Instructor(s): *Field/Matcheva*

PHYSICS DEPARTMENT
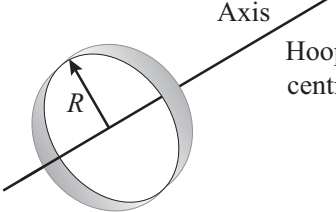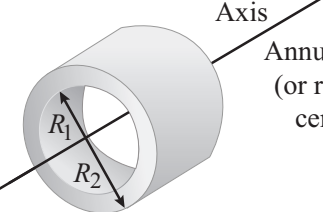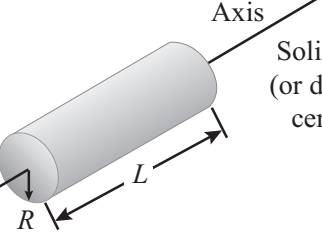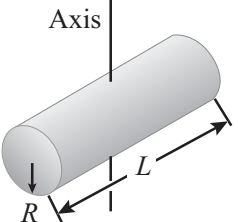PHY 2048   Final Exam   December 13, 2014
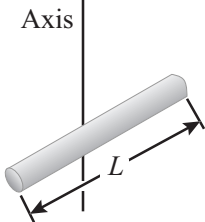
Name (print, last first): _____   Signature: _____

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.
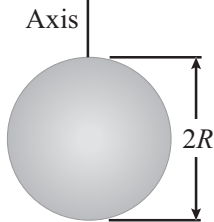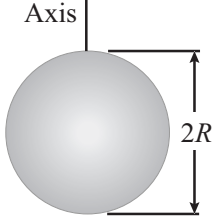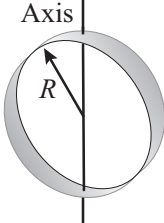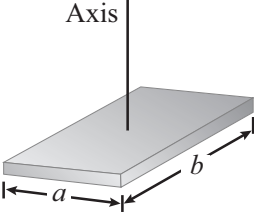(4) **Blacken the circle of your intended answer completely, using a #2 pencil or <u>blue</u> or <u>black</u> ink.** Do not make any stray marks or some answers may be counted as incorrect.
(5) **The answers are rounded off. Choose the closest to exact. There is no penalty for guessing. If you believe that no listed answer is correct, leave the form blank.**
(6) Hand in the answer sheet separately.

Use $g = 9.80 \text{ m/s}^2$

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

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

Scalar Product: $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$ 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 = smallest angle between $\vec{a}$ and $\vec{b}$)

Motion

Displacement: $\Delta x = x(t_2) - x(t_1)$ (1 dimension) $\Delta\vec{r} = \vec{r}(t_2) - \vec{r}(t_1)$ (3 dimensions)

Average Velocity: $v_{ave} = \dfrac{\Delta x}{\Delta t} = \dfrac{x(t_2) - x(t_1)}{t_2 - t_1}$ (1 dim) $\vec{v}_{ave} = \dfrac{\Delta\vec{r}}{\Delta t} = \dfrac{\vec{r}(t_2) - \vec{r}(t_1)}{t_2 - t_1}$ (3 dim)

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

Instantaneous Velocity: $v(t) = \dfrac{dx(t)}{dt}$ (1 dim) $\vec{v}(t) = \dfrac{d\vec{r}(t)}{dt}$ (3 dim)

Relative Velocity: $\vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC}$ (3 dim)

Average Acceleration: $a_{ave} = \dfrac{\Delta v}{\Delta t} = \dfrac{v(t_2) - v(t_1)}{t_2 - t_1}$ (1 dim) $\vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{\vec{v}(t_2) - \vec{v}(t_1)}{t_2 - t_1}$ (3 dim)

Instantaneous Acceleration: $a(t) = \dfrac{dv(t)}{dt} = \dfrac{d^2 x(t)}{dt^2}$ (1 dim) $\vec{a}(t) = \dfrac{d\vec{v}(t)}{dt} = \dfrac{d^2\vec{r}(t)}{dt^2}$ (3 dim)

Equations of Motion (Constant Acceleration)

$$v_x(t) = v_{x0} + a_x t \qquad v_y(t) = v_{y0} + a_y t \qquad v_z(t) = v_{z0} + a_z t$$

$$x(t) = x_0 + v_{x0}t + \tfrac{1}{2}a_x t^2 \qquad y(t) = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \qquad z(t) = z_0 + v_{z0}t + \tfrac{1}{2}a_z t^2$$

$$v_x^2(t) = v_{x0}^2 + 2a_x(x(t) - x_0) \qquad v_y^2(t) = v_{y0}^2 + 2a_y(y(t) - y_0) \qquad v_z^2(t) = v_{z0}^2 + 2a_z(z(t) - z_0)$$

Newton's Law and Weight

$\vec{F}_{net} = m\vec{a}$ (m = mass)   Weight (near the surface of the Earth) = W = mg (use g = 9.8 m/s^2)

