Instructor(s): *Woodard/Yelton*

PHYSICS DEPARTMENT

PHY 2048 Final Exam December 8, 2018

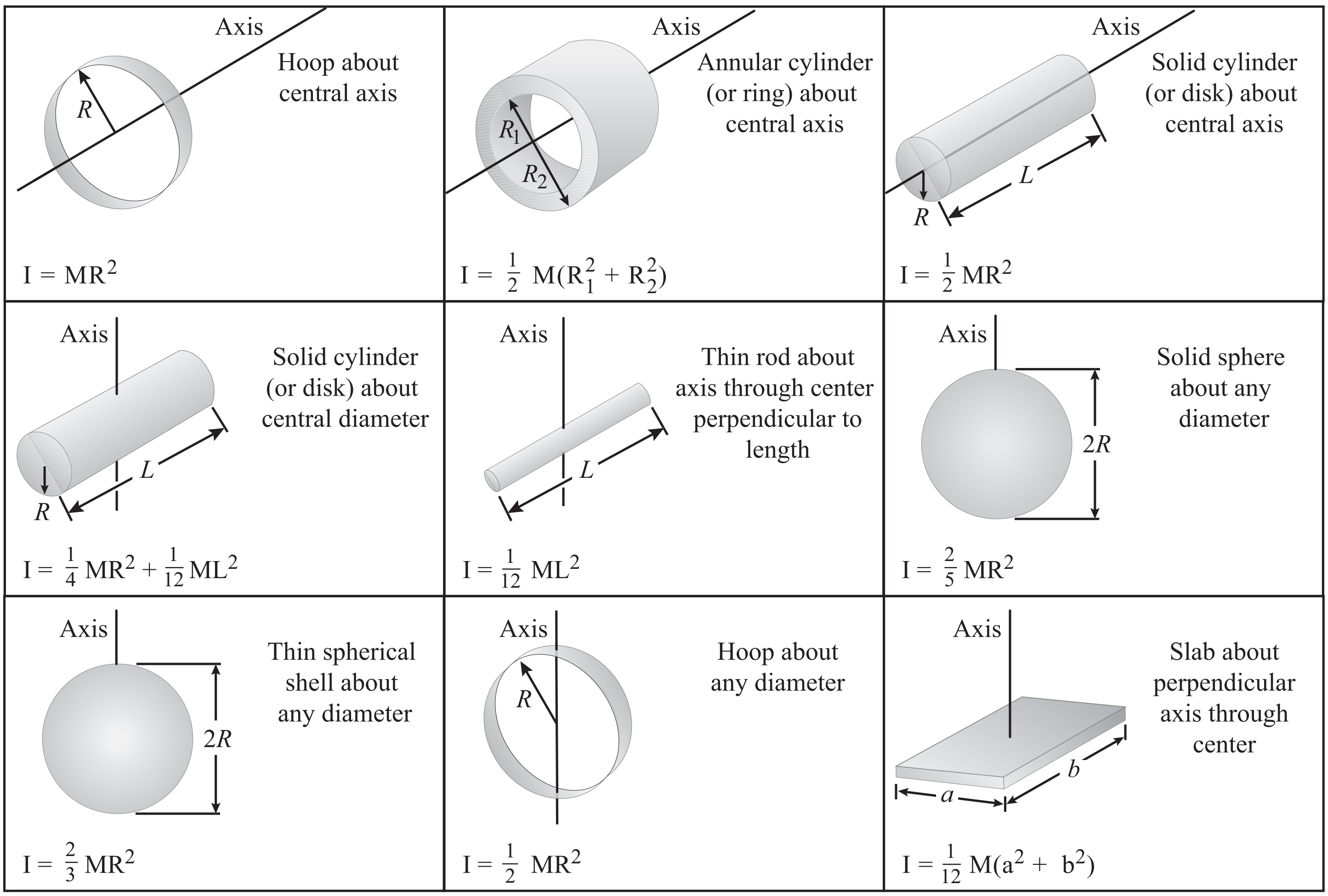
Name (print, last first): ______________________ Signature: ______________________

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(1) **Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number).** Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your UFID number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.
(4) **Blacken the circle of your intended answer completely, using a #2 pencil or <u>blue</u> or <u>black</u> ink**. Do not make any stray marks or some answers may be counted as incorrect.
(5) **The answers are rounded off. Choose the closest to exact. There is no penalty for guessing.**
(6) Hand in the answer sheet (scantron) separately. Only the scantron is graded.

