Instructor(s): *Matcheva/Yelton*

PHYSICS DEPARTMENT

PHY 2048 FINAL EXAM December 10th, 2016

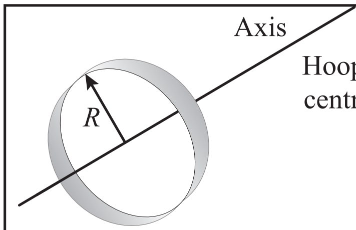
Name (print, last first): ______________________ Signature: ______________________

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.

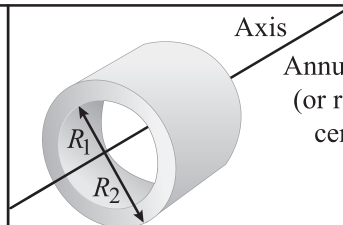
(1) **Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number)**. Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your UFID number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work 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 blue or black 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 separately.

Use $g = 9.8$ m/s^2 $\quad G = 6.67 \times 10^{-11}$Nm^2/kg^2 $\quad \rho_{\text{water}} = 1000\frac{\text{kg}}{\text{m}^3}$



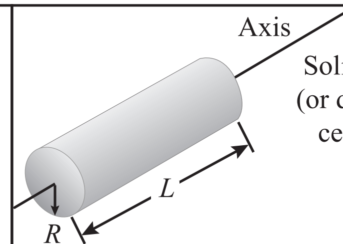
Hoop about central axis

$I = MR^2$



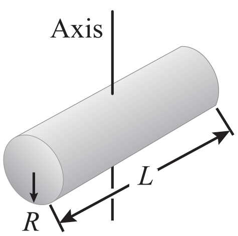
Annular cylinder (or ring) about central axis

$I = \frac{1}{2}M(R_1^2 + R_2^2)$



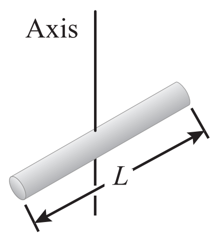
Solid cylinder (or disk) about central axis

$I = \frac{1}{2}MR^2$



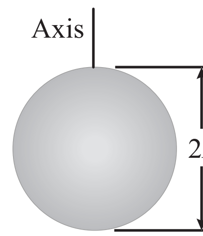
Solid cylinder (or disk) about central diameter

$I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$



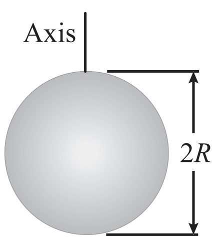
Thin rod about axis through center perpendicular to length

$I = \frac{1}{12}ML^2$



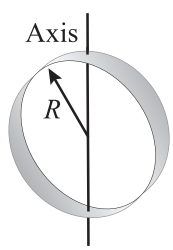
Solid sphere about any diameter

$I = \frac{2}{5}MR^2$



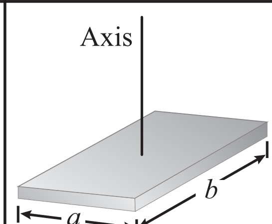
Thin spherical shell about any diameter

$I = \frac{2}{3}MR^2$



Hoop about any diameter

$I = \frac{1}{2}MR^2$



Slab about perpendicular axis through center

$I = \frac{1}{12}M(a^2 + b^2)$

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: $s_{ave} = (\text{total distance})/\Delta t$

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: $I=\sum_{i=1}^{N}m_ir_i^2$ (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)

$$\omega(t)=\omega_0+\alpha t \qquad \theta(t)=\theta_0+\omega_0t+\tfrac{1}{2}\alpha t^2 \qquad \omega^2(t)=\omega_0^2+2\alpha(\theta(t)-\theta_0)$$

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

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

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

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

Ideal Fluids

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

Equation of Continuity: $R_V = Av =$ constant (volume flow rate) $R_m = \rho Av =$ 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): $P_2 = P_1 + \rho g(y_1 - y_2)$ 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: $\omega = \sqrt{\frac{k}{m}}$ Simple Pendulum: $\omega = \sqrt{\frac{g}{L}}$

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

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

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

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

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

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

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

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

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

Sound Waves (P = Power)

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

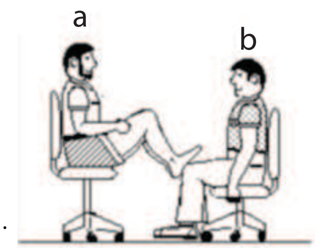
Doppler Shift: $f_{obs} = f_s\frac{v_{sound} - v_D}{v_{sound} - v_S}$ (f_s = frequency of source, v_s, v_D = speed of source, detector)

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. Student "a" has mass of 90 kg and student "b" has a mass of 60 kg. They sit in identical, mass-less office chairs facing each other as shown in the figure. Student "a" places his bare feet on the knees of student "b" as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs move. During the push, which of the following are true?