Magnitude of the Frictional Force

(μ_s = static coefficient of friction, μ_k = kinetic coefficient of friction)

Static: $(f_s)_{max} = \mu_s F_N$ Kinetic: $f_k = \mu_k F_N$ (F_N is the magnitude of the normal force)

Uniform Circular Motion (Radius R, Tangential Speed v = Rω, Angular Velocity ω)

Centripetal Acceleration & Force: $a = \dfrac{v^2}{R} = R\omega^2$ $F = \dfrac{mv^2}{R} = mR\omega^2$ Period: $T = \dfrac{2\pi R}{v} = \dfrac{2\pi}{\omega}$

Projectile Motion

(horizontal surface near Earth, v_0 = initial speed, θ_0 = initial angle with horizontal)

Range: $R = \dfrac{v_0^2 \sin(2\theta_0)}{g}$ Max Height: $H = \dfrac{v_0^2 \sin^2\theta_0}{2g}$ Time (of flight): $t_f = \dfrac{2v_0 \sin\theta_0}{g}$

Quadratic Formula

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

PHY2048 Exam 2 Formula Sheet

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

Kinetic Energy: $KE = \frac{1}{2}mv^2$ Work: $W = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r} \xrightarrow[Cons\tan t \ \vec{F}]{} \vec{F} \cdot \vec{d}$ Power: $P = \dfrac{dW}{dt} = \vec{F} \cdot \vec{v}$

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

Work-Energy: W(external) = ΔKE + ΔU + ΔE(thermal) + ΔE(internal)   Work: W = -ΔU

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: $E = KE + U$ Isolated and Conservative System: $\Delta E = \Delta KE + \Delta U = 0$ $E_f = E_i$

Linear Momentum, Angular Momentum, Torque

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

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

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

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

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

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

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

Rotational Varables

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

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

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

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

Rotational Equations of Motion (Constant Angular Acceleration α)

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

PHY2048 Exam 3 Formula Sheet

Law of Gravitation

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

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

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

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

Ideal Fluids

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

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

Bernoulli's Equation (y-axis up): $P_1 + \tfrac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho gy_2 = \text{constant}$

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 ω = 2πf = 2π/T)

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

Ideal Spring (k = spring constant)): $F_x = -kx$ $\omega = \sqrt{\dfrac{k}{m}}$ $E = \tfrac{1}{2}mv^2(t) + \tfrac{1}{2}kx^2(t) = \text{constant}$

Sinusoidal Traveling Waves (frequency f = 1/T = ω/2π, wave number k = 2π/λ)

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

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

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

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

Standing Waves (L = length, n = harmonic number)

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)

Intensity (W/m²): $I = \dfrac{P}{A}$ Isotropic Point Source: $I(r) = \dfrac{P_{source}}{4\pi r^2}$ Speed of Sound: $v_{sound} = \sqrt{\dfrac{B}{\rho}}$

Speed of Sound in Air (temperature T in Kelvin): $v_{sound}(T) = v_0\sqrt{\dfrac{T}{T_0}}$ $v_0 = 331$ m/s $T_0 = 273.15\ ^{\circ}K$

Temperature (Kelvin, Centegrade, Fahrenheit): T(in °K) = T(in °C) + 273.15   T(in °F) = 1.8×T(in °C) + 32

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. A motorist drives along a straight road at a constant speed of 40 m/s. At $t = 0$ she passes a parked motorcycle police officer, and the officer takes off after her with acceleration $a(t) = bt^2$, where b is a constant and t is the time. What is the speed of the police officer (in m/s) when he reaches the motorist?

   (1) 160   (2) 200   (3) 240   (4) 80   (5) 100

2. A motorist drives along a straight road at a constant speed of 50 m/s. At $t = 0$ she passes a parked motorcycle police officer, and the officer takes off after her with acceleration $a(t) = bt^2$, where b is a constant and t is the time. What is the speed of the police officer (in m/s) when he reaches the motorist?

   (1) 200   (2) 160   (3) 240   (4) 80   (5) 100

3. A motorist drives along a straight road at a constant speed of 60 m/s. At $t = 0$ she passes a parked motorcycle police officer, and the officer takes off after her with acceleration $a(t) = bt^2$, where b is a constant and t is the time. What is the speed of the police officer (in m/s) when he reaches the motorist?

   (1) 240   (2) 160   (3) 200   (4) 80   (5) 120

4. A rabbit is dashing through the forest. Its position as a function of time is given by $\vec{r}(t) = (3 - 5t)\hat{i} + (3t^2 - 2t^3)\hat{j}$, where position is measured in meters and time in seconds. What is the magnitude of the rabbit's acceleration (in m/s^2) at $t = 1$ s?

   (1) 6   (2) 18   (3) 24   (4) 2   (5) 32

5. A rabbit is dashing through the forest. Its position as a function of time is given by $\vec{r}(t) = (3 - 5t)\hat{i} + (3t^2 - 2t^3)\hat{j}$, where position is measured in meters and time in seconds. What is the magnitude of the rabbit's acceleration (in m/s^2) at $t = 2$ s?