Use $g = 9.80$ m/s^2



PHY2048 Exam 1 Formula Sheet

Vectors

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ $\quad \vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$ $\quad$ Magnitudes: $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$ $\quad |\vec{b}| = \sqrt{b_x^2 + b_y^2 + b_z^2}$

Scalar Product: $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$ $\quad$ Magnitude: $\vec{a} \cdot \vec{b} = |\vec{a}||\vec{b}| \cos\theta$ (θ = angle between $\vec{a}$ and $\vec{b}$)

Vector Product: $\vec{a} \times \vec{b} = (a_y b_z - a_z b_y)\hat{i} + (a_z b_x - a_x b_z)\hat{j} + (a_x b_y - a_y b_x)\hat{k}$

Magnitude: $|\vec{a} \times \vec{b}| = |\vec{a}||\vec{b}| \sin\theta$ (θ = angle between $\vec{a}$ and $\vec{b}$)

Motion

Displacement: $\Delta\vec{r} = \vec{r}(t_2) - \vec{r}(t_1)$

Average Velocity: $\vec{v}_{ave} = \dfrac{\Delta\vec{r}}{\Delta t} = \dfrac{\vec{r}(t_2) - \vec{r}(t_1)}{t_2 - t_1}$ $\quad$ Average Speed: $s_{ave} = (\text{total distance})/\Delta t$

Instantaneous Velocity: $\vec{v} = \dfrac{d\vec{r}(t)}{dt}$ $\quad$ Relative Velocity: $\vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC}$

Average Acceleration: $\vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{\vec{v}(t_2) - \vec{v}(t_1)}{t_2 - t_1}$ $\quad$ Instantaneous Acceleration: $\vec{a} = \dfrac{d\vec{v}}{dt} = \dfrac{d^2\vec{r}}{dt^2}$

Equations of Motion for Constant Acceleration

$\vec{v} = \vec{v}_0 + \vec{a}t$

$\vec{r} - \vec{r}_0 = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$ (in each of 3 dim)

Newton's Laws

$\vec{F}_{net} = 0 \Leftrightarrow \vec{v}$ is a constant (Newton's First Law)

$\vec{F}_{net} = m\vec{a}$ (Newton's Second Law)

"Action = Reaction" (Newton's Third Law)

Force due to Gravity

Weight (near the surface of the Earth) = mg (**use g=9.8** m/s^2)

Magnitude of the Frictional Force

Static: $f_s \leq \mu_s F_N$ $\quad$ Kinetic: $f_k = \mu_k F_N$

Uniform Circular Motion (Radius R, Tangential Speed $v = R\omega$, Angular Velocity ω)

Centripetal Acceleration: $a = \dfrac{v^2}{R} = R\omega^2$ $\quad$ Period: $T = \dfrac{2\pi R}{v} = \dfrac{2\pi}{\omega}$

Projectile Motion

Range: $R = \dfrac{v_0^2 \sin(2\theta_0)}{g}$

Quadratic Formula

If: $ax^2 + bx + c = 0$ $\quad$ Then: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Work (W), Mechanical Energy (E, Kinetic Energy (K)), Potential Energy (U)

Kinetic Energy: $K = \frac{1}{2}mv^2$ $\quad$ Work: $W = \displaystyle\int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r}$ $\quad$ When force is constant $W = \vec{F} \cdot \vec{d}$