   (1) Each student exerts the same amount of force on the other.
   (2) Neither exerts a force on the other.
   (3) Student "a" exerts a force on student "b", but "b" does not exert a force on "a".
   (4) Each student exerts a force on the other, but "b" exerts the larger force.
   (5) Each student exerts a force on the other, but "a" exerts the larger force.



2. After the push is over the two move apart (they are on wheels with no frictional losses). What is then the ratio of the kinetic energy of "a" to that of "b"?

   (1) 2/3 (2) 3/2 (3) 1 (4) 0 (5) 4/9

3. A boy in a hot air balloon leans over the side and drops a stone. At the moment he drops it, the balloon has (taking up to be positive), $v = 2.0$ m/s and $a = 3.0\,\text{m/s}^2$. What speed (relative to the ground and in m/s), is the stone travelling 1 second later?

   (1) 7.8 (2) 6.8 (3) 12.8 (4) 9.8 (5) 11.8

4. You drive 120 km north at 60 km/hr, then 50 km west at 50 km/hr. What, in km/hr, is the magnitude of your average velocity?

   (1) 43 (2) 57 (3) 170 (4) 55 (5) 85

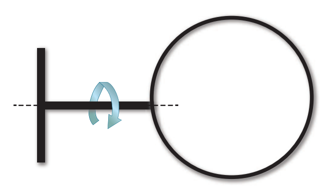
5. A potential energy function of a point mass is given by the expression $U(x) = 2x^2 + 4x$, where x is the position coordinate in meters, and U is measured in Joules. Only conservative forces are acting. If a mass is placed at $x = 0$ and released, how far (in meters) does it travel before it first reaches its maximum speed?

   (1) 1 (2) 2 (3) 3 (4) 4 (5) 0.5

6. A uniform solid cylinder, a uniform solid sphere, a thin annular cylinder, and a thin spherical shell are rolling without slipping along a horizontal surface. All objects have the same kinetic energy and the same mass. Which one has the highest value of the center-of-mass velocity?

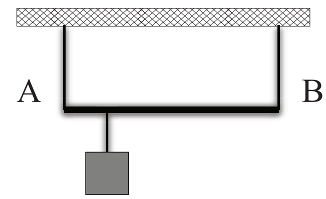
   (1) uniform solid sphere
   (2) thin spherical shell
   (3) uniform solid cylinder
   (4) thin annular cylinder
   (5) they all have the same center-of-mass velocity

7. Find the rotational inertia of the composite object in the figure. The axis of rotation is shown with a dashed line. The two thin rods are uniform and each has a length L and mass M. The hoop has a radius L and a mass M. The hoop, the rods, and the axis of rotation are all in the same plane.



   (1) $(7/12)\,MR^2$ (2) $(1/2)\,MR^2$ (3) $(29/6)\,MR^2$ (4) $(5/6)\,MR^2$ (5) $(13/12)\,MR^2$

8. A 1 m long beam with 5 kg is supported at its ends by two ropes A and B of equal length. A box is hanging 20 cm from the left end A of the beam. If the tension in the left rope is 30N, what is the mass of the box in kg?



(1) 0.7 kg (2) 2.0 kg (3) 1.4 kg (4) 2.8 kg (5) 1.7 kg

9. A projectile with a mass m is shot directly away from Earth's surface. Neglect the rotation of Earth. What is the least initial mechanical energy required at launch if the projectile is to escape Earth? M is the mass of the Earth, R is the radius of the Earth and $U(\infty) = 0$.

(1) 0 (2) GM/R^2 (3) GMm/R (4) $-GM/R^2$ (5) $-GMm/R$

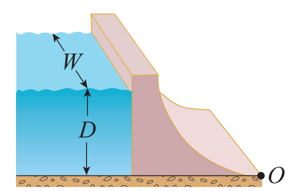
10. In 1993 the spacecraft *Galileo* sent an image of asteroid 243 Ida and a tiny orbiting moon (now known as Dactyl), the first confirmed example of an asteroid-moon system. In the image, the moon, which is 1.5 km wide, is 100 km from the center of the asteroid. Assume the moon's orbit is circular with a period of 27 h. What is the mass of the asteroid?

(1) 6.3×10^{16} kg (2) 3.7×10^{16} kg (3) 4.3×10^{15} kg (4) 9.5×10^{16} kg (5) 1.5×10^{15} kg

11. Certain neutron stars (extremely dense stars) are believed to be rotating at about 1 rev/s. If such a star has a radius of 20 km, what must be its minimum mass so that material on its surface remains in its place on the star's surface during the rapid rotation?

