

PHYSICS 101: Fundamentals of Physics – Final Exam

Final Exam

Name

TA/ Section #

Recitation Time

June 10, 2008, 1:00pm

You have 2 hour to complete the exam. Please answer all questions clearly and completely, and that you clearly indicate your final answer to each problem (put a box around the final answer, for example). Make sure that you show all of your work. If your exam sheets do not have enough room for you to write on, please ask for more paper.

You may use a calculator, and, of course, reference the formula sheet, attached. Beyond that, the exam is entirely closed book.

Formula Sheet

(You may tear these pages out)

Physical Constants

$$G = 6.67 \times 10^{-11} \text{Nm}^2/\text{kg}^2$$

$$g = 9.8\text{m/s}^2 \simeq 10\text{m/s}^2$$

$$c = 3 \times 10^8 \text{m/s}$$

Some useful math relations

$$\frac{dC}{dt} = 0$$

$$\frac{d(t^n)}{dt} = nt^{n-1}$$

$$\frac{d(\cos(at))}{dt} = -a \sin(at)$$

$$\frac{d(\sin(at))}{dt} = a \cos(at)$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \text{Quadratic Formula}$$

Projectile Relations

$$\Delta \vec{r} = \vec{r}_f - \vec{r}_i$$

$$\vec{r} = x\hat{i} + y\hat{j}$$

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{r}(t) = \vec{r}_i + \vec{v}_i t + \frac{1}{2} \vec{a} t^2$$

$$\vec{v}(t) = \vec{v}_i + \vec{a} t$$

$$v_f^2 - v_i^2 = 2a_x \Delta x$$

Circular Motion

$$a_c = \frac{v^2}{r}$$

$$a_t = \frac{dv}{dt} \quad \text{tangential acceleration}$$

Newton's Laws

$$\vec{F} = m\vec{a}$$

$$\sum \vec{F} = 0 \text{ equilibrium}$$

Some specific forces

$$F_{g,y} = -mg$$

$$F_s = -kx$$

$$F_{G,r} = -\frac{GMm}{r^2}$$

$$F_r = \mu F_N$$

$$R = \frac{1}{2} D \rho A v^2 \text{ (air resistance)}$$

$$V_t = \sqrt{\frac{2mg}{DA\rho}}$$

Solution of a spring

$$x(t) = x_0 \cos \omega t$$

$$\omega = \sqrt{k/m}$$

Energy

$$K = \frac{1}{2} m v^2$$

$$W = \vec{F} \cdot \Delta \vec{r}$$

$$W = \Delta K$$

$$E_{mech} = K + U$$

$$-\frac{dU}{dx} = F_x$$

$$E = K + U + E_{th}$$

$$P = \frac{dW}{dt}$$

$$= \vec{F} \cdot \vec{v}$$

Potential Energies

$$U_g = mgy$$

$$U_s = \frac{1}{2} kx^2$$

$$U_G = -\frac{GMm}{r}$$

Center of Mass

$$\begin{aligned}\vec{r}_{com} &= \frac{\sum_i m_i \vec{r}_i}{M} \\ \vec{v}_{com} &= \frac{d\vec{r}_{com}}{dt} \\ &= \frac{\sum_i m_i \vec{v}_i}{M} \\ M\vec{v}_{com} &= \vec{P} = \sum_i \vec{p}_i\end{aligned}$$

Momentum

$$\begin{aligned}\vec{p} &= m\vec{v} \\ \frac{d\vec{p}}{dt} &= \vec{F}_{ext}\end{aligned}$$

Elastic Collisions in 1-d

$$\begin{aligned}p_{1f} &= p_{1i} \left(\frac{m_1 - m_2}{m_1 + m_2} \right) \\ p_{2f} &= p_{1i} \left(\frac{2m_2}{m_1 + m_2} \right) \\ v_{1f} &= v_{1i} \left(\frac{m_1 - m_2}{m_1 + m_2} \right) \\ v_{2f} &= v_{1i} \left(\frac{2m_1}{m_1 + m_2} \right)\end{aligned}$$