Power: $P = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$ $\quad$ Work-Energy Theorem: $K_f = K_i + W$

PHY2048 Exam 2 Formula Sheet

$\Delta U = -W = -\int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r}$ $\quad F_x = -\frac{dU}{dx}$ $\quad$ Mechanical Energy: $E_{\text{mec}} = K + U$

Work-Energy: $W(\text{external}) = \Delta K + \Delta U + \Delta E(\text{thermal})$

Springs

Hooke's Law: $F_x = -kx$ $\quad$ Elastic Potential energy (x from spring equilibrium): $U(x) = \dfrac{1}{2}kx^2$

Center of Mass and Momentum

Center of Mass: $\vec{r}_{\text{com}} = \frac{1}{M_{\text{tot}}} \sum_{i=1}^{N} m_i \vec{r}_i$

Linear Momentum: $\vec{p} = m\vec{v}$ $\quad$ Impulse: $\vec{J} = \Delta\vec{p} = \int_{t_i}^{t_f} \vec{F}(t)dt$ $\quad \vec{F} = \frac{d\vec{p}}{dt}$

$\vec{P}_{\text{tot}} = M_{\text{tot}}\, \vec{v}_{\text{com}}$ $\quad \vec{F}_{\text{net}} = \frac{d\vec{P}_{\text{tot}}}{dt} = M_{\text{tot}}\, \vec{a}_{\text{com}}$

Rockets: Thrust $= Ma = v_{\text{rel}} \frac{dM}{dt}$ $\quad \Delta v = v_{\text{rel}} \ln(\frac{M_i}{M_f})$

Elastic Collisions of Two Bodies, 1D

$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i} + \frac{2m_2}{m_1 + m_2} v_{2i}$ $\quad v_{2f} = \frac{2m_1}{m_1 + m_2} v_{1i} + \frac{m_2 - m_1}{m_1 + m_2} v_{2i}$

Rotational Variables

angular position: $\theta(t)$ $\quad$ angular velocity: $\omega(t) = \frac{d\theta(t)}{dt}$ $\quad$ angular acceleration: $\alpha(t) = \frac{d\omega(t)}{dt} = \frac{d^2\theta(t)}{dt^2}$

arc length: $s = r\theta$ $\quad$ velocity: $v = r\omega$ tangential acceleration: $a_{\text{T}} = r\alpha$ $\quad$ centripetal acceleration: $a_{\text{c}} = r\omega^2$

For constant angular acceleration α:

$$\omega = \omega_0 + \alpha t \qquad \omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0) \qquad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

Rotational (Moment of) Inertia and Rolling

$I = \sum_{i=1}^{N} m_i r_i^2$ (discrete) $\quad I = \int r^2\, dm$ (continuous)

Parallel Axis: $I = I_{\text{com}} + M_{\text{tot}} d^2$ (d is displacement from c.o.m.)

Kinetic Energy: $K_{\text{rot}} = \dfrac{1}{2} I\omega^2$ $\quad K_{\text{roll}} = \frac{1}{2} M v_{\text{com}}^2 + \frac{1}{2} I_{\text{com}} \omega^2$

Torque etc.

$\vec{\tau} = \vec{r} \times \vec{F}$ $\quad \tau = rF\ \sin\theta$ $\quad$ Angular Momentum: $\vec{L} = \vec{r} \times \vec{p}$ $\quad L = I\omega$ $\quad \vec{\tau} = \frac{d\vec{L}}{dt}$

Work done by a constant torque: $W = \tau \Delta\theta = \Delta K_{\text{rot}}$

Power done by a constant torque: $P = \tau\omega$ $\quad$ For torque acting on a body with rotational inertia I: $\vec{\tau} = I\vec{\alpha}$

Precession frequency: $\Omega = \frac{mgr}{I\omega}$ (r is moment arm)

Stress and Strain(E = Young's modulus, B = bulk modulus)

