Name ______________________________

Dec. 7, 2006

Phys 2010, NSCC
Exam #3 — Fall 2006

1.	____________	(15)
2.	____________	(9)
3.	____________	(14)
4.	____________	(13)
5.	____________	(6)
6.	____________	(7)
7.	____________	(8)
8.	____________	(11)
9.	____________	(7)
MC	____________	(10)
Total	____________	(100)

Multiple Choice

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

1. The units of angular momentum (L) are

a) $1\,\frac{\mathrm{kg}^2\cdot\mathrm{m}^2}{\mathrm{s}}$

b) $1\,\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}$

c) $1\,\frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}^2}$

$\boxed{\text{d)}}$ $1\,\frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}}$

2. A mass oscillates on the end of an ideal vertical spring; the amplitude of the motion is 1.0 cm and the frequency of the motion is 3.0 Hz. If we set it in motion so that the amplitude is 2.0 cm, the frequency will be

a) 1.5 Hz

$\boxed{\textbf{b)}}$ 3.0 Hz

c) 6.0 Hz

d) 12.0 Hz

3. A 100 g mass oscillates on the end of an ideal vertical spring; the frequency of the motion is 3.00 Hz. If we replace the mass by a 200 g mass, the the new frequency will be

a) 1.50 Hz

$\boxed{\textbf{b)}}$ 2.12 Hz

c) 4.24 Hz

d) 6.00 Hz

4. If a total force of 5.0×10^2 N is applied over an area of 0.010 m^2, the pressure on that area is

a) 2.0×10^{-5} Pa.

b) 2.0×10^{-4} Pa.

c) 5.0×10^{3} Pa.

$\boxed{\textbf{d)}}$ 5.0×10^{4} Pa.

5. A sound of intensity $10^{-7}\,\frac{\mathrm{W}}{\mathrm{m}^2}$ has an intensity level of

a) 40 dB

$\boxed{\textbf{b)}}$ 50 dB

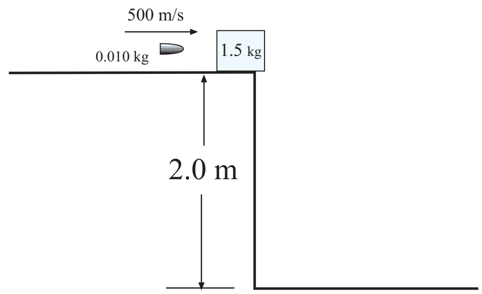
c) 60 dB

d) 70 dB

Problems

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

1. A 1.5 kg mass is at the edge of a table which is 2.0 m high. A bullet of mass 0.010 kg is fired at the block with a speed of $500\frac{\text{m}}{\text{s}}$; it becomes stuck in the block and the combined mass moves off the table with an initial horizontal velocity and later lands on the floor at a horizontal distance d from the starting point.



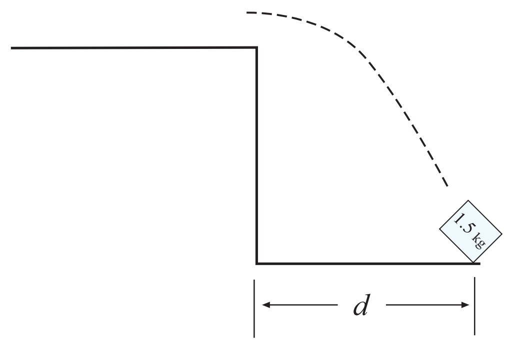
a) What was the speed of the block/bullet combination after the impact? (5)

Momentum is conserved in the collision (since it is very rapid). This gives:

$$(0.010\ \text{kg})(500\tfrac{\text{m}}{\text{s}}) = (1.510\ \text{kg})v$$

Solve for v, get:

$$v = 3.31\tfrac{\text{m}}{\text{s}}$$



b) How long did it take the block to hit the floor? (5)

The combined block/bullet is in free fall with an initial horizontal velocity ($v_{0y} = 0$). It hits the floor when $y = -2.00\ \text{m}$. The y equation of motion gives:

$$-2.0\ \text{m} = 0 + \tfrac{1}{2}(-9.8\tfrac{\text{m}}{\text{s}^2})t^2$$

Solve for t and get:

