Instructor(s): *Field/Matcheva/Detweiler*

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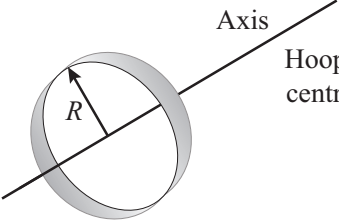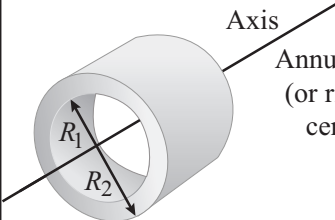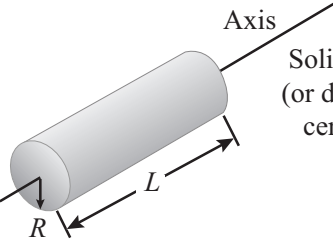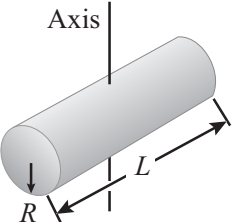PHYSICS DEPARTMENT

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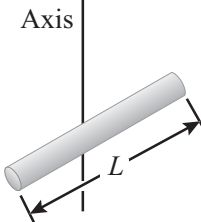
PHY 2048   Exam 2   March 25, 2015

Name (print, last first):   Signature:

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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.

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(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.
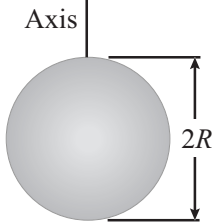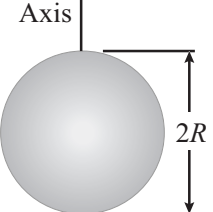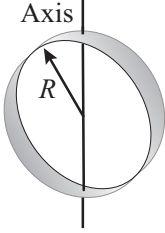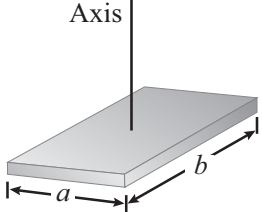(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.
(4) **Blacken the circle 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.

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Use $g = 9.80$ m/s^2

</div>

Axis Hoop about central axis $I = MR^2$	Axis Annular cylinder (or ring) about central axis $I = \frac{1}{2} M(R_1^2 + R_2^2)$	Axis Solid cylinder (or disk) about central axis $I = \frac{1}{2} MR^2$
Axis Solid cylinder (or disk) about central diameter $I = \frac{1}{4} MR^2 + \frac{1}{12} ML^2$	Axis Thin rod about axis through center perpendicular to length $I = \frac{1}{12} ML^2$	Axis Solid sphere about any diameter $I = \frac{2}{5} MR^2$
Axis Thin spherical shell about any diameter $I = \frac{2}{3} MR^2$	Axis Hoop about any diameter $I = \frac{1}{2} MR^2$	Axis 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) $\quad \Delta\vec{r} = \vec{r}(t_2) - \vec{r}(t_1)$ (3 dimensions)

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

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

Instantaneous Velocity: $v(t) = \dfrac{dx(t)}{dt}$ (1 dim) $\quad \vec{v}(t) = \dfrac{d\vec{r}(t)}{dt}$ (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) $\quad \vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t} = \dfrac{\vec{v}(t_2) - \vec{v}(t_1)}{t_2 - t_1}$ (3 dim)

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

Equations of Motion (Constant Acceleration)

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

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

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

Newton's Law and Weight

$\vec{F}_{net} = m\vec{a}$ (m = mass) $\quad$ 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: $(f_s)_{max} = \mu_s F_N$ $\quad$ Kinetic: $f_k = \mu_k F_N$ $\quad$ (F_N is the magnitude of the normal force)

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

Centripetal Acceleration & Force: $a = \dfrac{v^2}{R} = R\omega^2 \quad F = \dfrac{mv^2}{R} = mR\omega^2 \quad$ 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: $R = \dfrac{v_0^2 \sin(2\theta_0)}{g}$ $\quad$ Max Height: $H = \dfrac{v_0^2 \sin^2\theta_0}{2g}$ $\quad$ Time (of flight): $t_f = \dfrac{2v_0 \sin\theta_0}{g}$

Quadratic Formula

If: $ax^2 + bx + c = 0$ $\quad$ 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: $W = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r} \xrightarrow[Constant\ \vec{F}]{} \vec{F} \cdot \vec{d}$ Power: $P = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$

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

Work-Energy: W(external) = $\Delta KE + \Delta U + \Delta E$(thermal) + ΔE(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: $E = KE + U$ Isolated and Conservative System: $\Delta E = \Delta KE + \Delta U = 0$ $E_f = E_i$

Linear Momentum, Angular Momentum, Torque

Linear Momentum: $\vec{p} = m\vec{v}$ $\vec{F} = \frac{d\vec{p}}{dt}$ Kinetic Energy: $KE = \frac{p^2}{2m}$ 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: $I = \sum_{i=1}^{N} m_i r_i^2$ (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 $\vec{p}$ = constant and $\vec{p}_f = \vec{p}_i$

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

Rotational Varables

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: $x_{COM} = R\theta$ $v_{COM} = R\omega$ $a_{COM} = R\alpha$ $KE = \frac{1}{2}Mv_{COM}^2 + \frac{1}{2}I_{COM}\omega^2$

