Instructor(s): *Matcheva, Yelton*

PHYSICS DEPARTMENT

PHY 2048, Fall 2017 Final Exam December 9, 2017

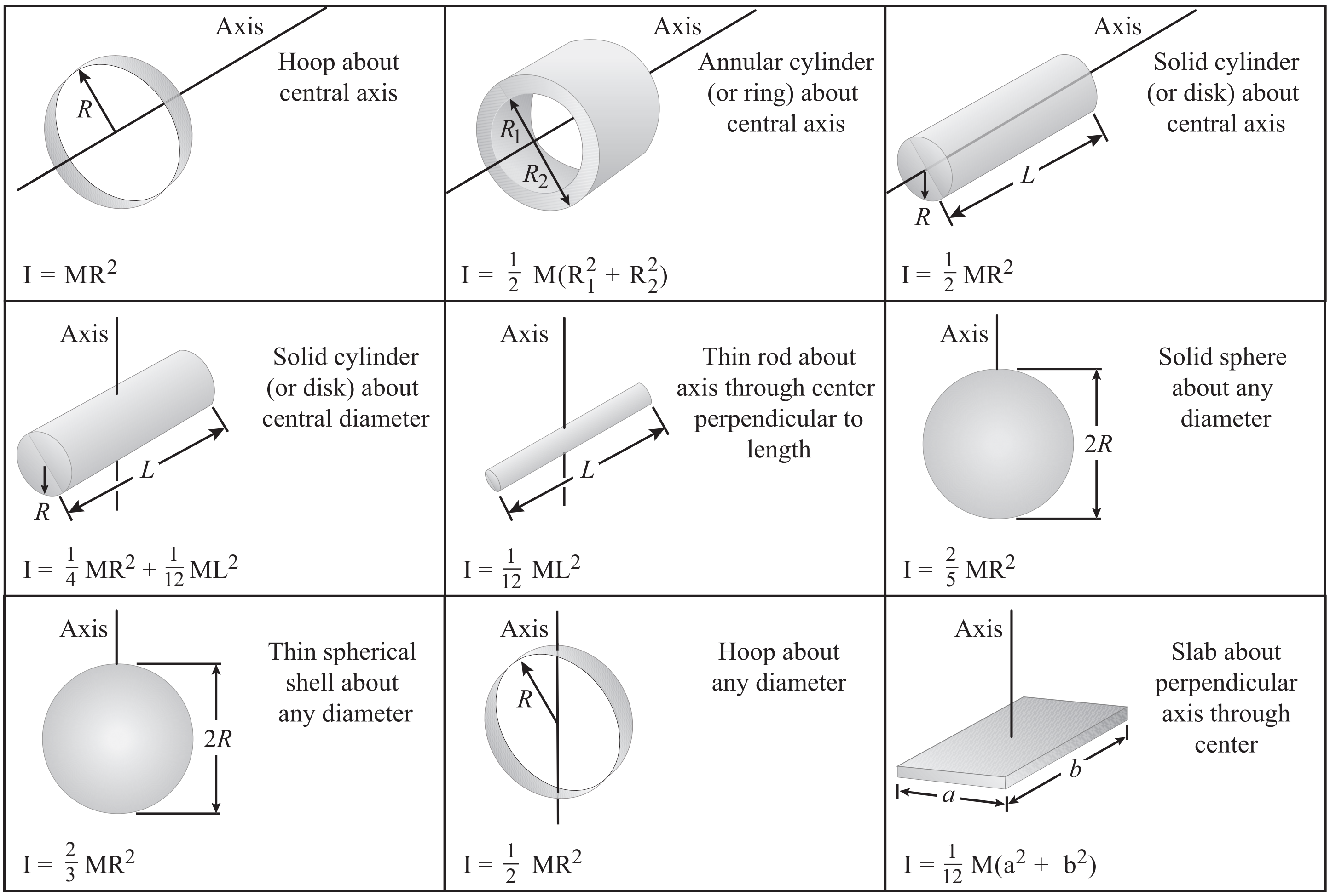
Name (print, last first): ______________________ Signature: ______________________

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. If you believe that no listed answer is correct, leave the form blank.**
(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

