Name____________________________

Dec. 9, 2005

Phys 2010, NSCC
Exam #3 — Fall 2005

1.	________________	(8)
2.	________________	(8)
3.	________________	(8)
4.	________________	(12)
5.	________________	(10)
6.	________________	(12)
7.	________________	(14)
8.	________________	(10)
9.	________________	(10)
MC	________________	(10)
Total	________________	(102) (!)

Multiple Choice

Choose the best answer from among the four!

1. Using $340\frac{\text{m}}{\text{s}}$ for the speed of sound, a sound wave with a wavelength of 34 cm has a frequency of

a) 1.0 kHz

b) 11.6 kHz

c) 100 kHz

d) 1.16 MHz

2. A mass M is attached to a spring and making (vertical) oscillations with period T. If the mass is replaced by a mass $9M$, the new period of oscillation will be

a) $\frac{1}{3}T$

$\boxed{\textbf{b)}}$ $3T$

c) $9T$

d) $27T$

3. If you increase your distance from an isotropic source of sound by a factor of 4, the intensity of the sound you hear changes by a factor of

a) $\frac{1}{2}$

b) $\frac{1}{4}$

$\boxed{\textbf{c)}}$ $\frac{1}{16}$

d) $\frac{1}{64}$

4. To double the speed of waves on a stretched string, you need to change the tension in the string by a factor of

a) $\frac{1}{4}$

b) $\frac{1}{2}$

c) 2

$\boxed{\textbf{d)}}$ 4

5. If a sound wave has an intensity of $10^{-8}\ \frac{\mathrm{W}}{\mathrm{m}^2}$, it has an *intensity level* of

a) 0.8 dB

b) 4 dB

$\boxed{\textbf{c)}}$ 40 dB

d) 80 dB

Problems

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

1. For the following quantities which you have encountered this semester, give the appropriate metric (SI) units in which they should be expressed: (8)

a) Rotational kinetic energy ($\mathrm{KE}_{\mathrm{rot}}$):

Joule, J

b) The force constant of a spring, k.

$\frac{\mathrm{N}}{\mathrm{m}}$

c) Angular acceleration, α.

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

d) Moment of inertia, I

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

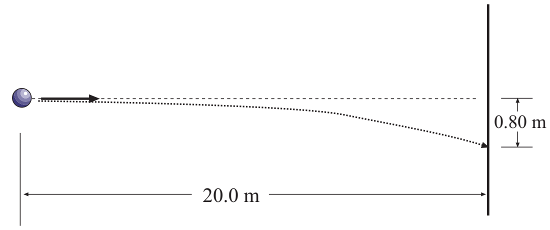
e) Torque, τ

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

f) Angular momentum, L

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

2. A projectile is fired horizontally; when it strikes a vertical wall which is 20.0 m from the starting point its vertical position has dropped by 0.80 m



a) How long was the projectile in flight? (4)

There is no initial y velocity v_{0y}, so the y eqn of motion is

$$y = -\tfrac{1}{2}gt^2 \qquad \Longrightarrow \qquad t^2 = -\frac{2y}{g}$$

At impact, $y = -0.80\ \mathrm{m}$, so

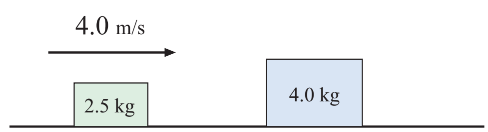
$$t^2 = -\frac{2(-0.80\ \mathrm{m})}{(9.8\frac{\mathrm{m}}{\mathrm{s}^2})} = 0.163\ \mathrm{s}^2 \qquad \Longrightarrow \qquad t = 0.404\ \mathrm{s}$$

b) What was the initial speed of the projectile? (4)

The x equation of motion is $x = v_{0x}t$. At impact, $x = 20.0\ \mathrm{m}$ and $t = 0.404\ \mathrm{s}$, so

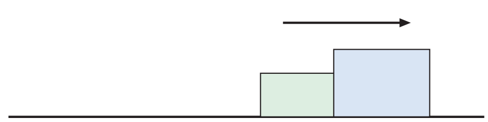
$$v_{0x} = \frac{x}{t} = \frac{(20.0\ \mathrm{m})}{(0.404\ \mathrm{s})} = 49.5\tfrac{\mathrm{m}}{\mathrm{s}}$$

3. Two masses move on a frictionless track; a 2.50 kg mass has a speed of $4.0\frac{\mathrm{m}}{\mathrm{s}}$ and moves toward a 4.00 kg mass which is at rest. The masses stick together in the collision.



a) What is the speed of the combined mass after the collision? (4)