Rotational Equations of Motion (Constant Angular Acceleration α)

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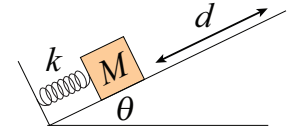$$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$
$$\omega^2(t) = \omega_0^2 + 2\alpha(\theta(t) - \theta_0)$$

1. Near the surface of the Earth, a block with a mass $M = 2$ kg is placed against a spring on a frictionless incline with angle $\theta = 30°$ as shown in the figure. The block is not connected to the spring. The spring has a spring constant of $k = 1960$ N/m and initially compressed by 20 cm. The spring is then released. How far (in m) along the incline from the release point will the block travel?
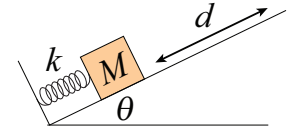
(1) 4   (2) 6   (3) 8   (4) 2   (5) 3

2. Near the surface of the Earth, a block with a mass $M = 2$ kg is placed against a spring on a frictionless incline with angle $\theta = 30°$ as shown in the figure. The block is not connected to the spring. The spring has a spring constant of $k = 2940$ N/m and initially compressed by 20 cm. The spring is then released. How far (in m) along the incline from the release point will the block travel?

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

3. Near the surface of the Earth, a block with a mass $M = 2$ kg is placed against a spring on a frictionless incline with angle $\theta = 30°$ as shown in the figure. The block is not connected to the spring. The spring has a spring constant of $k = 3920$ N/m and initially compressed by 20 cm. The spring is then released. How far (in m) along the incline from the release point will the block travel?
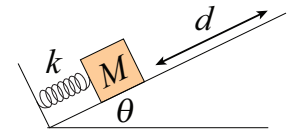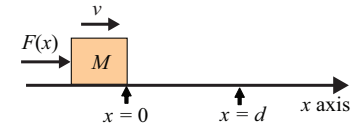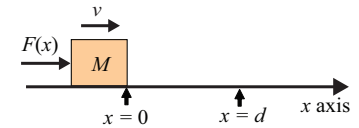
(1) 8   (2) 4   (3) 6   (4) 2   (5) 3

4. A 10-kg block slides along a horizontal frictionless surface with an initial speed $v = 2$ m/s. When the block reaches the point $x = 0$, a variable horizontal force with magnitude that depends on x according to the formula $F(x) = bx$, where $b = 2$ N/m, is applied to the block as shown in the figure. What is the speed of the block (in m/s) when it reaches the point $x = d = 5$ m?

(1) 3   (2) 7   (3) 6   (4) 4   (5) 5

5. A 10-kg block slides along a horizontal frictionless surface with an initial speed $v = 2$ m/s. When the block reaches the point $x = 0$, a variable horizontal force with magnitude that depends on x according to the formula $F(x) = bx$, where $b = 2$ N/m, is applied to the block as shown in the figure. What is the speed of the block (in m/s) when it reaches the point $x = d = 15$ m?

(1) 7   (2) 3   (3) 6   (4) 4   (5) 5

6. A 10-kg block slides along a horizontal frictionless surface with an initial speed $v = 4$ m/s. When the block reaches the point $x = 0$, a variable horizontal force with magnitude that depends on x according to the formula $F(x) = bx$, where $b = 2$ N/m, is applied to the block as shown in the figure. What is the speed of the block (in m/s) when it reaches the point $x = d = 10$ m?
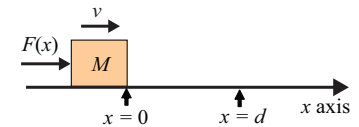
(1) 6   (2) 3   (3) 7   (4) 4   (5) 5

7. A 4-kg particle moves along the x-axis under the influence of a conservative force. The potential energy is given by $U(x) = bx^3$, where $b = 8.0$ J/m^3. What is the magnitude of the acceleration of the particle (in m/s^2) when it is at the point $x = 2$ m?

(1) 24   (2) 54   (3) 96   (4) 12   (5) 28

8. A 4-kg particle moves along the x-axis under the influence of a conservative force. The potential energy is given by $U(x) = bx^3$, where $b = 8.0$ J/m^3. What is the magnitude of the acceleration of the particle (in m/s^2) when it is at the point $x = 3$ m?
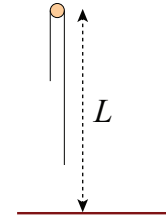
(1) 54   (2) 24   (3) 96   (4) 12   (5) 28

9. A 4-kg particle moves along the x-axis under the influence of a conservative force. The potential energy is given by $U(x) = bx^3$, where $b = 8.0$ J/m^3. What is the magnitude of the acceleration of the particle (in m/s^2) when it is at the point $x = 4$ m?

(1) 96   (2) 24   (3) 54   (4) 12   (5) 28

10. Starting from rest near the surface of the Earth, a 25-kg bear slides 12 m down a vertical pine tree, and has a speed of 6 m/s just before hitting the ground. What was the magnitude of the average frictional force (in N) acting on the bear during the slide?

(1) 207.5   (2) 178.3   (3) 140.8   (4) 225.6   (5) 120.5

11. Starting from rest near the surface of the Earth, a 25-kg bear slides 12 m down a vertical pine tree, and has a speed of 8 m/s just before hitting the ground. What was the magnitude of the average frictional force (in N) acting on the bear during the slide?