Linear: $\frac{F}{A} = E \frac{\Delta L}{L}$ $\quad$ Volume: $P = \frac{F}{A} = -B \frac{\Delta V}{V}$

PHY2048 Exam 3 Formula Sheet

Law of Gravitation

Magnitude of Force: $F_{grav} = G\frac{m_1 m_2}{r^2}$ $G = 6.67 \times 10^{-11}\text{Nm}^2/\text{kg}^2$

Potential Energy: $U_{grav} = -G\frac{m_1 m_2}{r}$ Total Mechanical Energy for circular orbit: $E = -\dfrac{GMm}{2r}$

Law of Periods: $T^2 = \left(\dfrac{4\pi^2}{GM}\right) r^3$ Escape Speed: $v_{escape} = \sqrt{\dfrac{2GM}{R}}$

Ideal Fluids

Pressure: $P = \dfrac{F}{A}$ Units: 1 Pa = 1 N/m^2; 10^5 Pa = 1 bar $\simeq$ 1 atm

Equation of Continuity: $R_V = Av =$ constant (volume flow rate)

Bernoulli's Equation (y-axis up): $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

Fluids at rest (y-axis up): $P_2 = P_1 + \rho g(y_1 - y_2)$ Buoyancy Force: $F_{Buoy} = M_{fluid}\, g$

Simple Harmonic Motion (SHM) (angular frequency $\omega = 2\pi f = 2\pi/T$)

$x(t) = x_{\max}\cos(\omega t + \phi)$

Linear Harmonic Oscillator: $T = 2\pi\sqrt{\dfrac{m}{k}}$ Simple Pendulum: $T = 2\pi\sqrt{\dfrac{L}{g}}$ Physical Pendulum: $T = 2\pi\sqrt{\dfrac{I}{Mgh}}$

Torsion Oscillator: $T = 2\pi\sqrt{\dfrac{I}{\kappa}}$ Damped harmonic oscillator: $x(t) = e^{-bt/2m}x_{\max}\cos(\omega t + \phi)$

Sinusoidal Traveling Waves (frequency $f = 1/T = \omega/2\pi$, wave number $k = 2\pi/\lambda$)

$$y(x,t) = y_{\max}\sin(\Phi) = y_{\max}\sin(kx \pm \omega t + \phi) \quad (- = \text{right moving}, + = \text{left moving})$$

Wave Speed: $v_{wave} = \dfrac{\omega}{k} = \dfrac{\lambda}{T} = \lambda f$ Wave Speed (taught string): $v_{wave} = \sqrt{\dfrac{\tau}{\mu}}$

Standing Waves on a String (L = length, n = harmonic number)

$$y'(x,t) = 2y_{\max}\sin(kx)\cos(\omega t)$$

Allowed Wavelengths & Frequencies: $\lambda_n = 2L/n$ $f_n = \dfrac{v_{wave}}{\lambda_n} = \dfrac{nv_{wave}}{2L}$ $n = 1, 2, 3\cdots$

Sound Waves (P = Power)

Sound wave displacement: $s(x,t) = s_m\cos(kx \pm \omega t)$ Sound wave pressure: $\Delta p(x,t) = \Delta p_m\cos(kx \pm \omega t)$

Intensity (W/m^2): $I = \dfrac{P}{A}$ Isotropic Point Source: $I(r) = \dfrac{P_{source}}{4\pi r^2}$ Speed of sound: $v_{sound} = \sqrt{\dfrac{B}{\rho}}$

Doppler Shift: $f_{obs} = f_s\dfrac{v_{sound} - v_D}{v_{sound} - v_s}$ (f_s = frequency of source, v_s, v_D = speed of source, detector)

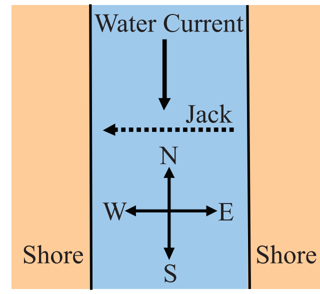
Change $-v_D$ to $+v_D$ if the detector is moving opposite the direction of the propagation of the sound wave.