   (1) 18   (2) 6   (3) 24   (4) 2   (5) 32

6. A rabbit is dashing through the forest. Its position as a function of time is given by $\vec{r}(t) = (3 - 5t)\hat{i} + (3t^2 - 2t^3)\hat{j}$, where position is measured in meters and time in seconds. What is the magnitude of the rabbit's acceleration (in m/s^2) at $t = 2.5$ s?

   (1) 24   (2) 6   (3) 18   (4) 2   (5) 32

7. A carnival ride near the surface of the Earth consists of the riders standing against the inside wall of a cylindrical room with radius $R = 6.0$ m. The room spins about the vertical cylinder axis with a constant speed. Once it is up to speed, the floor of the room falls away. If the cylindrical room completes 16 revolutions per minute, what minimum coefficient of static friction between the riders and the wall will keep them from dropping with the floor?
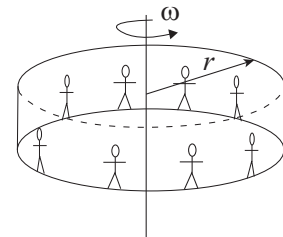
   (1) 0.582   (2) 0.460   (3) 0.372   (4) 0.288   (5) 0.685

8. A carnival ride near the surface of the Earth consists of the riders standing against the inside wall of a cylindrical room with radius $R = 6.0$ m. The room spins about the vertical cylinder axis with a constant speed. Once it is up to speed, the floor of the room falls away. If the cylindrical room completes 18 revolutions per minute, what minimum coefficient of static friction between the riders and the wall will keep them from dropping with the floor?
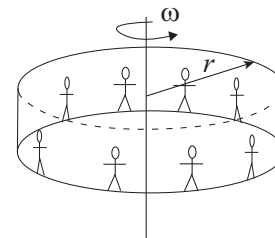
(1) 0.460   (2) 0.582   (3) 0.372   (4) 0.288   (5) 0.685

9. A carnival ride near the surface of the Earth consists of the riders standing against the inside wall of a cylindrical room with radius $R = 6.0$ m. The room spins about the vertical cylinder axis with a constant speed. Once it is up to speed, the floor of the room falls away. If the cylindrical room completes 20 revolutions per minute, what minimum coefficient of static friction between the riders and the wall will keep them from dropping with the floor?
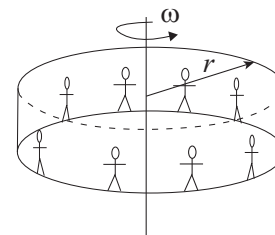
(1) 0.372   (2) 0.582   (3) 0.460   (4) 0.288   (5) 0.685

10. Near the surface of the Earth, a wooden block with mass $m = 4$ kg is attached to a string. The string is wrapped around a frictionless pulley with a radius $R = 0.5$ m, and rotational inertia I as shown in the figure. The pulley and the block are initially at rest. If when the system is released and the string begins to unwind, the tension in the string is 20 N, what is I (in kg·m^2)?
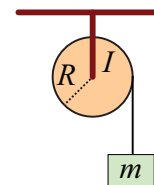
(1) 1.04   (2) 2.35   (3) 3.26   (4) 0.42   (5) 4.55

11. Near the surface of the Earth, a wooden block with mass $m = 4$ kg is attached to a string. The string is wrapped around a frictionless pulley with a radius $R = 0.5$ m, and rotational inertia I as shown in the figure. The pulley and the block are initially at rest. If when the system is released and the string begins to unwind, the tension in the string is 27.5 N, what is I (in kg·m^2)?
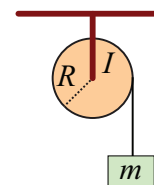
(1) 2.35   (2) 1.04   (3) 3.26   (4) 0.42   (5) 4.55

12. Near the surface of the Earth, a wooden block with mass $m = 4$ kg is attached to a string. The string is wrapped around a frictionless pulley with a radius $R = 0.5$ m, and rotational inertia I as shown in the figure. The pulley and the block are initially at rest. If when the system is released and the string begins to unwind, the tension in the string is 30 N, what is I (in kg·m^2)?
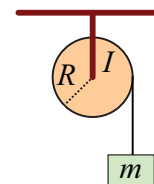
(1) 3.26   (2) 1.04   (3) 2.35   (4) 0.42   (5) 4.55

13. Near the surface of the Earth a block of mass M is released from rest at a height h on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat horizontal surface with a kinetic coefficient of friction $\mu_k = 0.5$. The block slides a horizontal distance d and then slides up a frictionless incline and reaches a maximum height H before sliding back down. If $h = d$, what is H?