(1) 178.3   (2) 207.5   (3) 140.8   (4) 225.6   (5) 120.5

12. Starting from rest near the surface of the Earth, a 25-kg bear slides 12 m down a vertical pine tree, and has a speed of 10 m/s just before hitting the ground. What was the magnitude of the average frictional force (in N) acting on the bear during the slide?

(1) 140.8   (2) 207.5   (3) 178.3   (4) 225.6   (5) 120.5

13. Near the surface of the Earth, a uniform limp rope of mass M and length L hangs over a (frictionless) peg a height L above the ground, as shown in the figure. If the rope is released from rest with $3/4$ of its length on one side and $1/4$ of its length on the other side, what is the speed of the rope when the first end hits the ground?

(1) $\sqrt{3gL/8}$ (2) $\frac{2}{3}\sqrt{gL}$ (3) $\frac{2}{5}\sqrt{3gL}$ (4) $\frac{1}{2}\sqrt{3gL}$ (5) $\frac{1}{2}\sqrt{gL}$

14. Near the surface of the Earth, a uniform limp rope of mass M and length L hangs over a (frictionless) peg a height L above the ground, as shown in the figure. If the rope is released from rest with $2/3$ of its length on one side and $1/3$ of its length on the other side, what is the speed of the rope when the first end hits the ground?

(1) $\frac{2}{3}\sqrt{gL}$ (2) $\sqrt{3gL/8}$ (3) $\frac{2}{5}\sqrt{3gL}$ (4) $\frac{1}{2}\sqrt{3gL}$ (5) $\frac{1}{2}\sqrt{gL}$

15. Near the surface of the Earth, a uniform limp rope of mass M and length L hangs over a (frictionless) peg a height L above the ground, as shown in the figure. If the rope is released from rest with $3/5$ of its length on one side and $2/5$ of its length on the other side, what is the speed of the rope when the first end hits the ground?

(1) $\frac{2}{5}\sqrt{3gL}$ (2) $\sqrt{3gL/8}$ (3) $\frac{2}{3}\sqrt{gL}$ (4) $\frac{1}{2}\sqrt{3gL}$ (5) $\frac{1}{2}\sqrt{gL}$

16. A 2-kg particle moves along the x axis under the influence of a conservative force. The potential energy function of the particle is given by the formula $U(x) = 10 + 5x^2$, where x is the coordinate (in m) as U is measured in Joules. What is the farthest point in the positive x direction that the particle can reach (in m) if at $x = 2$ m its kinetic energy is 50 J?

(1) 3.74   (2) 4.90   (3) 5.83   (4) 6.75   (5) 2.89

17. A 2-kg particle moves along the x axis under the influence of a conservative force. The potential energy function of the particle is given by the formula $U(x) = 10 + 5x^2$, where x is the coordinate (in m) as U is measured in Joules. What is the farthest point in the positive x direction that the particle can reach (in m) if at $x = 2$ m its kinetic energy is 100 J?

(1) 4.90   (2) 3.74   (3) 5.83   (4) 6.75   (5) 2.89

18. A 2-kg particle moves along the x axis under the influence of a conservative force. The potential energy function of the particle is given by the formula $U(x) = 10 + 5x^2$, where x is the coordinate (in m) as U is measured in Joules. What is the farthest point in the positive x direction that the particle can reach (in m) if at $x = 2$ m its kinetic energy is 150 J?

(1) 5.83   (2) 3.74   (3) 4.90   (4) 6.75   (5) 2.89

19. Near the surface of the Earth, a ball of mass M hangs vertically on a string of length L as shown in the figure. A lump of mud with mass m and horizontal speed v collides with the ball. The mud sticks to the ball causing it to swing on its string. If $m = M$, what maximum vertical height H does the mud-ball system reach after the collision?
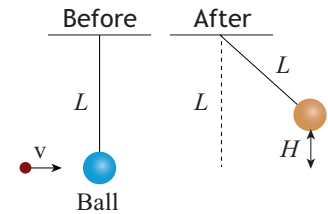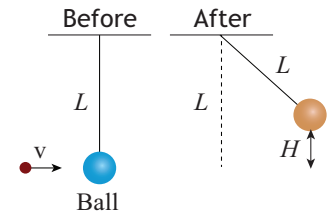
(1) $0.125v^2/g$ (2) $0.222v^2/g$ (3) $0.056v^2/g$ (4) $0.5v^2/g$ (5) $0.333v^2/g$

20. Near the surface of the Earth, a ball of mass M hangs vertically on a string of length L as shown in the figure. A lump of mud with mass m and horizontal speed v collides with the ball. The mud sticks to the ball causing it to swing on its string. If $m = 2M$, what maximum vertical height H does the mud-ball system reach after the collision?
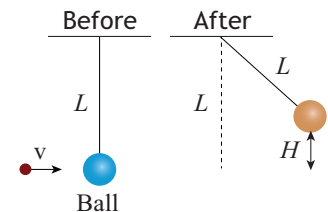
(1) $0.222v^2/g$ (2) $0.125v^2/g$ (3) $0.056v^2/g$ (4) $0.5v^2/g$ (5) $0.333v^2/g$

21. Near the surface of the Earth, a ball of mass M hangs vertically on a string of length L as shown in the figure. A lump of mud with mass m and horizontal speed v collides with the ball. The mud sticks to the ball causing it to swing on its string. If $m = M/2$, what maximum vertical height H does the mud-ball system reach after the collision?