Change $-v_s$ to $+v_s$ if the source is moving opposite the direction of the propagation of the sound wave.

Beat frequency: $f_{beat} = f_1 - f_2$ Resonance for pipe open on both ends: $f = \dfrac{nv}{2L}$ n = 1,2,3,...

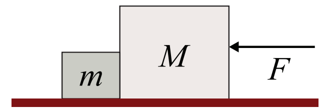
Resonance for pipe closed at one end: $f = \dfrac{nv}{4L}$ n = 1,3,5,... Sound level: $\beta = (10\text{ dB})\log_{10}\dfrac{I}{I_0}$

1. Jack rows across a river taking account of the current so that he actually moves at right angles to the east shore to a point on the west shore, as shown in the figure. The width of the river is 250 m and the current flows from north to south at 0.6 m/s. Jack rows at 1.0 m/s with respect to still water. How long does the trip take?



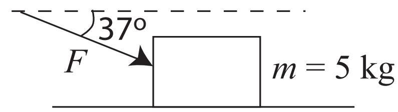
(1) 5.2 min
(2) 5.4 min
(3) 5.6 min
(4) 5.8 min
(5) 6.0 min

2. Two blocks with masses m = 2.0 kg and M= 8.0 kg are pushed along a horizontal surface and the coefficient of friction is $\mu_k = 0.51$. The horizontal applied force of F = 60 N as shown. What is the magnitude of the force of block m on block M?



(1) 12 N (2) 24 N (3) 36 N (4) 48 N (5) 6 N

3. Because of friction, a block of mass 5 kg is stationary on a horizontal table even though force of 10 Newtons is applied to the block at an angle of 37° below the horizontal. What is the smallest possible value for the coefficient of static friction?



(1) 0.15 (2) 0.10 (3) 0.20 (4) 0.25 (5) 0.30

4. A boy is in a hot-air balloon that is rising with (taking up to be positive) $v = 4\,\mathrm{m/s}$ and $a = 5\,\mathrm{m/s^2}$. He throws a ball out of the balloon, down with a speed of 3 m/s in his reference frame. With what speed (in m/s) does an observer on the ground observe the ball 0.5 seconds after it was thrown.

(1) 3.9 (2) 4.9 (3) 5.9 (4) 6.9 (5) 7.9

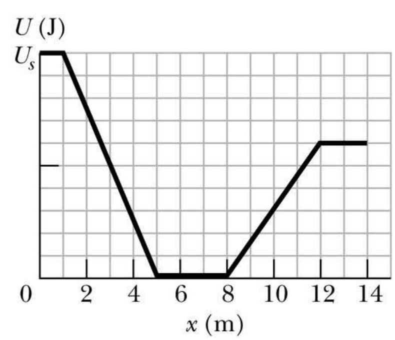
5. A 5.0-kg cart is moving horizontally at 6.0 m/s. If 70 J of work is done to speed it up, what is its final speed in m/s?

(1) 8 (2) 7 (3) 9 (4) 10 (5) 11

6. Two objects of mass m_1 and m_2 have the same momenta. What is the ratio of their kinetic energies, K_1/K_2.

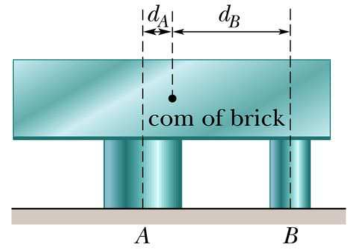
(1) m_2/m_1 (2) $\sqrt{m_1/m_2}$ (3) m_1/m_2 (4) $(m_1/m_2)^2$ (5) 1

7. The Figure shows the potential energy $U(x)$ of a solid ball that can roll along an x axis. The scale on the U axis runs from $U = 0$ to $U_s = 100$ J. The ball is uniform, rolls smoothly, and has a mass of 0.4 kg. It is released at $x = 7$ m headed in the negative direction of the x axis with a mechanical energy of 75 J. At what value of x does it turn around?