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

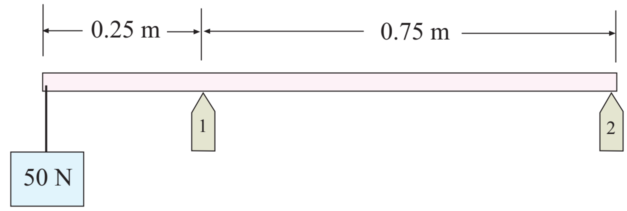
c) What is the distance d? (5)

Solve for the value of x at the time found in (b), using $v_{0x} = 3.31\frac{\text{m}}{\text{s}}$, which was found in (a). The x equation of motion gives:

$$x = v_{0x}t + 0 = (3.31\tfrac{\text{m}}{\text{s}})(0.639\ \text{s}) = 2.11\ \text{m}$$

2. A horizontal uniform bar of length 1.00 m and weight 80 N is supported at its right end and at a point 0.25 m from the left end. A 50 N hangs from the left end.

Find the magnitudes of the two (upward) forces from the two supports. (9)



Note that the weight of the bar itself puts a downward force of 80 N at the middle of the bar (0.50 m from either end).

With that in mind, put the axis at the right end of the bar and use the condition that the total torque is zero. Get:

$$(+50 \text{ N})(1.0 \text{ m}) - F_1(0.75 \text{ m}) + (80 \text{ N})(0.50 \text{ m}) = 0$$

Solve for F_1. Get:

$$F_1 = 120 \text{ N}$$

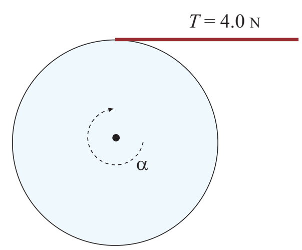
The sum of the (vertical) forces also gives zero, so:

$$-50 \text{ N} + F_1 - 80 \text{ N} + F_2 = 0 \qquad \Longrightarrow \qquad -50 \text{ N} + 120 \text{ N} - 80 \text{ N} + F_2 = 0$$

Solve for F_2. Get:

$$F_2 = 10 \text{ N}$$

3. A string is wrapped around the outside of a uniform cylinder of radius 15.0 cm; the cylinder rotates freely about its center and is initially at rest. The string is given a tension of 4.0 N and as a result of the torque from the string, the cylinder speeds up, making 20 revolutions in 8.0 s.



a) What is angular acceleration of the cylinder? (6)

The angular displacement is

$$20 \text{ rev} \left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right) = 125.7 \text{ rad} = \theta = \tfrac{1}{2}\alpha t^2$$

With $t = 8.0$ s, solve for α:

$$\alpha = \frac{2\theta}{t^2} = \frac{2(125.7 \text{ rad})}{(8.0 \text{ s})^2} = 3.93\tfrac{\text{rad}}{\text{s}^2}$$

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

The force of the string is perpendicular to the line connecting the axis and the point of application, so

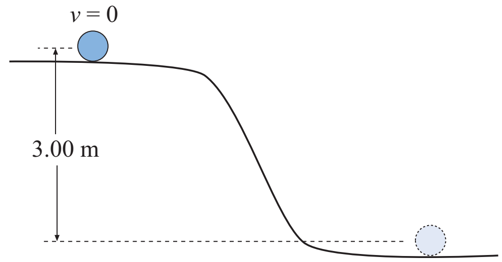
$$\tau_{\text{net}} = rF(1) = (0.15 \text{ m})(4.0 \text{ N}) = 0.60\,\text{N}\cdot\text{m}$$

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

Use $\tau_{\text{net}} = I\alpha$, then

$$I = \frac{\tau_{\text{net}}}{\alpha} = \frac{(0.60\,\text{N}\cdot\text{m})}{(3.93\frac{\text{rad}}{\text{s}^2})} = 0.152\,\text{kg}\cdot\text{m}^2$$

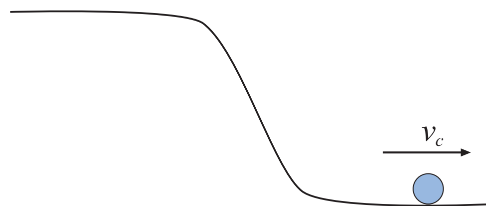
4. A solid uniform cylinder of mass 0.400 kg is at the top level of a two-level track, at a height of 3.00 m above the lower level. It is initially at rest, but it rolls down the track without slipping and on the bottom level the speed of its center of mass is v_c.