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ $\quad \vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$ $\qquad$ 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: $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$ $\qquad$ 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: $\vec{v}_{ave} = \dfrac{\Delta\vec{r}}{\Delta t} = \dfrac{\vec{r}(t_2) - \vec{r}(t_1)}{t_2 - t_1}$

Average Speed: s_{ave} = (total distance)/Δt

Instantaneous Velocity: $\vec{v} = \dfrac{d\vec{r}(t)}{dt}$

Relative Velocity: $\vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC}$

Average Acceleration: $\vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{\vec{v}(t_2) - \vec{v}(t_1)}{t_2 - t_1}$

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: $f_s \leq \mu_s F_N$ $\qquad$ Kinetic: $f_k = \mu_k F_N$

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

Centripetal Acceleration: $a = \dfrac{v^2}{R} = R\omega^2$

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

PHY2048 Exam 2 Formula Sheet

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

Kinetic Energy: $K=\frac{1}{2}mv^2$ Work: $W=\int_{\vec{r}_1}^{\vec{r}_2}\vec{F}\cdot d\vec{r} \xrightarrow{\text{Constant } \vec{F}} \vec{F}\cdot\vec{d}$ Power: $P=\frac{dW}{dt}=\vec{F}\cdot\vec{v}$

Work-Energy Theorem: $K_f = K_i + W$ Potential Energy: $\Delta U = -\int_{\vec{r}_1}^{\vec{r}_2}\vec{F}\cdot d\vec{r}$ $F_x(x) = -\frac{dU(x)}{dx}$

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

Gravity Near the Surface of the Earth (y-axis up): $F_y = -mg$ $U(y) = mgy$

Spring Force: $F_x(x) = -kx$ $U(x) = \frac{1}{2}kx^2$

Mechanical Energy: $E = K + U$ Isolated and Conservative System: $\Delta E = \Delta K + \Delta U = 0$

Linear Momentum, Angular Momentum, Torque

Linear Momentum: $\vec{p} = m\vec{v}$ $\vec{F} = \frac{d\vec{p}}{dt}$ Kinetic Energy: $K = \frac{p^2}{2m}$ Impulse: $\vec{J} = \Delta\vec{p} = \int_{t_i}^{t_f}\vec{F}(t)dt$

Center of Mass (COM): $M_{tot} = \sum_{i=1}^{N} m_i$ $\vec{r}_{COM} = \frac{1}{M_{tot}}\sum_{i=1}^{N} m_i\vec{r}_i$ $\vec{v}_{COM} = \frac{1}{M_{tot}}\sum_{i=1}^{N}\vec{p}_i$

Net Force: $\vec{F}_{net} = \frac{d\vec{P}_{tot}}{dt} = M_{tot}\,\vec{a}_{COM}$ $\vec{P}_{tot} = M_{tot}\,\vec{v}_{COM} = \sum_{i=1}^{N}\vec{p}_i$

Moment of Inertia (i.e. Rotational Inertia): $I=\sum_{i=1}^{N} m_i r_i^2$ (discrete) $I=\int r^2\,dm$ (uniform) Parallel Axis: $I=I_{COM}+Mh^2$

Angular Momentum: $\vec{L} = \vec{r}\times\vec{p}$ Torque: $\vec{\tau} = \vec{r}\times\vec{F} = \frac{d\vec{L}}{dt}$ Work: $W = \int_{\theta_i}^{\theta_f}\tau d\theta$

Conservation of Linear Momentum: if $\vec{F}_{net} = \frac{d\vec{p}}{dt} = 0$ then $\vec{p} = \text{constant}$ and $\vec{p}_f = \vec{p}_i$

Conservation of Angular Momentum: if $\vec{\tau}_{net} = \frac{d\vec{L}}{dt} = 0$ then $\vec{L} = \text{constant}$ and $\vec{L}_f = \vec{L}_i$

Rotational Variables

Angular Position: $\theta(t)$ Angular Velocity: $\omega(t) = \frac{d\theta(t)}{dt}$ Angular Acceleration: $\alpha(t) = \frac{d\omega(t)}{dt} = \frac{d^2\theta(t)}{dt^2}$