Rotational Kinematics

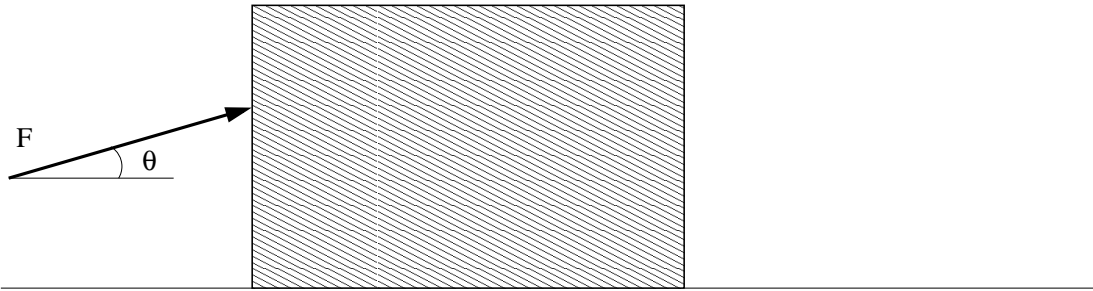
$$\begin{aligned}s &= r\Delta\theta \\ v_t &= r\omega \\ T &= \frac{2\pi}{\omega} \\ \omega &= \frac{d\theta}{dt} \\ \alpha &= \frac{d\omega}{dt} \\ \theta(t) &= \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \\ \omega(t) &= \omega_0 + \alpha t\end{aligned}$$

Energy of Rotation

$$I = \sum_i m_i r_i^2$$

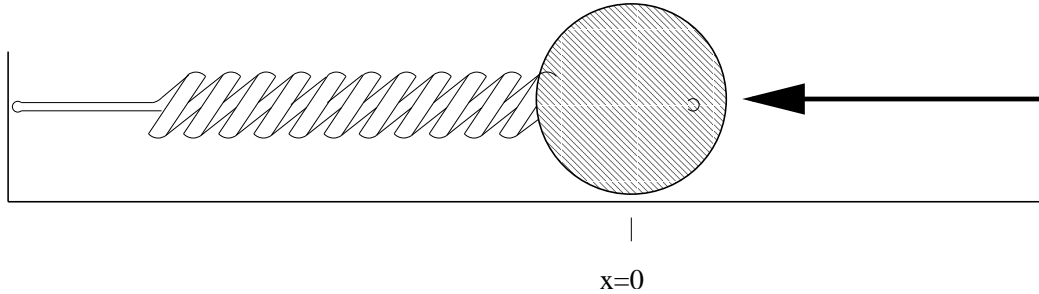
$$\begin{aligned}K_{rot} &= \frac{1}{2}I\omega^2 \\I_{circle} &= MR^2 \\I_{disk} &= \frac{MR^2}{2} \\ \tau &= rF_{\perp} \\ &= \frac{dL}{dt} \\ L &= I\omega\end{aligned}$$

1. [25 points] A big box of mass 200kg is stuck on a relatively rough floor with coefficient of static friction $\mu_s = 0.5$, and coefficient of kinetic friction, $\mu_k = 0.2$. I want to get this box moving, so I start pushing it with a force, F , (to be determined), in a direction 30 degrees above the horizontal.



- (a) Draw a free-body diagram for the system. Be sure to include all forces.
- (b) For a while, I push, and I push, but just can't get the block moving. What is the maximum force I can apply such that I won't overcome friction?
- (c) Let's assume that I push just the tiniest bit above the answer in part b), which we will call, F_A , and the block starts to move. Compute the net force, on the block, and express it as a vector (in Newtons).
- Note:** You should have a numerical answer. If for some reason, you couldn't compute the answer to part b), please assume for this and subsequent parts of the problem that $F_A = 2000N$. (This is NOT the actual answer, by the way).
- (d) Does it make more sense to push the block horizontally? That is, once the block is moving, assuming you can push a maximum of F_A , compute the net force on the block if you push with F_A horizontally, rather than at a 30 degree angle.
- (e) **E.C.** Compute the angle which produces the fastest acceleration if you can push with F_A .

2. [25 points] On the floor, there is a spring, with spring constant $k = 125\text{N/m}$, with a 0.2kg mass on the end. At $t = 0$, I come along and give the mass a kick (to the left) such that it has 10J of energy.