a) What is potential energy of the mass in the initial position (we'll agree that the final potential energy is *zero*)? (4)

Mass is initially at rest; total energy is the potential energy, which is

$$\mathrm{PE_{grav}} = mgh = (0.40\ \mathrm{kg})(9.8\tfrac{\mathrm{m}}{\mathrm{s}^2})(3.0\ \mathrm{m}) = 11.8\ \mathrm{J}$$



b) What is the *total* kinetic energy of the cylinder when it gets to the lower level? (This is easy if you got part (a), but give a *reason*.) (2)

Energy in conserved (no frictional forces doing any work here) so, since at the bottom the cylinder has no potential energy, its (total) kinetic energy is the same as the answer to (a),

$$\mathrm{KE_{tot}} = 11.8\ \mathrm{J}$$

c) Keeping in mind that the kinetic energy of the ball has *translational* and *rotational* parts, find the speed v_c of the cylinder's center. (7)

$$\begin{aligned} \mathrm{KE_{tot}} &= \tfrac{1}{2}mv_c^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv_c^2 + \tfrac{1}{2}\left(\tfrac{1}{2}mR^2\right)\left(\frac{v_c}{R}\right)^2 \\ &= \tfrac{1}{2}mv_c^2 + \tfrac{1}{4}mv_c^2 = \tfrac{3}{4}mv_c^2 = 11.8\ \mathrm{J} \end{aligned}$$

Now solve for v_c:

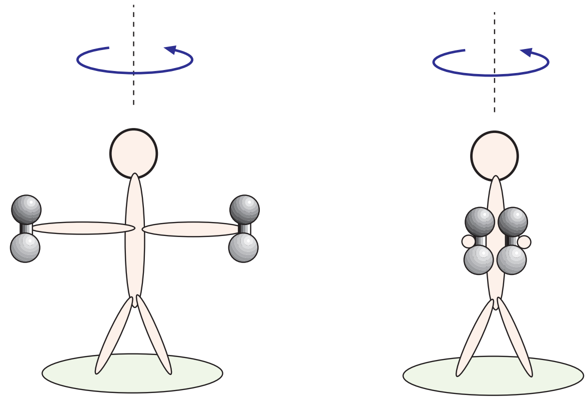
$$v_c^2 = \frac{4}{3}\frac{(11.8\ \mathrm{J})}{(0.40\ \mathrm{kg})} = 39.2\ \tfrac{\mathrm{m}^2}{\mathrm{s}^2}$$

Finally,

$$v_c = 6.26\tfrac{\mathrm{m}}{\mathrm{s}}$$

5. A man stands on a platform with arms outstretched holding onto two dumbells. The man and platform rotate with and angular speed of $6.00\frac{\text{rad}}{\text{s}}$. In this position, the total moment of inertia of the system is $6.20\,\text{kg}\cdot\text{m}^2$. By pulling in his arms he reduces the moment of inertia to $4.20\,\text{kg}\cdot\text{m}^2$.

Find his new angular speed. (6)



Angular momentum of the system is conserved, so

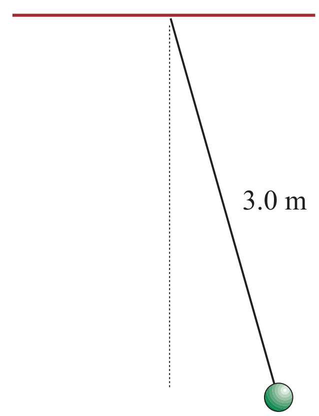
$$I_1\omega_1 = I_2\omega_2$$

Then the final angular speed is

$$\omega_2 = \frac{I_1}{I_2}\omega_1 = \frac{(6.20\,\text{kg}\cdot\text{m}^2)}{(4.20\,\text{kg}\cdot\text{m}^2)}(6.00\tfrac{\text{rad}}{\text{s}}) = 8.86\tfrac{\text{rad}}{\text{s}}$$

6. When a simple pendulum of length 3.0 m makes small oscillations on the surface of a certain planet, the period of the motion is found to be 4.00 s.

