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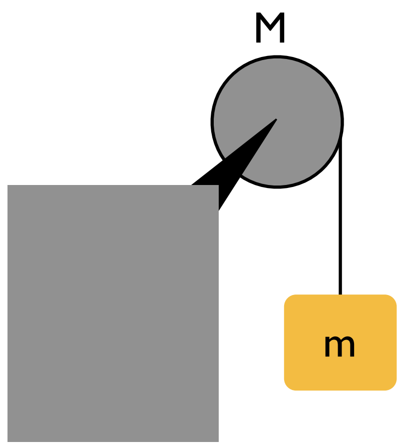
UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 105 / LeClair — Summer 2012

Exam 3

1. **Solve 5 of 6 problems below. Indicate which problems you have chosen.**
2. All problems have equal weight.
3. Show your work for full credit. Significant partial credit will be given.
4. You are allowed 1 sheet of 8.5 x 11 in paper with notes/formulas and a calculator.
5. Do all work on separate sheets.

□ **1.** A uniform disk with mass $M = 2.5$ kg and radius $R = 20$ cm is mounted on a fixed horizontal axle, as shown below. A block of mass $m = 1.2$ kg hangs from a massless cord that is wrapped around the rim of the disk. Find the acceleration of the falling block, the angular acceleration of the disk, and the tension in the cord. *Note: the moment of inertia of a disk about its center of mass is* $I = \frac{1}{2}MR^2$.



□ **2.** 1 kg of liquid nitrogen at its boiling point of −195.81°C is in an isolated container of negligible mass. A mass of liquid water m_w at 25°C is dropped into the container. What should m_w be in order to boil away (vaporize) all of the liquid nitrogen, leaving behind ice at 0°C? Assume that once the nitrogen is in vapor form it leaves the container (i.e., do not worry about the heat required to warm up the nitrogen gas). You may need the following data:

liquid nitrogen	$L_v = 2.01 \times 10^5$ J/kg			
water	$c = 4190$ J/kg·K	$L_f = 3.34 \times 10^5$ J/kg	$T = 0°C$	freezing point

□ **3.** A hollow spherical iron shell floats almost completely submerged in water. The outer diameter is 0.60 m, and the density of iron is 7870 kg/m^3. If the density of water is 1000 kg/m^3, find the inner diameter of the sphere.

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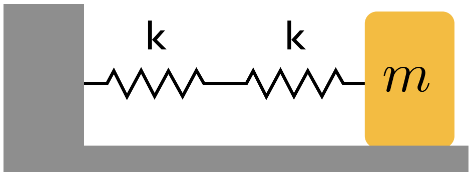
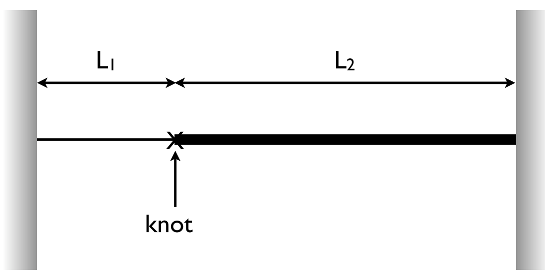
□ **4.** A mass m is connected to two springs in series as shown below. What is the period of simple harmonic motion if the mass is displaced from equilibrium. *Hint: what must be true of the displacement of each spring if the total displacement is* Δx*?*



□ **5.** In the figure below, two strings have been tied together with a knot and then stretched between two rigid supports. The strings have linear densities (mass per unit length) μ_1 and μ_2, with lengths L_1 and L_2, and tension T.

Simultaneously, on each string a pulse is sent from the rigid support end, toward the knot. The pulses from each end reach the knot at precisely the same moment. For that to be true, what is the relationship between L_1, L_2, μ_1, and μ_2?



□ **6.** Archimedes supposedly was asked to determine whether a crown made for the king consisted of pure gold. Legend has it that he solved this problem by weighing the crown first in air and then in water. Suppose the scale read 7.84 N in air and 6.84 N while submersed in water. What should Archimedes have told the king? (Note: $\rho_{\text{water}} = 1000\,\text{kg/m}^3$, $\rho_{\text{gold}} = 19.3 \times 10^3\,\text{kg/m}^3$.)

