Name____________________________

Dec. 6, 2007

Phys 2010, NSCC
Exam #3 — Fall 2007

1.	________________	(6)
2.	________________	(9)
3.	________________	(15)
4.	________________	(17)
5.	________________	(8)
6.	________________	(3)
7.	________________	(10)
8.	________________	(6)
9.	________________	(6)
10.	________________	(10)
MC	________________	(10)
Total	________________	(100)

Multiple Choice

Choose the best answer from among the four! (2) each.

1. The various points on a rotating object

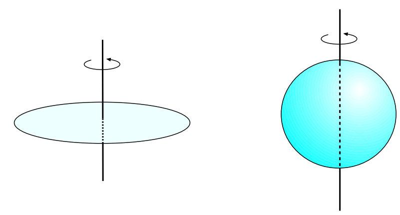
$\boxed{\textbf{a)}}$ Have the same angular speeds but different linear speeds.

b) Have the same linear speeds but different angular speeds.

c) Have the same angular speeds and the same linear speeds.

d) Have different angular speeds and different linear speeds.

2. A uniform disk and a solid sphere both have radius R and equal mass M. Both turn about fixed axes through their centers (for the disk, perp to face of disk) with the same angular speed ω. Which one has more kinetic energy?



$\boxed{\textbf{a)}}$ The disk.

b) The sphere.

c) Both have the same amount of KE.

d) It is impossible to say without knowing R, M and ω.

3. Two uniform sticks have the same mass but one is three times as long as the other. The moment of inertia of the longer stick about an axis through its end (and perp to the stick) is

a) $\sqrt{3}$ times that of the shorter stick.

b) 3 times that of the shorter stick.

c) $3\sqrt{3}$ times that of the shorter stick.

$\boxed{\textbf{d)}}$ 9 times that of the shorter stick.

4. Two simple pendulae are constructed, both of the same length but with the mass of the bob on pendulum B twice that of the mass on pendulum A. For small oscillations, the period of pendulum B as compared with that of A is

$\boxed{\textbf{a)}}$ The same.

b) $\sqrt{2}$ times as great.

c) Twice as great.

d) 4 times as great.

5. Total angular momentum will be conserved in a system if

a) The rotating objects are all symmetric.

b) There is no external force.

c) There are no friction forces between the components.

$\boxed{\textbf{d)}}$ There is no external torque.

Problems

Show your work and include the correct units with your answers!

1. What are the SI ("mks") units of: (6)

a) Angular Acceleration

$\frac{\mathrm{rad}}{\mathrm{s}^2}$

b) Torque

$\mathrm{N} \cdot \mathrm{m}$

c) Angular Momentum

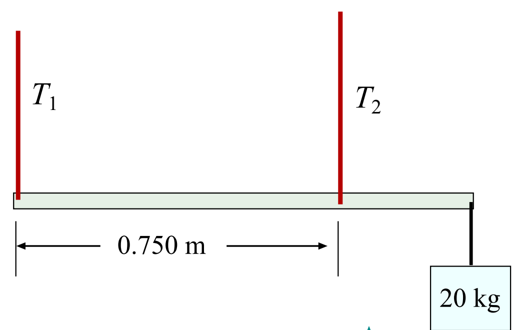
$$\frac{\mathrm{kg} \cdot \mathrm{m}^2}{\mathrm{s}}$$

d) Sound Intensity, I

$$\frac{\mathrm{W}}{\mathrm{m}^2}$$

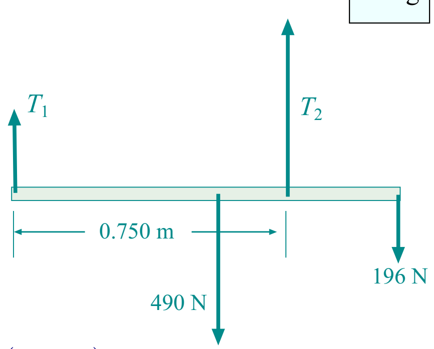
2. A uniform beam of length 1.00 m and *mass* 50.0 kg is supported horizontally by two cables attached to its ends, as shown; one is attached to the left end and one is attached 0.750 m from the left end. In addition, a 20.0 kg is hung from the right end.

Find the tensions in the cables. (9)



Forces acting on the bar are shown at the right; we show the weight of the bar ($490\ \mathrm{N}$) applied at the midpoint and the force from the string holding up the mass ($196\ \mathrm{N}$) at the right end.