(1) $0.056v^2/g$ (2) $0.125v^2/g$ (3) $0.222v^2/g$ (4) $0.5v^2/g$ (5) $0.333v^2/g$

22. A 0.5-kg ball is dropped from rest a height $H = 10$ m above the surface of the Earth, as shown in the figure. It strikes the sidewalk at $t = 0$ and experiences an upward force that depends on time according to the formula $F_y(t) = bt$, where b is a constant. If $b = 98$ N/s and the ball is in contact with the sidewalk for 0.45 seconds, what maximum height h (in m) is reached by the ball when it rebounds from the sidewalk?
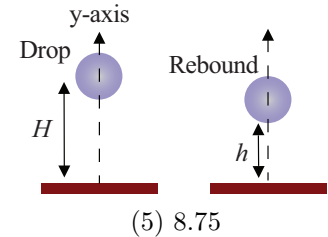
(1) 1.74   (2) 5.63   (3) 7.97   (4) 3.23   (5) 8.75

23. A 0.5-kg ball is dropped from rest a height $H = 10$ m above the surface of the Earth, as shown in the figure. It strikes the sidewalk at $t = 0$ and experiences an upward force that depends on time according to the formula $F_y(t) = bt$, where b is a constant. If $b = 98$ N/s and the ball is in contact with the sidewalk for 0.50 seconds, what maximum height h (in m) is reached by the ball when it rebounds from the sidewalk?
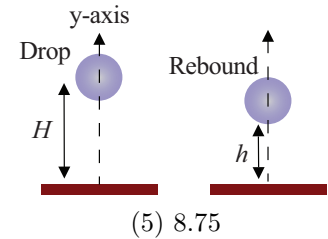
(1) 5.63   (2) 1.74   (3) 7.97   (4) 3.23   (5) 8.75

24. A 0.5-kg ball is dropped from rest a height $H = 10$ m above the surface of the Earth, as shown in the figure. It strikes the sidewalk at $t = 0$ and experiences an upward force that depends on time according to the formula $F_y(t) = bt$, where b is a constant. If $b = 98$ N/s and the ball is in contact with the sidewalk for 0.52 seconds, what maximum height h (in m) is reached by the ball when it rebounds from the sidewalk?
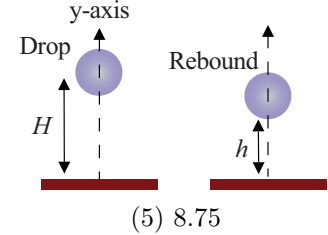
(1) 7.97   (2) 1.74   (3) 5.63   (4) 3.23   (5) 8.75

25. A 2-kg block with speed v = 5 m/s sliding along a horizontal frictionless surface collides with a second block at rest with a mass of 3 kg. The two blocks stick together to form a single object with a mass of 5-kg and continue to slide. How much kinetic energy (in J) is lost during the collision due to the heating up of the blocks?

(1) 15   (2) 60   (3) 135   (4) 30   (5) 175

26. A 2-kg block with speed v = 10 m/s sliding along a horizontal frictionless surface collides with a second block at rest with a mass of 3 kg. The two blocks stick together to form a single object with a mass of 5-kg and continue to slide. How much kinetic energy (in J) is lost during the collision due to the heating up of the blocks?

(1) 60   (2) 15   (3) 135   (4) 30   (5) 175

27. A 2-kg block with speed v = 15 m/s sliding along a horizontal frictionless surface collides with a second block at rest with a mass of 3 kg. The two blocks stick together to form a single object with a mass of 5-kg and continue to slide. How much kinetic energy (in J) is lost during the collision due to the heating up of the blocks?

(1) 135   (2) 15   (3) 60   (4) 30   (5) 175

28. Sand from a stationary hopper falls at a constant rate $R = 3$ kg/s on a moving belt with mass M as shown in the figure. The belt is supported by frictionless rollers and the belt and the sand that has fallen on the belt move with a constant speed V due to a constant horizontal external force F_{ext} applied to the belt. If $F_{ext} = 6$ N, what is the constant speed V (in m/s)?


Hopper
Sand Mass m
Belt Mass M
V
F_{ext}
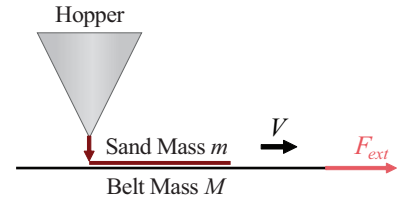
(1) 2   (2) 3   (3) 4   (4) 5   (5) 1

29. Sand from a stationary hopper falls at a constant rate $R = 3$ kg/s on a moving belt with mass M as shown in the figure. The belt is supported by frictionless rollers and the belt and the sand that has fallen on the belt move with a constant speed V due to a constant horizontal external force F_{ext} applied to the belt. If $F_{ext} = 9$ N, what is the constant speed V (in m/s)?