(1) $h/2$ (2) $3h/4$ (3) $h/4$ (4) h (5) $h/3$

14. Near the surface of the Earth a block of mass M is released from rest at a height h on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat horizontal surface with a kinetic coefficient of friction $\mu_k = 0.25$. The block slides a horizontal distance d and then slides up a frictionless incline and reaches a maximum height H before sliding back down. If $h = d$, what is H?

(1) $3h/4$ (2) $h/2$ (3) $h/4$ (4) h (5) $h/3$

15. Near the surface of the Earth a block of mass M is released from rest at a height h on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat horizontal surface with a kinetic coefficient of friction $\mu_k = 0.75$. The block slides a horizontal distance d and then slides up a frictionless incline and reaches a maximum height H before sliding back down. If $h = d$, what is H?

(1) $h/4$ (2) $h/2$ (3) $3h/4$ (4) h (5) $h/3$

16. Near the surface of the Earth a man whose weight at rest is 180 N stands on a scale in an elevator that starts from rest and accelerates upward with a constant acceleration. If after the elevator has travelled a distance of 10 m its speed is 4 m/s, what is his apparent weight (in N) on the scale in the elevator during his ride?

(1) 194.7 (2) 213.1 (3) 238.8 (4) 165.3 (5) 146.9

17. Near the surface of the Earth a man whose weight at rest is 180 N stands on a scale in an elevator that starts from rest and accelerates upward with a constant acceleration. If after the elevator has travelled a distance of 10 m its speed is 6 m/s, what is his apparent weight (in N) on the scale in the elevator during his ride?

(1) 213.1 (2) 194.7 (3) 238.8 (4) 165.3 (5) 146.9

18. Near the surface of the Earth a man whose weight at rest is 180 N stands on a scale in an elevator that starts from rest and accelerates upward with a constant acceleration. If after the elevator has travelled a distance of 10 m its speed is 8 m/s, what is his apparent weight (in N) on the scale in the elevator during his ride?

(1) 238.8 (2) 194.7 (3) 213.1 (4) 165.3 (5) 146.9

19. A race car starts from rest at $t = 0$ and travels around a circular track of radius R with a constant angular acceleration. If the magnitude of the tangential acceleration of the car is equal to the magnitude of the radial acceleration (*i.e.,* centripetal acceleration) of the car at $t = 20$ s, how long does it take for the race car to complete its first revolution around the track (in minutes)?

(1) 1.18 (2) 1.77 (3) 2.36 (4) 1.00 (5) 3.00

20. A race car starts from rest at $t = 0$ and travels around a circular track of radius R with a constant angular acceleration. If the magnitude of the tangential acceleration of the car is equal to the magnitude of the radial acceleration (*i.e.,* centripetal acceleration) of the car at $t = 30$ s, how long does it take for the race car to complete its first revolution around the track (in minutes)?

(1) 1.77 (2) 1.18 (3) 2.36 (4) 1.00 (5) 3.00

21. A race car starts from rest at $t = 0$ and travels around a circular track of radius R with a constant angular acceleration. If the magnitude of the tangential acceleration of the car is equal to the magnitude of the radial acceleration (*i.e.*, centripetal acceleration) of the car at $t = 40$ s, how long does it take for the race car to complete its first revolution around the track (in minutes)?

(1) 2.36   (2) 1.18   (3) 1.77   (4) 1.00   (5) 3.00

22. A 80-N uniform plank leans at rest against a frictionless wall at an angle θ with the horizontal as shown in the figure. If $\theta = 53.13°$, what is the magnitude of the force (in N) applied to the plank by the wall?

(1) 30   (2) 25   (3) 20   (4) 80   (5) 120

23. A 80-N uniform plank leans at rest against a frictionless wall at an angle θ with the horizontal as shown in the figure. If $\theta = 57.99°$, what is the magnitude of the force (in N) applied to the plank by the wall?

(1) 25   (2) 30   (3) 20   (4) 80   (5) 120

24. A 80-N uniform plank leans at rest against a frictionless wall at an angle θ with the horizontal as shown in the figure. If $\theta = 63.43°$, what is the magnitude of the force (in N) applied to the plank by the wall?

(1) 20   (2) 30   (3) 25   (4) 80   (5) 120

25. A 0.5-kg rubber ball is dropped from rest a height $H = 19.6$ m above the surface of the Earth. It strikes the sidewalk below and rebounds up to a maximum height of 4.9 m. If the ball was in contact with the sidewalk for 0.2 seconds, what is the magnitude of the average force that the sidewalk exerts on the ball during the collision (in N)?

(1) 73.5   (2) 58.8   (3) 49.0   (4) 38.5   (5) 82.2

26. A 0.5-kg rubber ball is dropped from rest a height $H = 19.6$ m above the surface of the Earth. It strikes the sidewalk below and rebounds up to a maximum height of 4.9 m. If the ball was in contact with the sidewalk for 0.25 seconds, what is the magnitude of the average force that the sidewalk exerts on the ball during the collision (in N)?