The total $y-$ force on the bar is zero; this gives



$$T_1 + T_2 - 490\ \mathrm{N} - 196\ \mathrm{N} = 0 \qquad \Longrightarrow \qquad T_1 + T_2 = 686\ \mathrm{N}$$

Consider the total torque, using the left end as the axis. We get:

$$-(490\ \mathrm{N})(0.50\ \mathrm{m}) + T_2(0.750\ \mathrm{m}) - (196\ \mathrm{N})(1.0\ \mathrm{m}) = 0$$

Solve for T_2 and get:

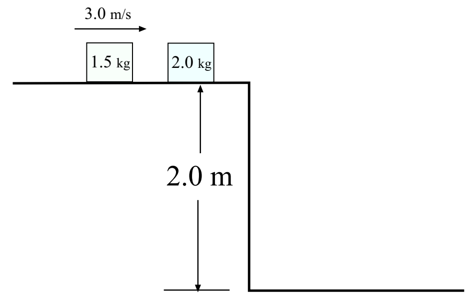
$$T_2 = 588\ \mathrm{N}$$

and then the first equation gives

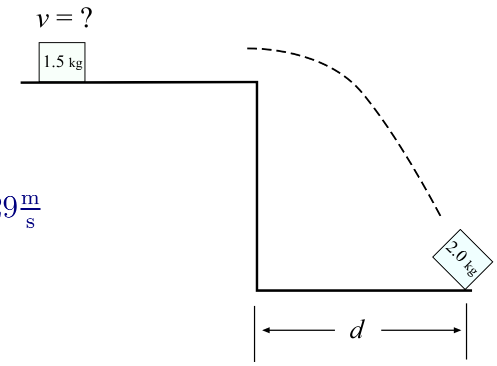
$$T_1 = 686\ \mathrm{N} - 588\ \mathrm{N} = 98\ \mathrm{N}$$

so the tensions are $\boxed{T_1 = 98\ \mathrm{N}}$ and $\boxed{T_2 = 588\ \mathrm{N}}$.

3. On a frictionless (horizontal) tabletop, a 1.50 kg block slides toward a stationary 2.0 kg block which sits near the edge of the table, with a speed of $3.00\frac{\mathrm{m}}{\mathrm{s}}$. It makes an *elastic* collision with the 2.00 kg block. The 2.00 kg slides forward and off the edge of the table and then it hits the ground which is 2.00 m (vertically) beneath the tabletop.



a) What is the velocity of the 1.50 kg mass just after the collision? (3)



Use the formula for the final velocities in an elastic 1-D collision where one mass is initially at rest (given on exam). We get:

$$v_1' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_1 = \left(\frac{1.5\ \mathrm{kg} - 2.0\ \mathrm{kg}}{1.5\ \mathrm{kg} + 2.0\ \mathrm{kg}}\right)(3.00\tfrac{\mathrm{m}}{\mathrm{s}}) = -0.429\tfrac{\mathrm{m}}{\mathrm{s}}$$

that is, it bounces $\boxed{\text{backwards}}$ with a speed of $\boxed{0.429\frac{\mathrm{m}}{\mathrm{s}}}$.

b) What is the velocity of the 2.00 kg mass just after the collision?(3)

Using the same formulae for the struck mass, we get

$$v_2' = \left(\frac{2m_1}{m_1 + m_2}\right) v_1 = \frac{2(1.5\ \mathrm{kg})}{(3.5\ \mathrm{kg})}(3.00\tfrac{\mathrm{m}}{\mathrm{s}}) = 2.57\tfrac{\mathrm{m}}{\mathrm{s}}$$

so the struck mass goes forward (and off the table) with a speed of $\boxed{2.57\frac{\mathrm{m}}{\mathrm{s}}}$.

c) How long does the 2.0 kg block spend in flight? (5)