Hopper
Sand Mass m
Belt Mass M
V
F_{ext}
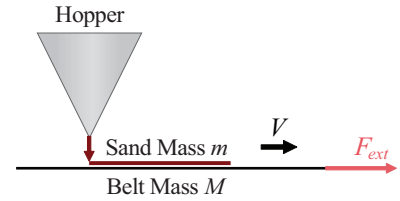
(1) 3   (2) 2   (3) 4   (4) 5   (5) 1

30. Sand from a stationary hopper falls at a constant rate $R = 3$ kg/s on a moving belt with mass M as shown in the figure. The belt is supported by frictionless rollers and the belt and the sand that has fallen on the belt move with a constant speed V due to a constant horizontal external force F_{ext} applied to the belt. If $F_{ext} = 12$ N, what is the constant speed V (in m/s)?

Hopper
Sand Mass m
Belt Mass M
V
F_{ext}
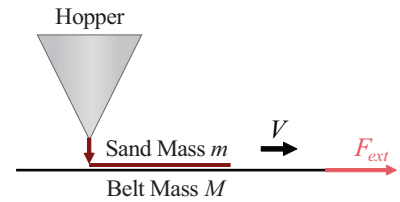
(1) 4   (2) 2   (3) 3   (4) 5   (5) 1

31. A race car accelerates uniformly from a speed of 40 m/s to a speed of 58 m/s in 6 seconds while traveling around a circular track of radius 529 m. When the magnitude of the car's total acceleration becomes 5 m/s^2, what is its speed (in m/s)?

(1) 46   (2) 50   (3) 54   (4) 42   (5) 56

32. A race car accelerates uniformly from a speed of 40 m/s to a speed of 58 m/s in 6 seconds while traveling around a circular track of radius 625 m. When the magnitude of the car's total acceleration becomes 5 m/s^2, what is its speed (in m/s)?

(1) 50   (2) 46   (3) 54   (4) 42   (5) 56

33. A race car accelerates uniformly from a speed of 40 m/s to a speed of 58 m/s in 6 seconds while traveling around a circular track of radius 729 m. When the magnitude of the car's total acceleration becomes 5 m/s^2, what is its speed (in m/s)?

(1) 54   (2) 46   (3) 50   (4) 42   (5) 56

34. A thin rod of length L and mass M is located on the x axis from $x = 0$ to $x = L$ as shown in the figure. It has a non-uniform linear mass density that varies with x according to the formula $\lambda(x) = \lambda_0 x$, where λ_0 is constant. What is the moment of inertia of the rod about the y-axis $(x = 0)$?

y-axis
x-axis
L
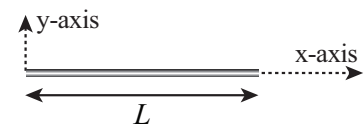
(1) $\frac{1}{2}ML^2$ (2) $\frac{3}{5}ML^2$ (3) $\frac{2}{3}ML^2$ (4) $\frac{1}{3}ML^2$ (5) $\frac{1}{12}ML^2$

35. A thin rod of length L and mass M is located on the x axis from $x = 0$ to $x = L$ as shown in the figure. It has a non-uniform linear mass density that varies with x according to the formula $\lambda(x) = \lambda_0 x^2$, where λ_0 is constant. What is the moment of inertia of the rod about the y-axis $(x = 0)$?
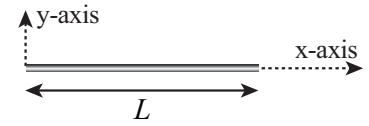
(1) $\frac{3}{5}ML^2$ (2) $\frac{1}{2}ML^2$ (3) $\frac{2}{3}ML^2$ (4) $\frac{1}{3}ML^2$ (5) $\frac{1}{12}ML^2$

36. A thin rod of length L and mass M is located on the x axis from $x = 0$ to $x = L$ as shown in the figure. It has a non-uniform linear mass density that varies with x according to the formula $\lambda(x) = \lambda_0 x^3$, where λ_0 is constant. What is the moment of inertia of the rod about the y-axis $(x = 0)$?
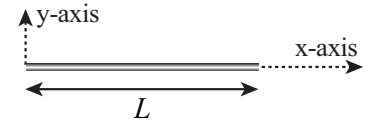
(1) $\frac{2}{3}ML^2$ (2) $\frac{1}{2}ML^2$ (3) $\frac{3}{5}ML^2$ (4) $\frac{1}{3}ML^2$ (5) $\frac{1}{12}ML^2$

37. An astronaut is being tested in a centrifuge. The centrifuge has a radius R and, in starting from rest at $t = 0$, rotates with a constant angular acceleration α. If the magnitude of the tangential acceleration is equal to the magnitude of the radial acceleration (*i.e.*, centripetal acceleration) at $t = 2$ s, what is the magnitude of the angular velocity (in rad/s) of the centrifuge at $t = 3$ s?

(1) 0.75   (2) 1.0   (3) 1.5   (4) 0.5   (5) 2.0

38. An astronaut is being tested in a centrifuge. The centrifuge has a radius R and, in starting from rest at $t = 0$, rotates with a constant angular acceleration α. If the magnitude of the tangential acceleration is equal to the magnitude of the radial acceleration (*i.e.*, centripetal acceleration) at $t = 2$ s, what is the magnitude of the angular velocity (in rad/s) of the centrifuge at $t = 4$ s?