Total momentum (mv_x) is conserved, so



$$(2.50\ \mathrm{kg})(4.0\tfrac{\mathrm{m}}{\mathrm{s}}) + 0 = (2.50\ \mathrm{kg} + 4.00\ \mathrm{kg})v_f$$

$$\Longrightarrow \qquad v_f = \frac{(2.50\ \mathrm{kg})(4.0\frac{\mathrm{m}}{\mathrm{s}})}{(6.50\ \mathrm{kg})} = 1.54\tfrac{\mathrm{m}}{\mathrm{s}}$$

b) How much kinetic energy was lost in the collision? (4)

Initial and final kinetic energies were

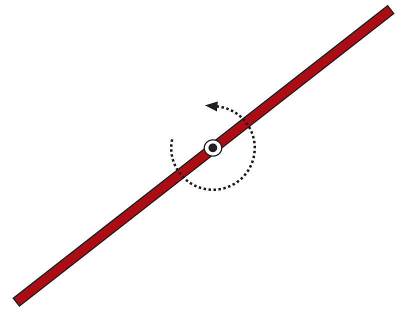
$$\mathrm{KE}_i = \tfrac{1}{2}(2.5\ \mathrm{kg})(4.0\tfrac{\mathrm{m}}{\mathrm{s}})^2 = 20.0\ \mathrm{J} \qquad \mathrm{KE}_f = \tfrac{1}{2}(6.5\ \mathrm{kg})(1.54\tfrac{\mathrm{m}}{\mathrm{s}})^2 = 7.69\ \mathrm{J}$$

So

$$20.0\ \mathrm{J} - 7.7\ \mathrm{J} = 12.3\ \mathrm{J}$$

of kinetic energy was lost.

4. A uniform rod of length 1.00 m and mass 1.50 kg is pivoted to turn freely about its center (as shown). It is initially at rest; a constant torque is applied to it and 3.00 s later it has made 12.5 complete revolutions.



a) What is the angular displacement in radians? (2)

$$\theta = 12.5\ \text{rev}\left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right) = 78.5\ \text{rad}$$

b) What is the angular acceleration of the rotating rod (while the torque is applied)? (4)

The rod starts from rest, so

$$\theta = \tfrac{1}{2}\alpha t^2 \qquad \Longrightarrow \qquad \alpha = \frac{2\theta}{t^2}$$

Plug in the numbers:

$$\alpha = \frac{2(78.5\ \text{rad}}{(3.00\ \text{s})^2} = 17.4\tfrac{\text{rad}}{\text{s}^2}$$

c) What is the moment of inertia of the rotating rod? (3)

For a rod rotating about its center, $I = \frac{1}{12}ML^2$, so

$$I = \tfrac{1}{12}(1.50\ \text{kg})(1.00\ \text{m})^2 = 0.125\,\text{kg}\cdot\text{m}^2$$

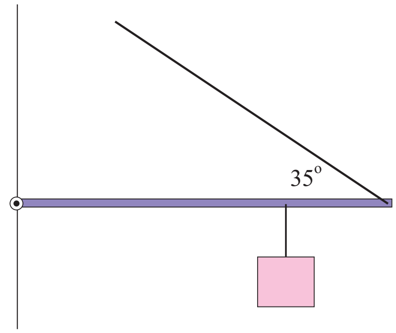
d) What is the magnitude of the net torque on the rod? (3)

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

$$\tau_{\text{net}} = I\alpha = (0.125\,\text{kg}\cdot\text{m}^2)(17.4\tfrac{\text{rad}}{\text{s}^2}) = 2.18\,\text{N}\cdot\text{m}$$

5. A 2.0 m–long rod with a *mass* of 15.0 kg is attached to a wall by a hinge. The rod has a weight W hanging from it at a distance of 1.6 m from the wall and is supported by a cable which is directed at 35° above the horizontal. (See figure at right.)

The cable will break if its tension exceeds 300 N. What is the largest weight W which can hang from the rod? (10)

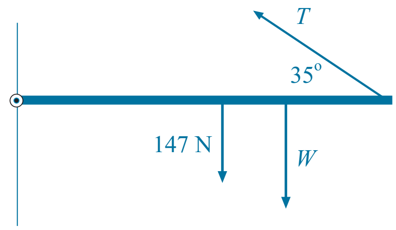


The forces acting on the rod (not counting those at the hinge itself; those forces give no torque) are gravity (Mg downward, at the center of the rod), the tension of the cord which supports the weight W (W downward, $1.60\ \mathrm{m}$ from the hinge) and the tension of the cable (T, at $2.0\ \mathrm{m}$ from the hinge and directed at 35° from the horizontal).

These forces are shown at the right.