The initial velocity of the $2.0\ \mathrm{kg}$ mass has $v_{0x} = 2.57\frac{\mathrm{m}}{\mathrm{s}}$ and $v_{0y} = 0$. While falling, $a_x = 0$ and $a_y = -g$. When it hits the ground, $y = -2.0\ \mathrm{m}$. Solve for t in

$$y = -2.0\ \mathrm{m} = 0 + \tfrac{1}{2}(-g)t^2 \qquad \Longrightarrow \qquad t^2 = \frac{2(2.0\ \mathrm{m})}{9.80\frac{\mathrm{m}}{\mathrm{s}^2}} = 0.408\ \mathrm{s}^2$$

which gives

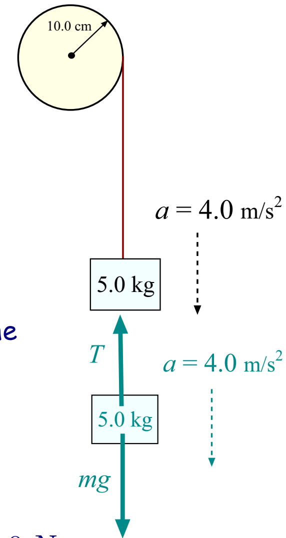
$$t = 0.639\ \mathrm{s}$$

d) How far has the 2.0 kg block traveled horizontally when it hits the floor? (4)

When it hits the floor, the x coordinate of the block is

$$x = v_{0x}t + 0 = (2.57\tfrac{\mathrm{m}}{\mathrm{s}})(0.639\ \mathrm{s}) = 1.64\ \mathrm{m}$$

4. A 5.00 kg mass is attached to a string which is wrapped tightly around a cylinder of radius 10.0 cm. The cylinder turns on a frictionless axle. The mass is released and it is found that the acceleration of the mass is $4.00\frac{\mathrm{m}}{\mathrm{s}^2}$ downward.



a) Find the tension in the string. (6)

Forces acting on the mass are as shown. Adding the *downward* forces on the mass and applying Newton's 2nd law gives

$$mg - T = ma$$

Then

$$T = mg - ma = m(g - a) = (5.0\ \mathrm{kg})(9.8\tfrac{\mathrm{m}}{\mathrm{s}} - 4.0\tfrac{\mathrm{m}}{\mathrm{s}}) = 29.0\ \mathrm{N}$$

b) What is the torque on the cylinder? (4)

The torque on the cylinder is from the tangential pull of the string; this gives (taking clockwise as positive, for convenience)

$$\tau = RF = (0.10\ \mathrm{m})(29.0\ \mathrm{N}) = 2.90\,\mathrm{N}\cdot\mathrm{m}$$

c) What is the angular acceleration of the cylinder? (Hint: Acceleration of the mass (a) is the same as tangential acceleration (a_t) of the cylinder's rim.) (3)

α is related to the acceleration of the mass by $a = r\alpha$. Then

$$\alpha = \frac{a}{r} = \frac{4.00\frac{\mathrm{m}}{\mathrm{s}^2}}{(0.100\ \mathrm{m})} = 40.0\frac{\mathrm{rad}}{\mathrm{s}^2}$$

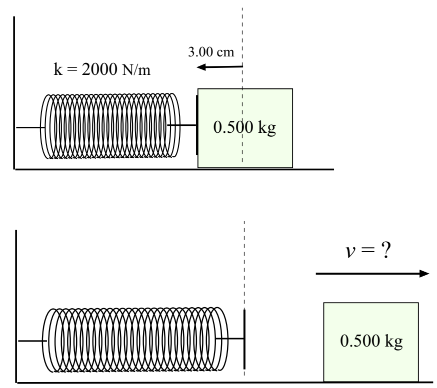
d) What is the moment of inertia of the cylinder? (4)

Use $\tau = I\alpha$ then

$$I = \frac{\tau}{\alpha} = \frac{(2.90\,\mathrm{N}\cdot\mathrm{m})}{(40.0\frac{\mathrm{rad}}{\mathrm{s}^2})} = 0.0725\,\mathrm{kg}\cdot\mathrm{m}^2$$

5. A 0.500 kg mass moves on a frictionless horizontal surface. We will launch the mass by holding it against a spring and releasing it.