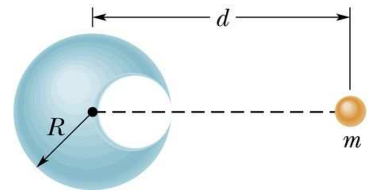
(1) 2 m
(2) 3 m
(3) 4 m
(4) 5 m
(5) 1 m

8. In the Figure, a lead brick rests horizontally on cylinders A and B. The areas of the top faces of the cylinders are related by $A_A = 2A_B$; the Young's moduli of the cylinders are related by $E_A = 2E_B$. The cylinders had identical lengths before the brick was placed on them. Assuming that each supporting cylinder's force acts along its central axis, what is the ratio d_A/d_B?



(1) $\frac{1}{4}$ (2) $\frac{1}{2}$ (3) 1 (4) 2 (5) 4

9. The Figure shows a spherical hollow inside a lead sphere of radius $R = 4$ cm; the surface of the hollow passes through the center of the sphere and "touches" the right side of the sphere. The mass of the sphere before hollowing was $M = 2.95$ kg. With what gravitational force (in units of 10^{-9} N) does the hollowed-out lead sphere attract a small sphere of mass $m = 0.431$ kg that lies a distance $d = 9$ cm from the center of the lead sphere, on the straight line connecting the centers of the spheres and of the hollow?



(1) 8.31 (2) 10.5 (3) 9.16 (4) 7.85 (5) 7.00

10. Suppose a planet has $\frac{1}{2}$ the mass of the Earth and $\frac{1}{3}$ the radius of the Earth. What is the ratio E_P/E_E of the kinetic energy needed to escape from the planet to the energy needed to escape from Earth?

(1) $\frac{3}{2}$ (2) $\frac{2}{3}$ (3) $\frac{1}{6}$ (4) $\frac{9}{2}$ (5) $\frac{4}{3}$

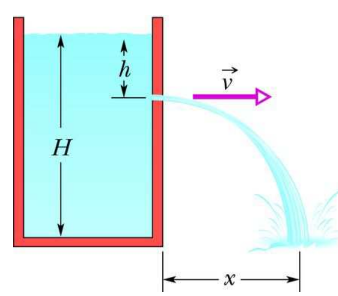
11. A satellite is in a circular Earth orbit of radius r. The area A enclosed by the orbit depends on r^2 because $A = \pi r^2$. How does the angular momentum depend on r?

(1) $r^{0.5}$ (2) $r^{-0.5}$ (3) r (4) r^{-1} (5) r^{-2}

12. A large aquarium of height 5 m is filled with fresh water (density 1000 kg/m^3) to a depth of 2 m. One wall of the aquarium consists of thick plastic 8 m wide. By how much does the total force (in units of 10^5 N) on that wall increase if the aquarium is next filled to a depth of 4 m?

(1) 4.7 (2) 1.6 (3) 6.3 (4) 9.4 (5) 13.

13. The Figure shows a stream of water flowing through a hole at depth $h = 10$ cm in a tank holding water (density 1000 kg/m^3) to height $H = 40$ cm. At what distance x does the stream strike the floor?



(1) 35 cm
(2) 17 cm
(3) 20 cm
(4) 40 cm
(5) 30 cm

14. At a certain harbor, the tides cause the ocean surface to rise and fall a distance d (from highest level to lowest level) in simple harmonic motion, with a period of 12 hrs. How long does it take for the water to fall a distance $0.25d$ from its highest level?

(1) 2 hrs (2) 4 hrs (3) 6 hrs (4) 8 hrs (5) 10 hrs

15. A loaded car of total mass 1000 kg travels over a "washboard" dirt road with corrugations 4.0 m apart. The car bounces with maximum amplitude when its speed is 5.0 m/s. What is the spring constant of the car's suspension?