What is the value of g (the acceleration of gravity) on the surface of this planet? (7)



$$T = 2\pi\sqrt{\frac{L}{g}} \qquad \Longrightarrow \qquad T^2 = 4\pi^2\frac{L}{g}$$

Find g:

$$g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2(3.00\ \text{m})}{(4.00\ \text{s})^2} = 7.4\tfrac{\text{m}}{\text{s}^2}$$

7. A train's horn has a characteristic frequency of 440 Hz. A commuter standing on the platform hears a frequency of 485 Hz.

a) Is the train approaching the station or going away from it? (How do you know?) (2)

The observer detects a *higher* frequency than that emitted by the source so that s/he is receiving the wave crests at an increased rate. This can only happen if the source (train) is $\boxed{\text{approaching}}$.

b) What is the speed of the train? (6)

Since the observer is waiting at the station, s/he is stationary and $v_o = 0$. Then use:

$$f_o = f_s \left(\frac{1}{1 - v_s/v} \right) \qquad \Longrightarrow \qquad 485 \text{ Hz} = (440 \text{ Hz}) \left(\frac{1}{(1 - v_s/v)} \right)$$

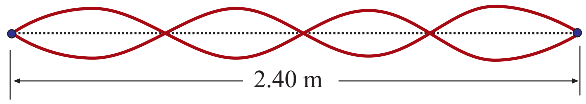
where $v = 343 \frac{\text{m}}{\text{s}}$. Solve for v_s:

$$1 - \frac{v_s}{v} = \frac{(440 \text{ Hz})}{(485 \text{ Hz})} = 0.907 \qquad \Longrightarrow \qquad \frac{v_s}{v} = 1 - 0.907 = 0.928$$

Then:

$$v_s = (0.928)v = (0.928)(343 \tfrac{\text{m}}{\text{s}}) = 31.1 \tfrac{\text{m}}{\text{s}}$$

8. A stretched string of length 2.40 m is under a tension of 60.0 N and has mass density 7.00×10^{-3} kg/m. The string is caused to vibrate in the stable pattern shown at the right



a) What is the wavelength of the wave? (3)

For a standing wave, one "bump" is a half-wavelength, so a *full* wavelength is clearly half the length of the string, namely $\boxed{1.2\ \mathrm{m}}$.

b) What is the speed of waves on the string? (5)

Use the given values of the tension and the mass density, then

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{(60.0\ \mathrm{N}}{(7.00 \times 10^{-3}\ \mathrm{kg/m})}} = 92.6 \tfrac{\mathrm{m}}{\mathrm{s}}$$

c) What is the frequency of oscillation of the wave? (3)

Use $\lambda f = v$, then

$$f = \frac{v}{\lambda} = \frac{(92.6 \frac{\mathrm{m}}{\mathrm{s}})}{(1.2\ \mathrm{m})} = 77.2\ \mathrm{Hz}$$

9. Find the mass density of cube which has a side of length 2.00 cm and a mass of 63.0 g. Express the answer in units of $\frac{\mathrm{kg}}{\mathrm{m}^3}$. (7)

The volume of the cube is $8.0\ \mathrm{cm}^3$, so in cgs units the density is

$$\rho = \frac{M}{V} = \frac{(63.0\ \mathrm{g})}{(8.0\ \mathrm{cm}^3)} = 7.87\ \frac{\mathrm{g}}{\mathrm{cm}^3}$$

In MKS units, this is

$$\rho = (7.87\ \tfrac{\mathrm{g}}{\mathrm{cm}^3}) \left(\frac{1\ \mathrm{kg}}{1000\ \mathrm{g}}\right) \left(\frac{100\ \mathrm{cm}}{1\ \mathrm{m}}\right)^3 = 7870\ \frac{\mathrm{kg}}{\mathrm{m}^3}$$

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

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

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

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

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

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

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

$\mathbf{p} = m\mathbf{v}$ For isolated system $\mathbf{p}_{\mathrm{Tot}}$ is conserved

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

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

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

$L = I\omega$ For system with no ext torques L_{Tot} is conserved

$$F_{\mathrm{spr},x} = -kx \qquad \mathrm{PE_{spr}} = \tfrac{1}{2}kx^2 \qquad T = \frac{1}{f} \qquad \omega = 2\pi f$$

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

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

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

Use $343\tfrac{\mathrm{m}}{\mathrm{s}}$ for speed of sound   1 rev = 360 deg = 2π rad