The spring has force constant 2000 N/m and with the mass held against it, it is compressed by 3.00 cm.



a) What is the magnitude of the force of the spring on the mass before the mass is released? (4)

$$|F_x| = |kx| = (2000\,\tfrac{\text{N}}{\text{m}})(0.030\text{ m}) = 60\text{ N}$$

b) What is the speed of the mass when it leaves the spring? (Hint: The force of the spring is not constant. Think about energy.) (4)

From energy conservation, the energy stored in the spring prior to launching is the same as the kinetic energy of the mass when it leaves the spring:

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2 \qquad \Longrightarrow \qquad v^2 = \frac{kx^2}{m} = \frac{(2000\,\frac{\text{N}}{\text{m}})(0.030\text{ m})^2}{0.500\text{ kg}} = 3.6\,\frac{\text{m}^2}{\text{s}^2}$$

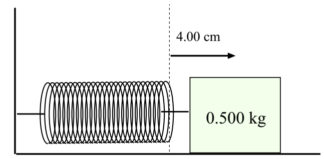
Then

$$v = 1.90\tfrac{\text{m}}{\text{s}}$$

6. Our formula for the period of a simple pendulum is valid only under a certain assumption about the pendulum's motion. What is that assumption? (3)

We assumed that the (angle) size of the oscillations would be "small" so that we could substitute θ itself for $\sin\theta$. If this approximation is bad for the motion of the pendulum, then our assumption is bad!

7. A 0.500 kg mass attached to a horizontal spring (and moving on a smooth horizontal surface) is made to oscillate by pulling it back by 4.00 cm and releasing it. It is then found that the mass oscillates at a rate of 3.00 Hz.



a) What is the period of the mass' motion? (2)

$$T = \frac{1}{f} = \frac{1}{3.00\ \mathrm{s}^{-1}} = 0.333\ \mathrm{s}$$

b) What is the force constant of the spring? (5)

Use

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad \Longrightarrow \qquad T^2 = 4\pi^2\frac{m}{k} \qquad \Longrightarrow \qquad k = \frac{4\pi^2 m}{T^2}$$

Then

$$k = \frac{4\pi^2(0.500\ \mathrm{kg})}{(0.333\ \mathrm{s})^2} = 178\ \tfrac{\mathrm{N}}{\mathrm{m}}$$

c) What is the maximum speed of the mass? (3)

$$v_{\max} = \omega A = 2\pi f A = 2\pi(3.00\ \mathrm{s}^{-1})(0.0400\ \mathrm{m}) = 0.754\tfrac{\mathrm{m}}{\mathrm{s}}$$

8. a) Explain the terms **transverse wave** and **longitudinal wave**. (3)

A transverse wave is one for which the displacement of the medium (through which the wave travels) is perpendicular to the motion of the wave disturbance itself. Example is a string wave.

Longitudinal wave is one for which the motion of the medium is along the direction of travel of the wave. Example is a sound wave (in air)

b) Explain in a few sentences how a sound wave is produced (and what a sound wave *is*). (3)

Sound waves are generated by a vibrating mechanical object (usually a surface) which sets the air in motion so that there are periodic regions of increased air density and pressure. These regions propagate through the air and are detected when they arrive at our ears.

9. A police car comes toward you with its siren emitting sound with frequency 800 Hz. You hear it as 825 Hz. What is the speed of the police car? Use $343\frac{\mathrm{m}}{\mathrm{s}}$ for the speed of sound. (6)

This is a case of a moving source, so that we have:

$$f_o = f_s\left(\frac{1}{1-\frac{v_s}{v}}\right) \qquad \text{with} \quad v = 343\tfrac{\mathrm{m}}{\mathrm{s}}$$

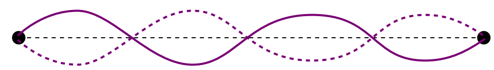
Do some algebra:

$$1 - \frac{v_s}{v} = \frac{f_s}{f_o} = \frac{800}{825} = 0.9697$$

Then

$$\frac{v_s}{v} = 1 - 0.9697 = 0.0303 \qquad \Longrightarrow \qquad v_s = (0.0303)(343\tfrac{\mathrm{m}}{\mathrm{s}}) = 10.4\tfrac{\mathrm{m}}{\mathrm{s}}$$

10. A string with two fixed ends is made to vibrate in a standing wave which has the appearance as shown at the right. The frequency of the vibrations is 180 Hz. The string has length 1.80 m and mass density 5.0×10^{-3} kg/m



a) Find the speed of waves on the string. (5)

From the pattern we see that a wavelength of the wave is *half* the string length, so $\lambda = 0.90$ m. Then

$$v = \lambda f = (0.90 \text{ m})(180 \text{ s}^{-1}) = 162\tfrac{\text{m}}{\text{s}}$$

b) Find the tension of the string. (5)