To find the largest possible value of W, set T equal to its largest possible value, $T = 300\ \mathrm{N}$. Also, the *weight* of the rod is

$$Mg = (15.0\ \mathrm{kg})(9.80\tfrac{\mathrm{m}}{\mathrm{s}^2}) = 147\ \mathrm{N}$$



The sum of the torques from these forces gives zero. Then:

$$-(147\ \mathrm{N})(1.00\ \mathrm{m}) - W(1.60\ \mathrm{m}) + (300\ \mathrm{N})(2.00\ \mathrm{m})\sin 35^\circ = 0$$

Solve for W:

$$W(1.60\ \mathrm{m}) = 197\,\mathrm{N}\cdot\mathrm{m} \qquad \Longrightarrow \qquad W = 123\ \mathrm{N}$$

6. A solid uniform sphere of radius 6.00 cm is rolling without slipping on a flat surface. It has a mass of 1.30 kg; its center of mass is moving with a speed of $2.6 \frac{\text{m}}{\text{s}}$.

a) What is the total kinetic energy of the sphere? (6)

The total kinetic energy of the (rolling) sphere is

$$\begin{aligned} \text{KE}_{\text{roll}} &= \text{KE}_{\text{trans}} + \text{KE}_{\text{rot}} = \tfrac{1}{2}Mv^2 + \tfrac{1}{2}I\omega^2 \\ &= \tfrac{1}{2}Mv^2 + \tfrac{1}{2}\left(\tfrac{2}{5}MR^2\right)\left(\frac{v}{R}\right)^2 = \tfrac{1}{2}Mv^2 + \tfrac{1}{5}Mv^2 \\ &= \tfrac{7}{10}Mv^2 \end{aligned}$$

Plug in the numbers:

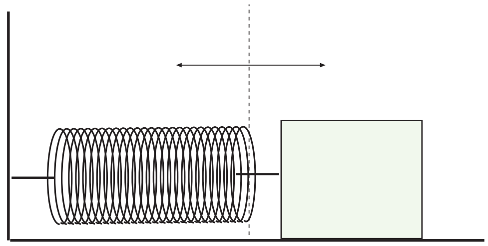
$$\text{KE}_{\text{roll}} = \tfrac{7}{10}(1.30\text{ kg})(2.6\tfrac{\text{m}}{\text{s}})^2 = 6.15\text{ J}$$

b) From the flat surface, the sphere rolls up a slope, again without slipping. What is the maximum height attained by the sphere? (Hint: Use energy conservation.) (6)

At maximum height the sphere is motionless, so all of the energy found in part (a) is now potential energy (gravity):

$$6.15\text{ J} = Mgh = (1.3\text{ kg})(9.80\tfrac{\text{m}}{\text{s}^2})h \qquad \Longrightarrow \qquad h = \frac{(6.15\text{ J})}{(1.3\text{ kg})(9.8\frac{\text{m}}{\text{s}^2})} = 0.48\text{ m}$$

7. A 800-gram mass attached to a spring oscillates on a horizontal frictionless surface. The amplitude of its motion is 5.5 cm. It is found to make 25.0 oscillations in 10.0 seconds.



a) Find the period of the motion. (3)

The frequency is

$$f = \frac{(25.0 \text{ osc})}{(10.0 \text{ s})} = 2.5 \text{ Hz}$$

and the period is

$$T = \frac{1}{f} = \frac{1}{(2.5 \text{ Hz})} = 0.40 \text{ s}$$

b) Find the force constant of the spring. (5)

Use

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

Plug in the numbers,

$$k = \frac{4\pi^2(0.800 \text{ kg})}{(0.40 \text{ s})^2} = 197 \, \tfrac{\text{N}}{\text{m}}$$

c) Find the maximum speed of the mass. (3)

The angular frequency of the system is

$$\omega = 2\pi f = 2\pi(2.5 \text{ Hz}) = 15.7\tfrac{\text{rad}}{\text{s}}$$

and the maximum speed is

$$v_{\max} = \omega A = (15.7\tfrac{\text{rad}}{\text{s}})(0.055 \text{ m}) = 0.864\tfrac{\text{m}}{\text{s}}$$

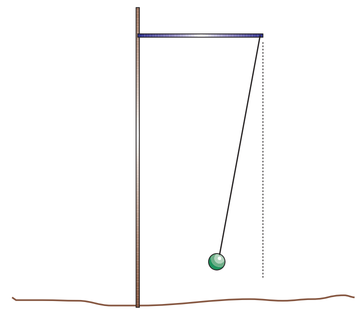
d) Find the total energy of the system. (3)

The total energy of the system can be found from

$$E_{\text{tot}} = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(197 \, \tfrac{\text{N}}{\text{m}})(0.055 \text{ m})^2 = 0.299 \text{ J}$$

8. A simple pendulum has a period of 2.80 s when it makes small oscillations on earth.

a) Find the length of the pendulum. (5)