(1) 5×10^{24} kg (2) 2×10^{24} kg (3) 6×10^{24} kg (4) 1.2×10^{25} kg (5) 1.5×10^{25} kg

12. In the figure water stands at depth $D = 35\,\text{m}$ behind the vertical upstream face of a dam of width $W = 314\,\text{m}$. Find the net horizontal force on the dam from the gauge pressure of the water. ($\rho_{\text{water}} = 1000\frac{\text{kg}}{\text{m}^3}$)

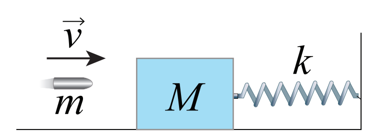


(1) 1.9×10^9 N (2) 3.8×10^9 N (3) 7.6×10^9 N (4) 5.5×10^9 N (5) 4.2×10^9 N

13. A hollow spherical iron shell floats almost completely submerged in water. The outer diameter is 60.0 cm, and the density of iron is 7.87 g/cm^3. Find the inner diameter of the shell. ($\rho_{\text{water}} = 1000\frac{\text{kg}}{\text{m}^3} = 1.000\frac{\text{g}}{\text{cm}^3}$)

(1) 57 cm (2) 43 cm (3) 36 cm (4) 25 cm (5) 30 cm

14. A block of mass $M = 5.4$ kg at rest on a horizontal frictionless table, is attached to a rigid support by a spring of constant $k = 6000\,\text{N/m}$. A bullet of mass $m = 9.5\,\text{g}$ and velocity $\vec{v}$ of magnitude 630 m/s strikes and is embedded in the block. Assuming the compression of the spring is negligible until the bullet is embedded, determine the amplitude of the resulting simple harmonic oscillation?



(1) 3.3 cm (2) 2.5 cm (3) 4.6 cm (4) 5.2 cm (5) 6.0 cm

15. You are at rest and holding a simple pendulum with a period of 1 s. You are then in an elevator and observe that the period of the same pendulum is now 0.8 s. You can conclude that:

(1) the elevator is accelerating upward
(2) the elevator is at rest
(3) the elevator is moving upwards
(4) the elevator is moving downwards
(5) the elevator is accelerating downwards

16. You have been abducted by aliens and find yourself on a strange planet. Fortunately, you have a uniform meter stick with you. You observe that, if the stick oscillates around one end as a physical pendulum, it has a period of 0.85 s. What is the acceleration of gravity on this planet?

(1) $36\,\mathrm{m/s^2}$ (2) $10\,\mathrm{m/s^2}$ (3) $12\,\mathrm{m/s^2}$ (4) $20\,\mathrm{m/s^2}$ (5) $28\,\mathrm{m/s^2}$

17. A transverse wave on a cable is described by the function $y(x,t) = 2.3\cos(4.7x + 12t - \pi/2)$ where distance is measured in meters and time in seconds. If the tension in the cable is 25 N, what is the linear mass density of the cable?

(1) 3.8 kg/m (2) 9.8 kg/m (3) 163 kg/m (4) 56 kg/m (5) 42 kg/m

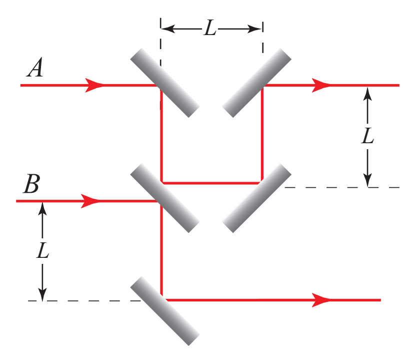
18. What is the lowest frequency for standing waves on a wire that is 10.0 m long, has a mass of 100 g, and is stretched under a tension of 250 N?

(1) 8 Hz (2) 16 Hz (3) 32 Hz (4) 24 Hz (5) 4 Hz

19. A stationary motion detector sends sound waves of frequency 150 kHz toward a truck approaching at a speed of 45 m/s. What frequency will the detector measure for waves reflected back to it from the truck? The speed of sound in air is $V_{\text{sound}} = 340\,\mathrm{m/s}$.

(1) 195 kHz (2) 115 kHz (3) 150 kHz (4) 170 kHz (5) 130 kHz

20. Sound waves A and B, both of wavelength λ are initially in phase and traveling rightward, as indicated by the two rays. Wave A is reflected from four surfaces but ends up traveling in its original direction. Wave B ends in that direction after reflecting from two surfaces. Let distance L in the figure be expressed as $L = q\lambda$. What is the smallest value of $q > 0$ that put A and B exactly out of phase with each other after all the reflections?



(1) 0.5
(2) 1.0
(3) 0.25
(4) 1.25
(5) 1.5