(1) 58.8   (2) 73.5   (3) 49.0   (4) 38.5   (5) 82.2

27. A 0.5-kg rubber ball is dropped from rest a height $H = 19.6$ m above the surface of the Earth. It strikes the sidewalk below and rebounds up to a maximum height of 4.9 m. If the ball was in contact with the sidewalk for 0.3 seconds, what is the magnitude of the average force that the sidewalk exerts on the ball during the collision (in N)?

(1) 49.0   (2) 73.5   (3) 58.8   (4) 38.5   (5) 82.2

28. A block slides along a horizontal frictionless surface with speed v. When the block reaches the point $x = 0$, two forces with magnitudes $F_1 = 3x^2$ N and $F_2 = 10$ N are applied on the block as shown in the figure. What is the total work (in J) done on the box if the box travels a distance d from $x = 0$ to $x = 10$ m in the positive x direction?

(1) 900   (2) 273   (3) 75   (4) 1200   (5) 35

29. A block slides along a horizontal frictionless surface with speed v. When the block reaches the point $x = 0$, two forces with magnitudes $F_1 = 3x^2$ N and $F_2 = 10$ N are applied on the block as shown in the figure. What is the total work (in J) done on the box if the box travels a distance d from $x = 0$ to $x = 7$ m in the positive x direction?

(1) 273   (2) 900   (3) 75   (4) 1200   (5) 35

30. A block slides along a horizontal frictionless surface with speed v. When the block reaches the point $x = 0$, two forces with magnitudes $F_1 = 3x^2$ N and $F_2 = 10$ N are applied on the block as shown in the figure. What is the total work (in J) done on the box if the box travels a distance d from $x = 0$ to $x = 5$ m in the positive x direction?

(1) 75   (2) 900   (3) 273   (4) 1200   (5) 35

31. Two stars with masses M_1 and M_2 orbit with uniform circular motion around their common center of mass. If $M_1 = 3 \times 10^{30}$ kg and $M_2 = 2M_1$, and the distance between the stars is 1×10^{10} km, what is the period of their orbit (in years)?

(1) 257   (2) 472   (3) 727   (4) 315   (5) 578

32. Two stars with masses M_1 and M_2 orbit with uniform circular motion around their common center of mass. If $M_1 = 3 \times 10^{30}$ kg and $M_2 = 2M_1$, and the distance between the stars is 1.5×10^{10} km, what is the period of their orbit (in years)?

(1) 472   (2) 257   (3) 727   (4) 315   (5) 578

33. Two stars with masses M_1 and M_2 orbit with uniform circular motion around their common center of mass. If $M_1 = 3 \times 10^{30}$ kg and $M_2 = 2M_1$, and the distance between the stars is 2×10^{10} km, what is the period of their orbit (in years)?

(1) 727   (2) 257   (3) 472   (4) 315   (5) 890

34. Planet Roton, with a mass of 7×10^{24} kg and a radius of 1,500 km, gravitationally attracts a meteorite that is initially at rest relative to the planet, at a distance great enough to take as infinite. The meteorite falls toward the planet. Assuming the planet is airless, what is the speed (in km/s) of the meteorite relative to the planet when it reaches the planet's surface?

(1) 25.0   (2) 17.6   (3) 14.4   (4) 31.2   (5) 11.6

35. Planet Roton, with a mass of 7×10^{24} kg and a radius of 3,000 km, gravitationally attracts a meteorite that is initially at rest relative to the planet, at a distance great enough to take as infinite. The meteorite falls toward the planet. Assuming the planet is airless, what is the speed (in km/s) of the meteorite relative to the planet when it reaches the planet's surface?

(1) 17.6   (2) 25.0   (3) 14.4   (4) 31.2   (5) 11.6

36. Planet Roton, with a mass of 7×10^{24} kg and a radius of 4,500 km, gravitationally attracts a meteorite that is initially at rest relative to the planet, at a distance great enough to take as infinite. The meteorite falls toward the planet. Assuming the planet is airless, what is the speed (in km/s) of the meteorite relative to the planet when it reaches the planet's surface?

(1) 14.4   (2) 25.0   (3) 17.6   (4) 31.2   (5) 11.6

37. A block of mass $M = 4$ kg is at rest on a horizontal frictionless surface and is connected to an ideal spring as shown in the figure. A 2-gram bullet traveling horizontally at 290 m/s strikes the block and becomes embedded in the block. If the bullet-block system comes to rest after compressing the spring a distance of 4 cm, what is the period (in s) of the subsequent simple harmonic motion of the system?

(1) 1.73   (2) 2.60   (3) 3.47   (4) 0.87   (5) 4.95
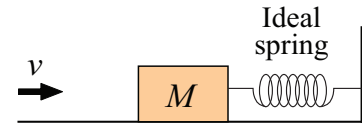
38. A block of mass $M = 4$ kg is at rest on a horizontal frictionless surface and is connected to an ideal spring as shown in the figure. A 2-gram bullet traveling horizontally at 290 m/s strikes the block and becomes embedded in the block. If the bullet-block system comes to rest after compressing the spring a distance of 6 cm, what is the period (in s) of the subsequent simple harmonic motion of the system?