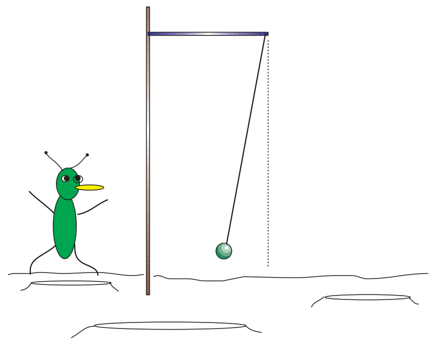
Use

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

Plug in the numbers:

$$L = \frac{(2.80\ \mathrm{s})^2(9.80\frac{\mathrm{m}}{\mathrm{s}^2})}{3\pi^2} = 1.95\ \mathrm{m}$$

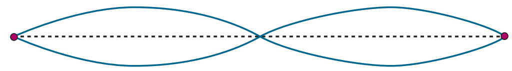
b) If the same pendulum is taken to a strange planet it is found to have a period of 3.30 s. What is the value of g on this planet? (5)



Pendulum has the *same length* as before, but a different period (and g is different). Solving for g,

$$g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2(1.95\ \mathrm{m})}{(3.30\ \mathrm{s})^2} = 7.05\frac{\mathrm{m}}{\mathrm{s}^2}$$

9. A standing wave pattern on a string is set up as shown at the right. The length of the string is 1.40 m and the frequency of oscillation is 180 Hz.



a) Find the speed of waves on the string. (4)

Here, the wavelength of the standing wave is *the same* as the length of the string, so $\lambda = 1.40$ m. We have the frequency of the wave, so the speed of waves on the string is

$$v = \lambda f = (1.40 \text{ m})(180 \text{ Hz}) = 252 \tfrac{\text{m}}{\text{s}}$$

b) If the mass density of the string is $5.5 \times 10^{-3} \frac{\text{kg}}{\text{m}}$, what is the tension in the string? (6)

Use

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

Plug in the numbers

$$F = (5.5 \times 10^{-3} \tfrac{\text{kg}}{\text{m}})(252 \tfrac{\text{m}}{\text{s}})^2 = 349 \text{ N}$$

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

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

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

$$v_y = v_{0y} + a_y t \qquad y = v_{0y}t + \tfrac{1}{2}a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2a_y y \qquad y = \tfrac{1}{2}(v_{0y} + v_y)t$$

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

$$F = G\frac{m_1 m_2}{r^2} \qquad G = 6.67\times 10^{-11}\,\tfrac{\mathrm{N\cdot m^2}}{\mathrm{kg^2}} \qquad 4\pi^2 r^3 = GMT^2$$

$$F_{\mathrm{s}}^{\mathrm{Max}} = \mu_{\mathrm{s}} F_N \qquad F_{\mathrm{k}} = \mu_{\mathrm{k}} F_N \qquad v = \frac{2\pi R}{T} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r}$$

$$W = Fs\cos\theta \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad \mathrm{PE}_{\mathrm{grav}} = mgy \qquad E = \mathrm{KE} + \mathrm{PE} \qquad \Delta E = W_{\mathrm{fric,\,misc}}$$

$$\mathbf{p} = m\mathbf{v} \qquad v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_{1i} \qquad v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right)v_{1i}$$

$$2\pi \text{ rad} = 360 \text{ deg} = 1 \text{ rev} \qquad s = \theta r \qquad C = 2\pi R$$

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

$$a_T = r\alpha \qquad a_c = r\omega^2 \qquad v_{\mathrm{CM}} = \omega R \qquad \tau = Fr\sin\phi \qquad \tau = I\alpha$$

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

$$\mathrm{KE}_{\mathrm{rot}} = \tfrac{1}{2}I\omega^2 \qquad \mathrm{KE}_{\mathrm{roll}} = \mathrm{KE}_{\mathrm{trans}} + \mathrm{KE}_{\mathrm{rot}} = \tfrac{1}{2}Mv^2 + \tfrac{1}{2}I\omega^2 \qquad L = I\omega$$

$$F = -kx \qquad \mathrm{PE}_{\mathrm{spring}} = \tfrac{1}{2}kx^2 \qquad T = \frac{1}{f} \qquad \omega = 2\pi f \qquad v_{\mathrm{max}} = \omega A \qquad a_{\mathrm{max}} = \omega^2 A$$

$$E_{\mathrm{tot}} = \tfrac{1}{2}kA^2 = \tfrac{1}{2}mv_{\mathrm{max}}^2 \qquad T = 2\pi\sqrt{\frac{m}{k}} \qquad T = 2\pi\sqrt{\frac{L}{g}} \qquad T = 2\pi\sqrt{\frac{I}{Mgd}}$$

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