(1) 1.0   (2) 0.75   (3) 1.5   (4) 0.5   (5) 2.0

39. An astronaut is being tested in a centrifuge. The centrifuge has a radius R and, in starting from rest at $t = 0$, rotates with a constant angular acceleration α. If the magnitude of the tangential acceleration is equal to the magnitude of the radial acceleration (*i.e.*, centripetal acceleration) at $t = 2$ s, what is the magnitude of the angular velocity (in rad/s) of the centrifuge at $t = 6$ s?

(1) 1.5   (2) 0.75   (3) 1.0   (4) 0.5   (5) 2.0

40. Near the surface of the Earth a solid object of mass M and radius R rolls smoothly along a horizontal surface with speed $V_{COM} = V$ and then up a ramp that makes an angle of θ with the horizontal surface as shown in the figure. If the object reaches a maximum height $H = 3V^2/(4g)$ before rolling back down the incline, what is its moment of inertia?
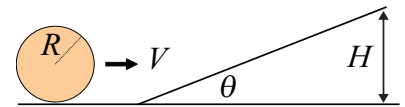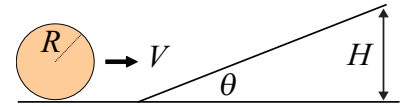

(1) $MR^2/2$ (2) $MR^2/3$ (3) MR^2 (4) $2MR^2/3$ (5) $3MR^2/5$

41. Near the surface of the Earth a solid object of mass M and radius R rolls smoothly along a horizontal surface with speed $V_{COM} = V$ and then up a ramp that makes an angle of θ with the horizontal surface as shown in the figure. If the object reaches a maximum height $H = 2V^2/(3g)$ before rolling back down the incline, what is its moment of inertia?
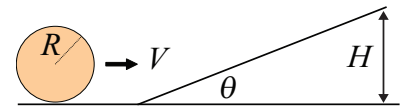
(1) $MR^2/3$ (2) $MR^2/2$ (3) MR^2 (4) $2MR^2/3$ (5) $3MR^2/5$

42. Near the surface of the Earth a solid object of mass M and radius R rolls smoothly along a horizontal surface with speed $V_{COM} = V$ and then up a ramp that makes an angle of θ with the horizontal surface as shown in the figure. If the object reaches a maximum height $H = V^2/g$ before rolling back down the incline, what is its moment of inertia?

(1) MR^2 (2) $MR^2/2$ (3) $MR^2/3$ (4) $2MR^2/3$ (5) $3MR^2/5$

43. A point particle with mass M and speed V is moving in the xy plane as shown in the figure. At the moment it crosses the x-axis ($y = 0$) at $x = d$, its velocity vector points at an angle of $45°$ relative to the x-axis and the magnitude of its angular momentum about the origin, (*i.e.*, $x = y = 0$) is L_0. What is the magnitude of its angular momentum about point P located on the y-axis a distanced $y = 4d$ from the origin at this same moment?
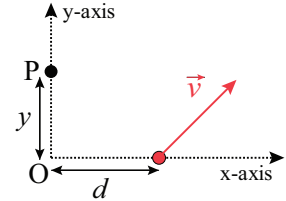
(1) $5L_0$ (2) $3L_0$ (3) $4L_0$ (4) $2L_0$ (5) $L_0/2$

44. A point particle with mass M and speed V is moving in the xy plane as shown in the figure. At the moment it crosses the x-axis ($y = 0$) at $x = d$, its velocity vector points at an angle of $45°$ relative to the x-axis and the magnitude of its angular momentum about the origin, (*i.e.*, $x = y = 0$) is L_0. What is the magnitude of its angular momentum about point P located on the y-axis a distanced $y = 2d$ from the origin at this same moment?
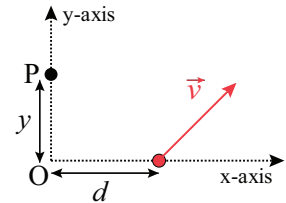
(1) $3L_0$ (2) $5L_0$ (3) $4L_0$ (4) $2L_0$ (5) $L_0/2$

45. A point particle with mass M and speed V is moving in the xy plane as shown in the figure. At the moment it crosses the x-axis ($y = 0$) at $x = d$, its velocity vector points at an angle of $45°$ relative to the x-axis and the magnitude of its angular momentum about the origin, (*i.e.*, $x = y = 0$) is L_0. What is the magnitude of its angular momentum about point P located on the y-axis a distanced $y = 3d$ from the origin at this same moment?
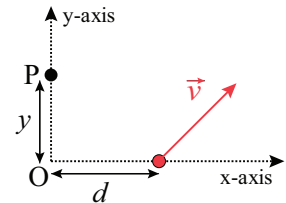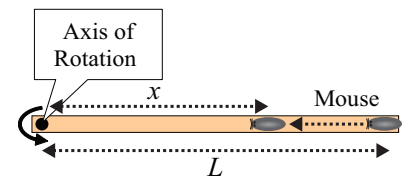
(1) $4L_0$ (2) $5L_0$ (3) $3L_0$ (4) $2L_0$ (5) $L_0/2$