Torque: $\tau_{net} = I\alpha$ Angular Momentum: $L = I\omega$ Kinetic Energy: $E_{rot} = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$ Power: $P = \tau\omega$

Arc Length: $s = R\theta$ Tangential Speed: $v = R\omega$ Tangential Acceleration: $a = R\alpha$

Rolling Without Slipping: $x_{COM} = R\theta$ $v_{COM} = R\omega$ $a_{COM} = R\alpha$ $K = \frac{1}{2}Mv_{COM}^2 + \frac{1}{2}I_{COM}\omega^2$

Rotational Equations of Motion (Constant Angular Acceleration α)

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

Elastic Collisions of Two Bodies, 1D

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

PHY2048 Exam 3 Formula Sheet

Law of Gravitation

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

Potential Energy: $U_{grav} = -G\frac{m_1 m_2}{r}$ $\quad$ Escape Speed: $v_{escape} = \sqrt{\dfrac{2GM}{R}}$

Tension & Compression (Y = Young's Modulus, B = Bulk Modulus)

Linear: $\dfrac{F}{A} = Y\dfrac{\Delta L}{L}$ $\quad$ Volume: $P = \dfrac{F}{A} = B\dfrac{\Delta V}{V}$

Ideal Fluids

Pressure (variable force): $P = \dfrac{dF}{dA}$ $\quad$ Pressure (constant force): $P = \dfrac{F}{A}$ $\quad$ Units: 1 Pa = 1 N/m^2

Equation of Continuity: $R_V = Av = \text{constant}$ (volume flow rate) $\quad R_m = \rho A v = \text{constant}$ (mass flow rate)

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

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

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

$$x(t) = x_{\max}\cos(\omega t + \phi)$$
$$v(t) = -\omega x_{\max}\sin(\omega t + \phi) \qquad v_{\max} = \omega x_{\max}$$
$$a(t) = -\omega^2 x_{\max}\cos(\omega t + \phi) = -\omega^2 x(t) \qquad a_{\max} = \omega^2 x_{\max}$$

Linear Harmonic Oscillator: $\omega = \sqrt{\dfrac{k}{m}}$ $\quad$ Simple Pendulum: $\omega = \sqrt{\dfrac{g}{L}}$

Angular Harmonic Oscillator: $\omega = \sqrt{\dfrac{\kappa}{I}}$ $\quad$ Physical Pendulum: $\omega = \sqrt{\dfrac{hmg}{I}}$

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

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

Phase: $\Phi = kx \pm \omega t$ $\quad$ Wave Speed: $v_{wave} = \dfrac{\omega}{k} = \dfrac{\lambda}{T} = \lambda f$ $\quad$ Wave Speed (tight string): $v_{wave} = \sqrt{\dfrac{\tau}{\mu}}$

Interference (Max Constructive): $\Delta\Phi = 2n\pi \quad n = 0, \pm 1, \pm 2, \cdots \qquad \Delta d = n\lambda \quad n = 0, \pm 1, \pm 2, \cdots$

Interference (Max Destructive): $\Delta\Phi = (2n+1)\pi \quad n = 0, \pm 1, \pm 2, \cdots \qquad \Delta d = (n + \frac{1}{2})\lambda \quad n = 0, \pm 1, \pm 2, \cdots$

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

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

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

Sound Waves (P = Power)

Intensity (W/m^2): $I = \dfrac{P}{A}$ $\quad$ Isotropic Point Source: $I(r) = \dfrac{P_{source}}{4\pi r^2}$ $\quad$ 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)

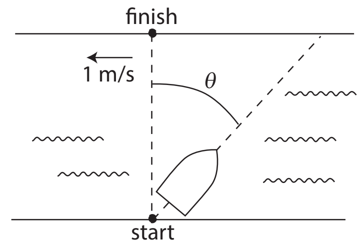
Change $-v_D$ to $+v_D$ if the detector is moving opposite the direction of the propagation of the sound wave.