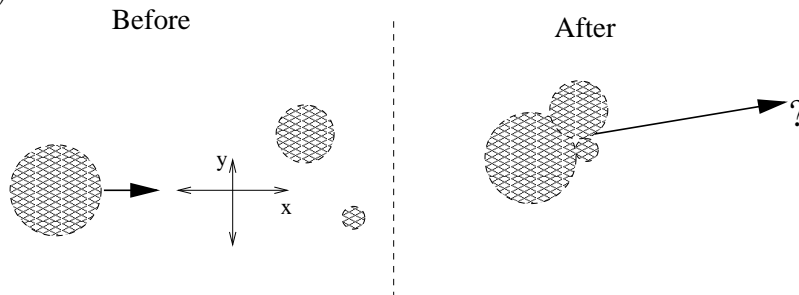


- What is the initial velocity of the mass? ("Initial" means in the instant after I kicked it.)
- What was the Impulse applied to the mass?
- How far does the block move before it turns around?
- At that instant, what is the acceleration on the block?
- Please draw an energy diagram of the system. Indicate the potential, kinetic, and mechanical energy. On the diagram, be sure to label the range of motion of the block, as well as any equilibrium points, and be sure to say whether they are stable or unstable.
- In fact, now imagine that the floor has a small coefficient of kinetic friction ($\mu_k = 0.1$). What is the force of friction between the block and the floor?
- Approximately, how much work will friction do from when the block starts moving at $t = 0$, and when it reaches the point of maximum stretching as given in part b)?
- E.C.** Sketch the position of the block as a function of time. Be sure to label your time axis.

3. [25 points] Bored one day, I decide to play with my Play-Doh, and make three big balls of clay, $m_1 = 0.6\text{kg}$, $m_2 = 0.3\text{kg}$, and $m_3 = 0.1\text{kg}$, and arrange them such that:

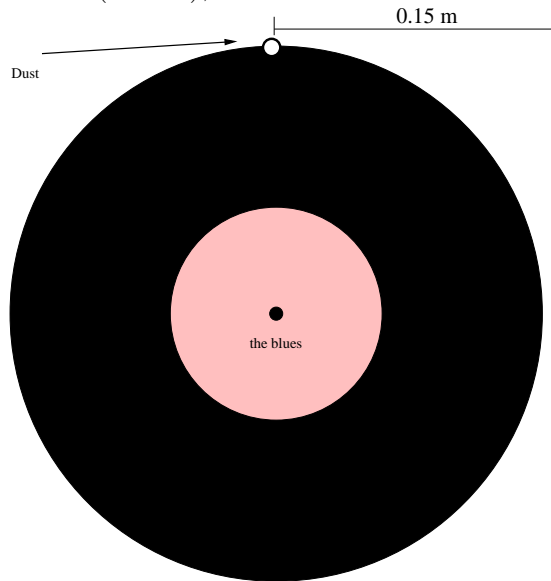
$$\begin{aligned}\vec{r}_1 &= -0.5m\hat{i} \\ \vec{r}_2 &= 0.2m\hat{i} + 0.1m\hat{j} \\ \vec{r}_3 &= 0.3m\hat{i} - 0.2m\hat{j}\end{aligned}$$

(as shown).



- What is the center of mass of the three balls of clay at this instant?
- At some time, I “flick” the first sphere (the one with a mass of 0.6kg) giving it a velocity of $3m/s\hat{i}$. What is the total momentum of the system?
- What is the kinetic energy of the system?
- The 1st ball collides with the other two, and all three stick together. What type of collision is this?
- What is the velocity of the resulting mass?
- What is the kinetic energy of the resulting mass? If your answer is different from that in part c), please explain.

4. [25 points] I have me one of those olde-tyme vinyl record players, where the “albums” have a radius of about 6” (0.15m), and a mass of about 0.02kg.



- (a) What is the moment of inertia of a vinyl record when revolving around the spindle (axis)?
- (b) Now, at some moment, the the record starts to spin up. Looking at a mote of dust, I notice that the dust sitting on the edge of the record makes an angle with respect to the horizontal of:

$$\theta(t) = \frac{\pi}{2} + 5s^{-2}t^2$$

- (c) After 0.2 seconds, what is the angular velocity of the dust?
- (d) At that time, what is the speed of the dust?
- (e) Given that, how much centripetal acceleration must be provided to keep the dust from sliding?
- (f) At that time, what is the angular acceleration of the dust?
- (g) At that time, what is the angular momentum of the record?
- (h) These records are also known as 33's, because they will ultimately spin with a frequency of $33 \frac{1}{3}$ revolution per minute. How long