(1) 2.60   (2) 1.73   (3) 3.47   (4) 0.87   (5) 4.95
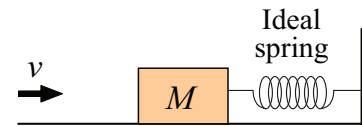
39. A block of mass $M = 4$ kg is at rest on a horizontal frictionless surface and is connected to an ideal spring as shown in the figure. A 2-gram bullet traveling horizontally at 290 m/s strikes the block and becomes embedded in the block. If the bullet-block system comes to rest after compressing the spring a distance of 8 cm, what is the period (in s) of the subsequent simple harmonic motion of the system?

(1) 3.47   (2) 1.73   (3) 2.60   (4) 0.87   (5) 4.95
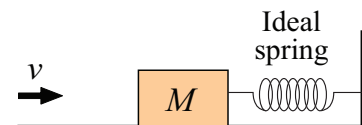
40. A cubical metal box with sides of mass M and length L has a square lid also with mass M and length L. The lid is not attached to the box, however, the lid and the box form an airtight seal. Near the surface of the Earth, the lid is held at rest by a steel cable, as shown in the figure. The pressure outside the box is the atmospheric pressure, $P_{out} = P_{atm} = 101$ kPa. The box is partially evacuated to an inside pressure $P_{in} = 95$ kPa. If $L = 0.2$ m, what is the maximum mass M (in kg) of the sides of the cubical metal box such that the box remains at rest and does not fall?

(1) 4.90   (2) 8.98   (3) 13.06   (4) 2.65   (5) 18.89
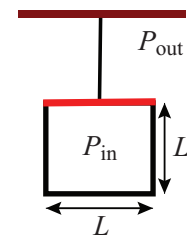
41. A cubical metal box with sides of mass M and length L has a square lid also with mass M and length L. The lid is not attached to the box, however, the lid and the box form an airtight seal. Near the surface of the Earth, the lid is held at rest by a steel cable, as shown in the figure. The pressure outside the box is the atmospheric pressure, $P_{out} = P_{atm} = 101$ kPa. The box is partially evacuated to an inside pressure $P_{in} = 90$ kPa. If $L = 0.2$ m, what is the maximum mass M (in kg) of the sides of the cubical metal box such that the box remains at rest and does not fall?

(1) 8.98   (2) 4.90   (3) 13.06   (4) 2.65   (5) 18.89
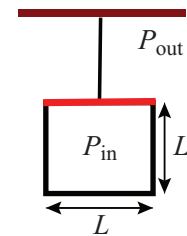
42. A cubical metal box with sides of mass M and length L has a square lid also with mass M and length L. The lid is not attached to the box, however, the lid and the box form an airtight seal. Near the surface of the Earth, the lid is held at rest by a steel cable, as shown in the figure. The pressure outside the box is the atmospheric pressure, $P_{\text{out}} = P_{\text{atm}} = 101$ kPa. The box is partially evacuated to an inside pressure $P_{\text{in}} = 85$ kPa. If $L = 0.2$ m, what is the maximum mass M (in kg) of the sides of the cubical metal box such that the box remains at rest and does not fall?
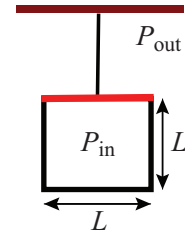
(1) 13.06   (2) 4.90   (3) 8.98   (4) 2.65   (5) 18.89

43. Stan and Ollie are standing next to a train track. Stan puts his ear to the steel track to hear the train coming. When the train is 750 m away he hears the sound of the train whistle through the track 2.1 s before Ollie hears it through the air. If the speed of sound in steel is 5790 m/s, what is the temperature of the air (in °C)?

(1) 9.0   (2) 23.3   (3) 37.9   (4) 18.2   (5) 15.5

44. Stan and Ollie are standing next to a train track. Stan puts his ear to the steel track to hear the train coming. When the train is 770 m away he hears the sound of the train whistle through the track 2.1 s before Ollie hears it through the air. If the speed of sound in steel is 5790 m/s, what is the temperature of the air (in °C)?

(1) 23.3   (2) 9.0   (3) 37.9   (4) 18.2   (5) 15.5

45. Stan and Ollie are standing next to a train track. Stan puts his ear to the steel track to hear the train coming. When the train is 790 m away he hears the sound of the train whistle through the track 2.1 s before Ollie hears it through the air. If the speed of sound in steel is 5790 m/s, what is the temperature of the air (in °C)?