Use

$$v = \sqrt{\frac{F}{\mu}} \qquad \Longrightarrow \qquad v^2 = \frac{F}{\mu}$$

Then:

$$F = v^2\mu = (162\tfrac{\text{m}}{\text{s}})^2(5.0 \times 10^{-3} \text{ kg/m}) = 131 \text{ N}$$

You must show all your work and include the right units with your answers!

$$A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad A = \sqrt{A_x^2 + A_y^2} \qquad \tan\theta = A_y/A_x$$

$$v_x = v_{0x} + a_x t \qquad x = v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2a_x x \qquad x = \tfrac{1}{2}(v_{0x} + v_x)t$$

$$g = 9.80\tfrac{\text{m}}{\text{s}^2} \qquad R = \frac{2v_0^2 \sin\theta\cos\theta}{g} \qquad \mathbf{F}_{\text{net}} = m\mathbf{a} \qquad \text{Weight} = mg$$

$$F = G\frac{m_1 m_2}{r^2} \qquad G = 6.67\times 10^{-11}\,\tfrac{\text{N}\cdot\text{m}^2}{\text{kg}^2} \qquad f_{\text{s}}^{\text{Max}} = \mu_s F_N \qquad f_{\text{k}} = \mu_{\text{k}} F_N$$

$$v = \frac{2\pi R}{T} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad W = Fs\cos\theta$$

$$\text{PE}_{\text{grav}} = mgh \qquad \text{KE} = \tfrac{1}{2}mv^2 \qquad E = \text{PE} + \text{KE} \qquad \Delta E = W_{\text{nc}} \qquad P = \frac{W}{t}$$

$$\mathbf{p} = m\mathbf{v} \qquad \text{For isolated system} \quad \mathbf{p}_{\text{Tot}} \quad \text{is conserved} \qquad 1\text{ rev} = 360\text{ deg} = 2\pi\text{ rad}$$

$$v_1' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_1 \qquad v_2' = \left(\frac{2m_1}{m_1 + m_2}\right)v_1$$

$$\omega = \omega_0 + \alpha t \qquad \theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_0^2 + 2\alpha\theta \qquad \theta = \tfrac{1}{2}(\omega_0 + \omega)t \qquad s = r\theta \qquad v_T = r\omega$$

$$a_T = r\alpha \qquad a_c = r\omega^2 \qquad \tau = Fr\sin\phi \qquad \tau = I\alpha \qquad \text{KE}_{\text{rot}} = \tfrac{1}{2}I\omega^2$$

$$I_{\text{disk}} = \tfrac{1}{2}MR^2 \qquad I_{\text{sph}} = \tfrac{2}{5}MR^2 \qquad I_{\text{rod, end}} = \tfrac{1}{3}ML^2 \qquad I_{\text{rod, mid}} = \tfrac{1}{12}ML^2$$

$$v_{\text{ctr}} = r\omega \qquad a_{\text{ctr}} = r\alpha \qquad \text{KE}_{\text{roll}} = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 \qquad L = I\omega$$

$$F_{\text{spr},x} = -kx \qquad \text{PE}_{\text{spr}} = \tfrac{1}{2}kx^2 \qquad E = \tfrac{1}{2}kx^2 + \tfrac{1}{2}mv^2 \qquad T = \frac{1}{f} \qquad \omega = 2\pi f$$

$$\omega = \sqrt{\frac{k}{m}} \qquad v_{\max} = \omega A \qquad a_{\max} = \omega^2 A \qquad T = 2\pi\sqrt{\frac{L}{g}} \qquad \omega = \sqrt{\frac{I}{mgL}}$$

$$\lambda f = v \qquad v = \sqrt{\frac{F}{\mu}} \qquad \mu = \frac{M}{L} \qquad I = \frac{P}{4\pi r^2} \qquad \beta = (10\text{ dB})\log_{10}\left(\frac{I}{I_0}\right) \qquad I_0 = 10^{-12}\,\tfrac{\text{W}}{\text{m}^2}$$

$$f_{\text{beat}} = |f_1 - f_2| \qquad f_o = f_s\left(\frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}\right) \qquad \text{with:}\begin{pmatrix}\text{Toward}\\ \text{Away}\end{pmatrix}$$

$$\text{Use} \quad 343\tfrac{\text{m}}{\text{s}} \quad \text{for speed of sound} \qquad \rho = \frac{m}{V} \qquad P = \frac{F}{A}$$