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

1. If the mass of the Sun is M_S and the mass of the Earth is M_E, and if F_1 is the magnitude of the gravitational force exerted on the Sun by Earth and F_2 is the magnitude of the force exerted on Earth by the Sun, then the ratio F_1/F_2 is:

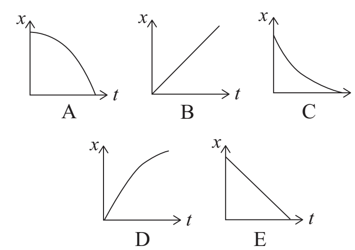
   (1) 1 (2) M_E/M_S (3) $\sqrt{M_E/M_S}$ (4) M_S/M_E (5) $\sqrt{M_S/M_E}$

2. A girl wishes to row across a river to a point directly opposite as shown. She can row at 2 m/s in still water and the river is flowing at 1 m/s. At what angle with respect to the line joining the starting and finishing points should she point the bow (front) of her boat?



   (1) 30°
   (2) 45°
   (3) 60°
   (4) 63°
   (5) 90°

3. Which of the five graphs of position, x, versus time, t, represents the motion of an object whose speed is increasing with time?



   (1) A
   (2) B
   (3) C
   (4) D
   (5) E

4. An amusement park ride consists of a car, moving in a vertical circle at a uniform speed of 5.0 m/s, on the end of a strong rigid rod of negligible mass. The combined mass of the car and rider is 200 kg, and the radius of the circle is 10.0 meters. At the top of the circle, what is the magnitude of the net force on the car and rider?

   (1) 500 N (2) 1480 N (3) 980 N (4) 100 N (5) 1080 N

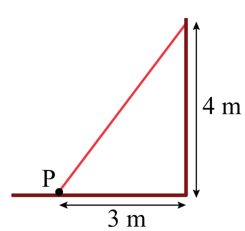
5. You have a mass of 40 kg. You stand on a bathroom scale in an elevator which is moving with a velocity given $v = 4t - 2t^2$, where up is the positive direction, v is in m/s and t is in seconds. At $t = 2$ seconds, what will the bathroom scale read in kg?

   (1) 24 (2) 0 (3) 40 (4) 56 (5) 64

6. At t=0 s, a hand grenade of mass M is thrown horizontally off the top of a tall vertical cliff with a speed of 10 m/s. At t = 1 s it explodes into two equal pieces. At t = 2 s, one of the pieces is seen to be 25 meters away from the cliff. How far away from the cliff (measured horizontally) is the other piece at that moment?

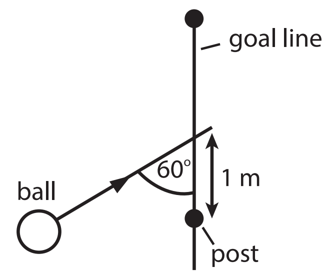
   (1) 15 m (2) 25 m (3) 20 m (4) 5 m (5) 40 m

7. A uniform plank of weight 100 N leans at equilibrium against a frictionless wall as shown. The magnitude of the torque (about the point P) applied to the plank by the wall is:



   (1) 150 N·m
   (2) 100 N·m
   (3) 500 N·m
   (4) 200 N·m
   (5) 75 N·m

8. A soccer ball of mass 2 kg travels in a straight line at 5 m/s at an angle of 60° to the goal line as shown, crossing the line 1 meter away from the goalpost. What is the magnitude of its angular momentum (in kg m^2/s) about the goalpost?



(1) $5\sqrt{3}$
(2) 5
(3) 10
(4) 0
(5) $10\sqrt{3}$

9. Consider a uniform stick with mass M and length L. Find the rotational inertia of the stick with respect to an axis of rotation, perpendicular to the stick, which passes through a point on the stick a distance L/4 from its end.

(1) 0.148 ML^2 (2) 0.083 ML^2 (3) 0.270 ML^2 (4) 0.208 ML^2 (5) 0.333 ML^2

10. You push, with a horizontal force, a box of mass M across a horizontal floor with a constant velocity of v for a total of t seconds. The coefficient of kinetic friction between box and floor is μ_k. How much work do you do?

(1) $\mu_k Mgvt$ (2) 0 (3) $\mu_k Mv^2t^2$ (4) Mgvt (5) $\mu_k gt$

11. In a binary-star system, each star has the same mass which is 9 times that of the Sun, and they revolve about their common center of mass. The distance between the stars is 6 times the distance between the Earth and the Sun. What is their period of revolution in Earth years?