(1) 37.9   (2) 9.0   (3) 23.3   (4) 18.2   (5) 15.5

46. A large cargo container has a square base with an area of 4 m^2 and height $H = 6$ m. When empty, it floats on the water ($\rho_{\text{water}} = 1,000$ kg/m^3) with 4 meters above the surface of the water and 2 m below the surface as shown in the figure. The cargo container is being loaded with small 50-kg boxes. What is the maximum number of boxes the cargo container can hold without sinking?
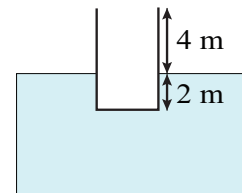
(1) 320   (2) 400   (3) 500   (4) 240   (5) 300

47. A large cargo container has a square base with an area of 4 m^2 and height $H = 6$ m. When empty, it floats on the water ($\rho_{\text{water}} = 1,000$ kg/m^3) with 4 meters above the surface of the water and 2 m below the surface as shown in the figure. The cargo container is being loaded with small 40-kg boxes. What is the maximum number of boxes the cargo container can hold without sinking?
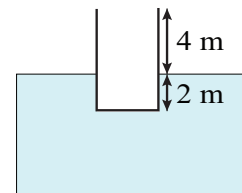
(1) 400   (2) 320   (3) 500   (4) 240   (5) 300

48. A large cargo container has a square base with an area of 4 m^2 and height $H = 6$ m. When empty, it floats on the water ($\rho_{\text{water}} = 1,000$ kg/m^3) with 4 meters above the surface of the water and 2 m below the surface as shown in the figure. The cargo container is being loaded with small 32-kg boxes. What is the maximum number of boxes the cargo container can hold without sinking?
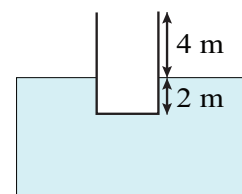

(1) 500   (2) 320   (3) 400   (4) 240   (5) 300

49. What is the maximum total mass (including the mass of the empty balloon) that a spherical helium balloon with a radius of 1.5 m can lift off the ground? The density of helium and the air are $\rho_{\text{He}} = 0.18$ kg/m^3 and $\rho_{\text{air}} = 1.2$ kg/m^3, respectively.

(1) 14.42 kg   (2) 34.18 kg   (3) 66.76 kg   (4) 10.45 kg   (5) 72.25 kg

50. What is the maximum total mass (including the mass of the empty balloon) that a spherical helium balloon with a radius of 2.0 m can lift off the ground? The density of helium and the air are $\rho_{\text{He}} = 0.18$ kg/m^3 and $\rho_{\text{air}} = 1.2$ kg/m^3, respectively.

(1) 34.18 kg   (2) 14.42 kg   (3) 66.76 kg   (4) 10.45 kg   (5) 72.25 kg

51. What is the maximum total mass (including the mass of the empty balloon) that a spherical helium balloon with a radius of 2.5 m can lift off the ground? The density of helium and the air are $\rho_{\text{He}} = 0.18$ kg/m^3 and $\rho_{\text{air}} = 1.2$ kg/m^3, respectively.

(1) 66.76 kg   (2) 14.42 kg   (3) 34.18 kg   (4) 10.45 kg   (5) 72.25 kg

52. A stationary motion detector on the x-axis sends sound waves of frequency of 500 Hz, as shown in the figure. The waves sent out by the detector are reflected off a truck traveling along the x-axis and then are received back at the detector. If the frequency of the waves received back at the detector is 750 Hz, what is the x-component of the velocity of the truck (in m/s)? (Take the speed of sound to be 343 m/s.)
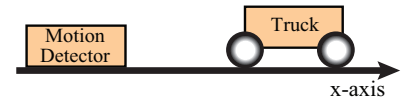

(1) −68.6   (2) 38.1   (3) 60.5   (4) 90.3   (5) 68.6

53. A stationary motion detector on the x-axis sends sound waves of frequency of 500 Hz, as shown in the figure. The waves sent out by the detector are reflected off a truck traveling along the x-axis and then are received back at the detector. If the frequency of the waves received back at the detector is 400 Hz, what is the x-component of the velocity of the truck (in m/s)? (Take the speed of sound to be 343 m/s.)
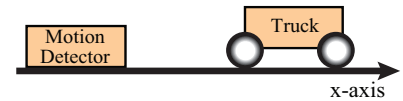

(1) 38.1   (2) −68.6   (3) 60.5   (4) 90.3   (5) −38.1

54. A stationary motion detector on the x-axis sends sound waves of frequency of 500 Hz, as shown in the figure. The waves sent out by the detector are reflected off a truck traveling along the x-axis and then are received back at the detector. If the frequency of the waves received back at the detector is 350 Hz, what is the x-component of the velocity of the truck (in m/s)? (Take the speed of sound to be 343 m/s.)
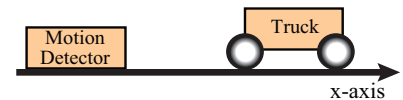
(1) 60.5   (2) −68.6   (3) 38.1   (4) 90.3   (5) −60.5