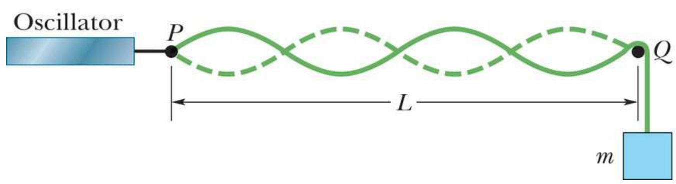
(1) 62×10^3 kg/s^2 (2) 75×10^3 kg/s^2 (3) 88×10^3 kg/s^2 (4) 49×10^3 kg/s^2 (5) 36×10^3 kg/s^2

16. Use the wave equation to find the speed of a wave generated by

$$y(x,t) = (2.00 \text{ mm}) \sin[(20 \text{ m}^{-1})x - (4.0 \text{ s}^{-1})t] \,.$$

(1) 0.2 m/s (2) 0.4 m/s (3) 0.6 m/s (4) 0.8 m/s (5) 1.0 m/s

17. In the figure, a string tied to a sinusoidal oscillator at P and running over a support at Q, is stretched by a block of mass m. The other relevant parameters are separation $L = 1.2$ m, linear mass density $\mu = 1.6$ g/m, and the oscillator frequency $f = 120$ Hz. The amplitude of the motion at P is small enough for that point to be considered a node. A node also exists at Q. What mass m allows the oscillator to set up the fourth harmonic on the string?



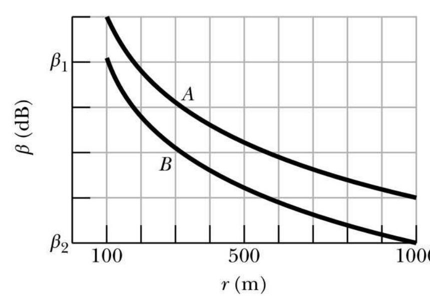
(1) 0.85 kg (2) 0.70 kg (3) 0.55 kg (4) 0.40 kg (5) 1.0 kg

18. A sound wave of the form $s = s_m \cos(kx - \omega t + \phi)$ travels at 343 m/s through air in a long horizontal tube. At one instant, air molecule A at $x = 2.00$ m is at its maximum positive displacement of 6.00 nm and air molecule B at $x = 2.07$ m is at a positive displacement of 2.00 nm. All the molecules between A and B are at intermediate displacements. What is the frequency of the wave?

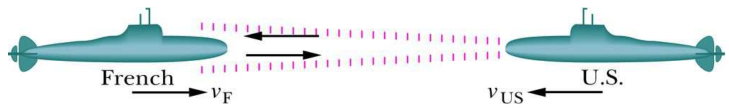
(1) 960 Hz (2) 880 Hz (3) 800 Hz (4) 720 Hz (5) 640 Hz

19. Two atmospheric sound sources A and B emit isotropically at constant power. The sound levels β of their emissions are plotted in the Figure versus the radila distance r from the sources. The vertical axis scale is set by $\beta_1 = 85$ dB and $\beta_2 = 65$ dB. What is the ratio of the larger power to the smaller power?

(1) 3.2
(2) 1.8
(3) 5.6
(4) 10
(5) 1.0



20. In the Figure, a French submarine and a U.S. submarine move toward each other during maneuvers in motionless water in the North Atlantic. The French sub moves at speed $v_F = 50$ km/h and the U.S. sub at $v_{US} = 70$ km/hr. The French sub sends out a sonar signal (wound wave in water) at 1000 Hz. Sonar waves travel at 5470 km/h. What is the signal's frequency as detected by the U.S. sub?



(1) 1020 Hz (2) 1040 Hz (3) 1000 Hz (4) 996 Hz (5) 978 Hz