46. A thin horizontal 1-kg rod of length L rotates horizontally around its end with an angular velocity ω_0 as shown in the figure. A 0.5 kg mouse originally at rest on the far end of the rod a distance L from the axis of rotation moves to new resting position a distance x from the axis of rotation. If the new angular velocity of the mouse-rod system is $1.25\omega_0$, what is the distance x?
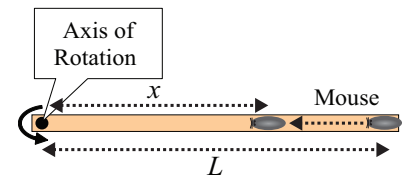
(1) $0.816L$ (2) $0.535L$ (3) $0.272L$ (4) $0.167L$ (5) $0.915L$

47. A thin horizontal 1-kg rod of length L rotates horizontally around its end with an angular velocity ω_0 as shown in the figure. A 0.5 kg mouse originally at rest on the far end of the rod a distance L from the axis of rotation moves to new resting position a distance x from the axis of rotation. If the new angular velocity of the mouse-rod system is $1.75\omega_0$, what is the distance x?

(1) $0.535L$ (2) $0.816L$ (3) $0.272L$ (4) $0.167L$ (5) $0.915L$

48. A thin horizontal 1-kg rod of length L rotates horizontally around its end with an angular velocity ω_0 as shown in the figure. A 0.5 kg mouse originally at rest on the far end of the rod a distance L from the axis of rotation moves to new resting position a distance x from the axis of rotation. If the new angular velocity of the mouse-rod system is $2.25\omega_0$, what is the distance x?

Axis of Rotation

x

Mouse

L
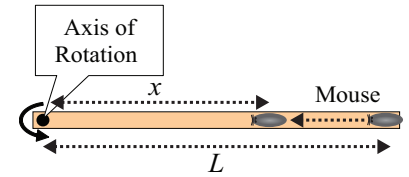
(1) $0.272L$ (2) $0.816L$ (3) $0.535L$ (4) $0.167L$ (5) $0.915L$

49. A horizontal uniform bar with length L and a weight of 200 N is held in place by a hinge at one end and a wire at angle $\theta = 30°$ at the other end as shown in the figure. There is a block with weight $W = 300$ N on the bar a distance x from the wall. If the maximum tension the wire can supply without breaking is 400 N, what is the largest value of the distance x such that the wire will not break?
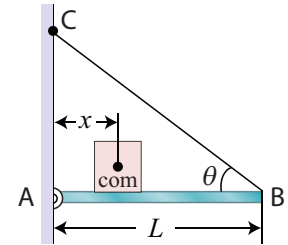

(1) $L/3$ (2) $L/2$ (3) $2L/3$ (4) $L/4$ (5) $3L/4$

50. A horizontal uniform bar with length L and a weight of 200 N is held in place by a hinge at one end and a wire at angle $\theta = 30°$ at the other end as shown in the figure. There is a block with weight $W = 300$ N on the bar a distance x from the wall. If the maximum tension the wire can supply without breaking is 500 N, what is the largest value of the distance x such that the wire will not break?
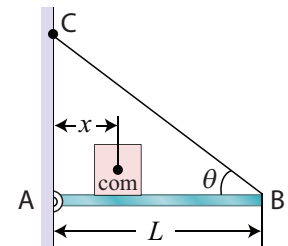
(1) $L/2$ (2) $L/3$ (3) $2L/3$ (4) $L/4$ (5) $3L/4$

51. A horizontal uniform bar with length L and a weight of 200 N is held in place by a hinge at one end and a wire at angle $\theta = 30°$ at the other end as shown in the figure. There is a block with weight $W = 300$ N on the bar a distance x from the wall. If the maximum tension the wire can supply without breaking is 600 N, what is the largest value of the distance x such that the wire will not break?
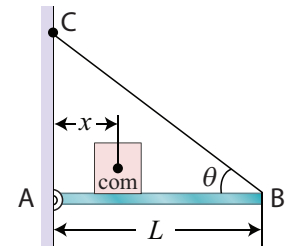
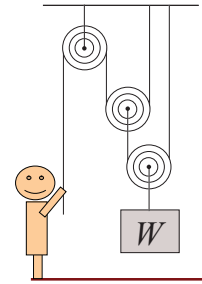(1) $2L/3$ (2) $L/3$ (3) $L/2$ (4) $L/4$ (5) $3L/4$

52. A man with a weight of 75 N is at rest on the ground and is using the pulley system shown in the figure to lift a weight W off the ground. Assuming that the pulleys rotate without friction and without the rope slipping, what is the maximum weight W (in N) he can lift?


(1) 300
(2) 500
(3) 600
(4) 200
(5) 100
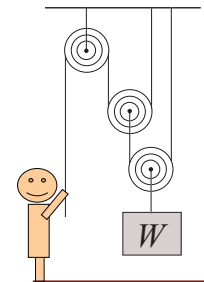
53. A man with a weight of 125 N is at rest on the ground and is using the pulley system shown in the figure to lift a weight W off the ground. Assuming that the pulleys rotate without friction and without the rope slipping, what is the maximum weight W (in N) he can lift?

    (1) 500
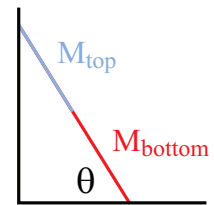   (2) 300
    (3) 600
    (4) 200
    (5) 125

54. A man with a weight of 150 N is at rest on the ground and is using the pulley system shown in the figure to lift a weight W off the ground. Assuming that the pulleys rotate without friction and without the rope slipping, what is the maximum weight W (in N) he can lift?