55. The figure shows two isotropic point sources of sound on the x-axis, source S_1 at $x = 0$ and source S_2 at $x = d$. The sources emit sound at the same wavelength λ and the same amplitude A, and they emit in phase. A point P is shown on the x-axis with $0 < x < d$. Assume that as the sound waves travel to the point P, the decrease in their amplitude is negligible. If $\lambda = d$, at what points P along the x-axis does maximally destructive interference occur?
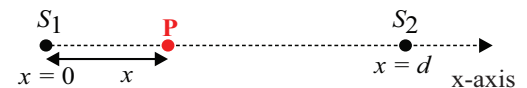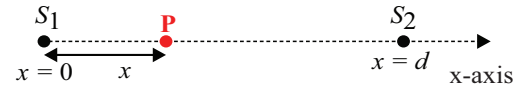

(1) $x = 0.25d$ and $x = 0.75d$
(2) $x = 0.20d$ and $x = 0.80d$
(3) $x = 0.15d$ and $x = 0.85d$
(4) $x = 0.10d$ and $x = 0.90d$
(5) Only at $x = 0.50d$

56. The figure shows two isotropic point sources of sound on the x-axis, source S_1 at $x = 0$ and source S_2 at $x = d$. The sources emit sound at the same wavelength λ and the same amplitude A, and they emit in phase. A point P is shown on the x-axis with $0 < x < d$. Assume that as the sound waves travel to the point P, the decrease in their amplitude is negligible. If $\lambda = 1.2d$, at what points P along the x-axis does maximally destructive interference occur?
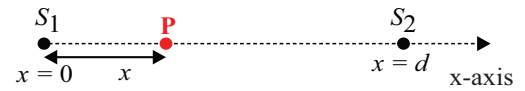
(1) $x = 0.20d$ and $x = 0.80d$
(2) $x = 0.25d$ and $x = 0.75d$
(3) $x = 0.15d$ and $x = 0.85d$
(4) $x = 0.10d$ and $x = 0.90d$
(5) Only at $x = 0.50d$

57. The figure shows two isotropic point sources of sound on the x-axis, source S_1 at $x = 0$ and source S_2 at $x = d$. The sources emit sound at the same wavelength λ and the same amplitude A, and they emit in phase. A point P is shown on the x-axis with $0 < x < d$. Assume that as the sound waves travel to the point P, the decrease in their amplitude is negligible. If $\lambda = 1.4d$, at what points P along the x-axis does maximally destructive interference occur?

(1) $x = 0.15d$ and $x = 0.85d$
(2) $x = 0.25d$ and $x = 0.75d$
(3) $x = 0.20d$ and $x = 0.80d$
(4) $x = 0.10d$ and $x = 0.90d$
(5) Only at $x = 0.50d$

58. A travelling wave on a string is described with the equation $y(x, t) = 0.5 \cos(5\pi t - 3\pi x + 0.5\pi)$, where t is in seconds, and x and y are in meters. How long does it take (in s) for the wave to travel a distance of 10 m along the string?

(1) 6   (2) 9   (3) 12   (4) 3   (5) 15

59. A travelling wave on a string is described with the equation $y(x, t) = 0.5 \cos(5\pi t - 3\pi x + 0.5\pi)$, where t is in seconds, and x and y are in meters. How long does it take (in s) for the wave to travel a distance of 15 m along the string?

(1) 9   (2) 6   (3) 12   (4) 3   (5) 15

60. A travelling wave on a string is described with the equation $y(x, t) = 0.5 \cos(5\pi t - 3\pi x + 0.5\pi)$, where t is in seconds, and x and y are in meters. How long does it take (in s) for the wave to travel a distance of 20 m along the string?

(1) 12   (2) 6   (3) 9   (4) 3   (5) 15

FOLLOWING GROUPS OF QUESTIONS WILL BE SELECTED AS ONE GROUP FROM EACH TYPE
TYPE 1
Q# S 1
Q# S 2
Q# S 3
TYPE 2
Q# S 4
Q# S 5
Q# S 6
TYPE 3
Q# S 7
Q# S 8
Q# S 9
TYPE 4
Q# S 10
Q# S 11
Q# S 12

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TYPE 5
Q# S 13
Q# S 14
Q# S 15
TYPE 6
Q# S 16
Q# S 17
Q# S 18
TYPE 7
Q# S 19
Q# S 20
Q# S 21
TYPE 8
Q# S 22
Q# S 23
Q# S 24
TYPE 9
Q# S 25
Q# S 26
Q# S 27
TYPE 10
Q# S 28
Q# S 29
Q# S 30
TYPE 11
Q# S 31
Q# S 32
Q# S 33
TYPE 12
Q# S 34
Q# S 35
Q# S 36
TYPE 13
Q# S 37
Q# S 38
Q# S 39
TYPE 14
Q# S 40
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Q# S 42
TYPE 15
Q# S 43
Q# S 44
Q# S 45
TYPE 16
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TYPE 18
Q# S 52
Q# S 53
Q# S 54
TYPE 19
Q# S 55
Q# S 56
Q# S 57
TYPE 20
Q# S 58
Q# S 59
Q# S 60
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