(1) 3.5 (2) 1.1 (3) 2.5 (4) 4.2 (5) 5.3

12. A 1 kg basketball is shot to space from the surface of the Earth. What is the least initial mechanical energy required at the launch if the ball is to escape the Earth? Assume that the mass of the Earth is 6×10^{24} kg and the radius of the Earth is about 6400 km. Neglect air resistance and take the gravitational potential energy far from Earth to be 0.

(1) 0 J (2) 6.25×10^7 J (3) -6.25×10^7 J (4) 3.12×10^7 J (5) -3.12×10^7 J

13. The gravity acceleration at the surface of planet UF is a_g. Assume that the planet is a uniform solid sphere of radius R = 5000 km. At what distance above the surface of the planet the gravitational acceleration is $a_g/4$?

(1) 5000 km (2) 10000 km (3) 100 km (4) 2500 km (5) 3500 km

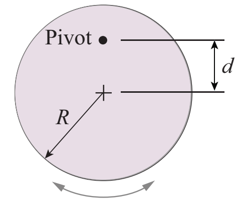
14. A space ship is in a circular orbit around a newly discovered planet. The astronauts measured that it takes 2 hours to complete a full orbit and noted that the distance to the center of the planet is 1000 km. Find the mass of the planet in kg.

(1) 1.14×10^{22} (2) 7.6×10^{21} (3) 2.8×10^{22} (4) 5.5×10^{21} (5) 2.8×10^{20}

15. A block rides on a piston that is moving vertically with simple harmonic motion. If the piston has an amplitude of 4.9 cm, what is the maximum frequency for which the block and piston will be in contact continuously?

(1) 2.25 Hz (2) 14.1 Hz (3) 5 Hz (4) 7.2 Hz (5) 9.5 Hz

16. In the figure, a physical pendulum consists of a uniform solid disk (of radius R = 26 cm) supported in a vertical plane by a pivot located a distance d = 20 cm from the center of the disk. The disk is displaced by a small angle and released. What is the period of the resulting simple harmonic motion?

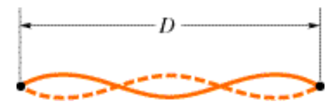


(1) 1.2 s (2) 0.8 s (3) 0.4 s (4) 0.2 s (5) 1.6 s

17. The equation of a transverse wave traveling along a very long string is $y = 2\sin(0.065\pi x + 8\pi t)$, where x and y are expressed in centimeters and t is in seconds. Determine the maximum transverse speed of a particle on the string. Be careful with the units.

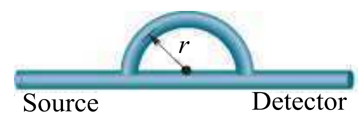
(1) 0.5 m/s (2) 1.23 m/s (3) 0.01 m/s (4) 0.16 m/s (5) 1.5 m/s

18. A nylon guitar string has a linear density of 5.53 g/m and is under a tension of 117 N. The fixed supports are D = 91.4 cm apart. The string is oscillating in the standing wave pattern shown in the figure. Calculate the frequency of the traveling waves whose superposition gives this standing wave.



(1) 239 Hz (2) 145 Hz (3) 345 Hz (4) 423 Hz (5) 386 Hz

19. In the figure, sound with a 40.0 cm wavelength travels rightward from a source and through a tube that consists of a straight portion and a half-circle. Part of the sound wave travels through the half-circle and then rejoins the rest of the wave, which goes directly through the straight portion. This rejoining results in interference. What is the smallest radius r that results in an intensity minimum at the detector?



(1) 17.5 cm (2) 35 cm (3) 70 cm (4) 26.3 cm (5) 40 cm

20. An ambulance with a siren emitting a whine at 1600 Hz overtakes and passes a cyclist pedaling a bike at 20 km/h . After being passed, the cyclist hears a frequency of 1590 Hz. How fast is the ambulance moving? The speed of sound is 330 m/s.

(1) 7.6 m/s (2) 22 m/s (3) 10.5 m/s (4) 60 m/s (5) 5.5 m/s