Math & numbers:

$$g = 9.81\,\mathrm{m/s^2}$$
$$ax^2 + bx^2 + c = 0 \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Rotation: we use radians

$$s = \theta r \quad \leftarrow \text{arclength}$$
$$\omega = \frac{d\theta}{dt} = \frac{v}{r} \qquad \alpha = \frac{d\omega}{dt}$$
$$a_t = \alpha r \quad \text{tangential} \qquad a_r = \frac{v^2}{r} = \omega^2 r \quad \text{radial}$$
$$I_z = I_{com} + md^2 \quad \text{axis } z \text{ parallel, dist } d$$
$$\tau_{net} = \sum \vec{\tau} = I\vec{\alpha} = \frac{d\vec{L}}{dt}$$
$$\vec{\tau} = \vec{r} \times \vec{F} \qquad |\vec{\tau}| = rF\sin\theta_{rF}$$
$$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$$
$$K = \frac{1}{2}I\omega^2 = L^2/2I$$

1-D motion:

$$v(t) = \frac{\mathrm{d}}{\mathrm{d}t}x(t)$$
$$a(t) = \frac{\mathrm{d}}{\mathrm{d}t}v(t) = \frac{\mathrm{d}^2}{\mathrm{d}t^2}x(t)$$

const. acc.

$$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$$
$$v_{xf}^2 = v_{xi}^2 + 2a_x\Delta x \quad \text{const. acc.}$$
$$v_f = v_i + at$$
$$a_c = \frac{v^2}{r} \quad \text{circular}$$

Work-Energy-Potential:

$$K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$
$$\Delta K = K_f - K_i = W$$
$$W = \int F(x)\,dx = -\Delta U$$
$$U_g(y) = mgy$$
$$U_s(x) = \frac{1}{2}kx^2$$
$$F = -\frac{dU(x)}{dx}$$
$$K_i + U_i = K_f + U_f + W_{\text{ext}} = K_f + U_f + \int F_{\text{ext}}\,dx$$

Momentum, etc.:

$$F_{\text{net}} = M_{\text{tot}}a_{\text{com}} = \frac{dp}{dt}$$
$$p_{\text{tot}} = M_{\text{tot}}v_{\text{com}}$$
$$\sum_i m_i v_i = \sum_f m_f v_f$$

Isolated systems: $\vec{p}$, $E = K + PE$, L are all conserved.
Static equilibrium: $\sum F = 0$ and $\sum \tau = 0$ about any axis.
Elastic collision: KE and p are both conserved.
Inelastic collision: only p is conserved, not KE.

waves:

$$y = A\sin(2\pi/\lambda - \omega t) \qquad \omega = 2\pi f$$
$$v = \frac{\lambda}{T} = \lambda f \quad \text{wave speed}$$
$$v = \sqrt{T/\mu} \quad \mu = M_{\text{string}}/L_{\text{string}} \quad T = \text{tension} \qquad \text{strings}$$
$$f_n = \frac{nv}{\lambda} = \frac{nv}{2L} \quad \lambda_n = \frac{2L}{n} \quad n = 1, 2, 3\ldots \qquad \text{strings \& open-open pipe}$$
$$f_n = \frac{nv}{\lambda} = \frac{nv}{4L} \quad \lambda_n = \frac{4L}{n} \quad n = 1, 3, 5\ldots \qquad \text{closed-open pipe}$$

Oscillations:

$$T = \frac{1}{f} = \frac{2\pi}{\omega} \quad \omega = \frac{2\pi}{T} = 2\pi f$$
$$x(t) = x_m\cos(\omega t + \varphi)$$
$$a = -\omega^2 x \qquad \frac{d^2\theta}{dt^2} = -\omega^2\theta$$
$$\omega = \sqrt{k/m} \quad \text{spring.}$$
$$T = \begin{cases} 2\pi\sqrt{L/g} & \text{simple pendulum} \\ 2\pi\sqrt{I/mgh} & \text{physical pendulum} \end{cases}$$
$$U = -\frac{1}{2}kx^2 \quad U = -\frac{1}{2}\kappa\theta^2 \quad F = -\frac{dU}{dx} = ma \quad \text{SHM}$$

fluids:

$$P = F/A$$
$$P(h) = P_{\text{above}} + \rho g h$$
$$\rho = M/V$$
$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \quad F_1x_1 = F_2x_2 \qquad \text{hydraulics}$$
$$B = \text{buoyant force} = \text{weight of water displaced}$$

thermal stuff:

$$T(K) = T(^\circ C) + 273.15^\circ$$
$$Q = mc\Delta t \quad c = \text{specific heat} \qquad \text{no phase chg}$$
$$Q = \pm mL \qquad \text{phase chg}$$
$$PV = NkT = nRT$$

Derived unit	Symbol	equivalent to
newton	N	$\mathrm{kg{\cdot}m/s^2}$
joule	J	$\mathrm{kg{\cdot}m^2/s^2} = \mathrm{N{\cdot}m}$
watt	W	$\mathrm{J/s = m^2{\cdot}kg/s^3}$