temporarily forms a new particle of mass $5m$. The velocity of the proton is 1% of the speed of light, to the right, and the velocity of the heliumis 1% of the speed of light, to the left. What is the velocity of the final particle, as a fraction of the speed of light?

2. Two billard balls each have a mass of 0.16 kg. One ball is stationary, and another strikes it with a velocity of 3 m/s, then stops. (a) What is the velocity of the struck ball? (b) What is the final momentum of the ball? (c) If the struck ball rolls towards a wall, hits it, and rebounds with the same velocity, what is the change in momentum, and what is the force exerted on the ball as it rebounds?

3. Two orbiting satellites are attached, and we view them in a reference frame in which they are stationary. The first has a mass of 8.00×10^3 kg, and the second a mass of 4×10^3 kg. (a) A mechanism is triggered that does 1 kJ of work on each satellite, and they fly apart. (a) What is the final velocity of the first craft? (b) What is the final velocity of the second craft? (c) Is kinetic energy conserved? Why or why not?

4 Chapter 10: Rotational Motion and Angular Momentum

1. Suppose we hang the fish we've caught on a fishing pole. The first fish has a mass of 0.6 kg, and we hang it at the end of a 1.6 meter fishing pole. The second fish has a mass of 0.8 kg, and we hang it half-way down the pole. (a) Draw a diagram including the pole (lever arm), and the weight vector of each fish. (b) In which direction are the torques? (c) What is the magnitude of the torque due to each fish, and what is the total torque?

2. A baseball pitcher throws the ball in a motion where there is rotation of the forearm about the elbow joint as well as other movements. The linear velocity of the ball relative to the elbow joint goes from 0 m/s to 20.0 m/s in 0.4 seconds, at a distance of 0.480 m from the joint. The moment of inertia of the forearm is 0.500 kg m^2. What is the torque on the forearm? (Neglect the mass of the ball).

3. Suppose you exert a force of 200 N tangential to a 0.15 m radius, 0.1 kg hoop ($I = MR^2$). (a) What torque is exerted? (b) What is the angular acceleration assuming negligible opposing friction? (b) Suppose instead the object is a point mass rotating about the same radius, and you exert the same force. What will be the angular acceleration?