    (1) 600
    (2) 300
    (3) 500
    (4) 200
    (5) 150
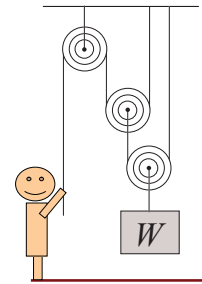
55. An extension ladder consists of two uniform planks of equal length. The top plank has mass M_{top} and the bottom plank has mass M_{bottom}. A window washer attempts to lean this extension ladder against a frictionless vertical wall as shown in the figure. He finds that the ladder slips on the ground when it is placed at an angle, θ, less than 30° to the ground, but remains in place when the angle is greater than 30°. If $M_{\text{bottom}} = 2M_{\text{top}}$, what is the coefficient of static friction between the ladder and the ground?
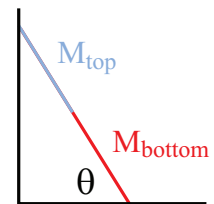
    (1) 0.722　　　　(2) 0.650　　　　(3) 0.606　　　　(4) 0.866　　　　(5) 0.495

56. An extension ladder consists of two uniform planks of equal length. The top plank has mass M_{top} and the bottom plank has mass M_{bottom}. A window washer attempts to lean this extension ladder against a frictionless vertical wall as shown in the figure. He finds that the ladder slips on the ground when it is placed at an angle, θ, less than 30° to the ground, but remains in place when the angle is greater than 30°. If $M_{\text{bottom}} = 3M_{\text{top}}$, what is the coefficient of static friction between the ladder and the ground?
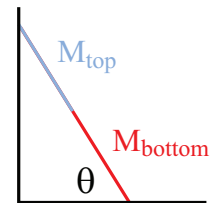
   (1) 0.650　　　　(2) 0.722　　　　(3) 0.606　　　　(4) 0.866　　　　(5) 0.495

57. An extension ladder consists of two uniform planks of equal length. The top plank has mass M_{top} and the bottom plank has mass M_{bottom}. A window washer attempts to lean this extension ladder against a frictionless vertical wall as shown in the figure. He finds that the ladder slips on the ground when it is placed at an angle, θ, less than 30° to the ground, but remains in place when the angle is greater than 30°. If $M_{\text{bottom}} = 4M_{\text{top}}$, what is the coefficient of static friction between the ladder and the ground?
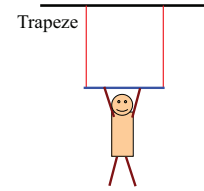
    (1) 0.606　　　　(2) 0.722　　　　(3) 0.650　　　　(4) 0.866　　　　(5) 0.495

58. Near the surface of the Earth, a trapeze consists of a rod with length L and negligible mass supported at its ends by vertical ropes of equal length as shown in the figure. Each rope can withstand a maximum tension of $T_{\max}$ before breaking. When hanging at rest, a trapeze artist can hold on with each hand a distance of $L/4$ from the ends of the rod, and neither rope breaks. However, if she takes one hand off, and does not move the other hand, she finds that one rope breaks causing her to fall. What is her minimum possible mass?
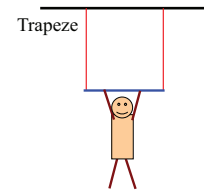

Trapeze

(1) $4T_{\max}/(3g)$ (2) $5T_{\max}/(4g)$ (3) $3T_{\max}/(2g)$ (4) $T_{\max}/(2g)$ (5) $2T_{\max}/g$

59. Near the surface of the Earth, a trapeze consists of a rod with length L and negligible mass supported at its ends by vertical ropes of equal length as shown in the figure. Each rope can withstand a maximum tension of $T_{\max}$ before breaking. When hanging at rest, a trapeze artist can hold on with each hand a distance of $L/5$ from the ends of the rod, and neither rope breaks. However, if she takes one hand off, and does not move the other hand, she finds that one rope breaks causing her to fall. What is her minimum possible mass?

Trapeze

(1) $5T_{\max}/(4g)$ (2) $4T_{\max}/(3g)$ (3) $3T_{\max}/(2g)$ (4) $T_{\max}/(2g)$ (5) $2T_{\max}/g$

60. Near the surface of the Earth, a trapeze consists of a rod with length L and negligible mass supported at its ends by vertical ropes of equal length as shown in the figure. Each rope can withstand a maximum tension of $T_{\max}$ before breaking. When hanging at rest, a trapeze artist can hold on with each hand a distance of $L/3$ from the ends of the rod, and neither rope breaks. However, if she takes one hand off, and does not move the other hand, she finds that one rope breaks causing her to fall. What is her minimum possible mass?

Trapeze
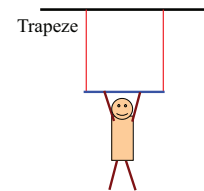
(1) $3T_{\max}/(2g)$ (2) $4T_{\max}/(3g)$ (3) $5T_{\max}/(4g)$ (4) $T_{\max}/(2g)$ (5) $2T_{\max}/g$

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
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
Q# S 41
Q# S 42
TYPE 15
Q# S 43
Q# S 44
Q# S 45
TYPE 16
Q# S 46
Q# S 47
Q# S 48
TYPE 17
Q# S 49
Q# S 50
Q# S 51
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