

Instructor(s): *Field/Matcheva*PHYSICS DEPARTMENT
Exam 2

October 31, 2014

PHY 2048

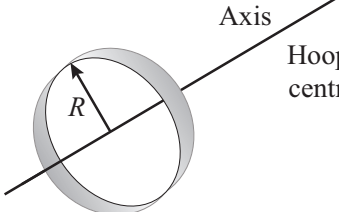
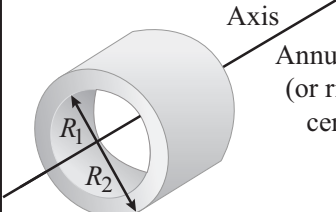
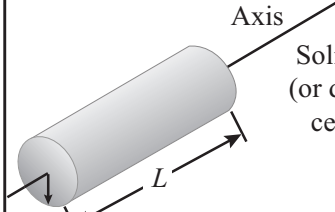
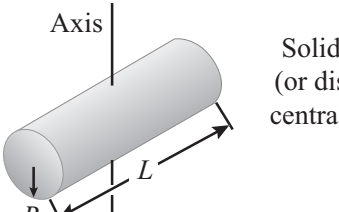
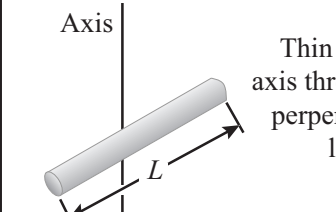
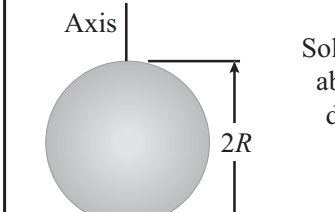
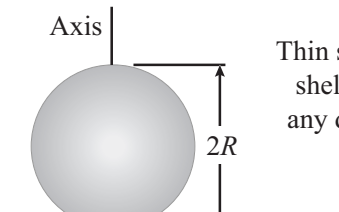
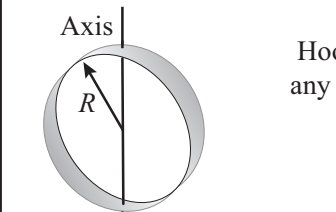
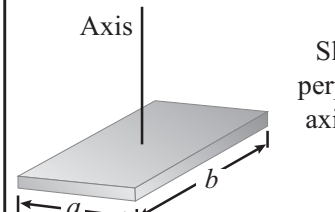
Name (print, last first): _____

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

 <p>Axis Hoop about central axis</p> <p>$I = MR^2$</p>	 <p>Axis Annular cylinder (or ring) about central axis</p> <p>$I = \frac{1}{2} M(R_1^2 + R_2^2)$</p>	 <p>Axis Solid cylinder (or disk) about central axis</p> <p>$I = \frac{1}{2} MR^2$</p>
 <p>Axis Solid cylinder (or disk) about central diameter</p> <p>$I = \frac{1}{4} MR^2 + \frac{1}{12} ML^2$</p>	 <p>Axis Thin rod about axis through center perpendicular to length</p> <p>$I = \frac{1}{12} ML^2$</p>	 <p>Axis Solid sphere about any diameter</p> <p>$I = \frac{2}{5} MR^2$</p>
 <p>Axis Thin spherical shell about any diameter</p> <p>$I = \frac{2}{3} MR^2$</p>	 <p>Axis Hoop about any diameter</p> <p>$I = \frac{1}{2} MR^2$</p>	 <p>Axis Slab about perpendicular axis through center</p> <p>$I = \frac{1}{12} M(a^2 + b^2)$</p>

PHY2048 Exam 1 Formula Sheet

Vectors

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

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

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

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

Motion

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

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

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

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

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

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

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

Equations of Motion (Constant Acceleration)

$$\begin{aligned} v_x(t) &= v_{x0} + a_x t & v_y(t) &= v_{y0} + a_y t & v_z(t) &= v_{z0} + a_z t \\ x(t) &= x_0 + v_{x0} t + \frac{1}{2} a_x t^2 & y(t) &= y_0 + v_{y0} t + \frac{1}{2} a_y t^2 & z(t) &= z_0 + v_{z0} t + \frac{1}{2} a_z t^2 \\ v_x^2(t) &= v_{x0}^2 + 2a_x(x(t) - x_0) & v_y^2(t) &= v_{y0}^2 + 2a_y(y(t) - y_0) & v_z^2(t) &= v_{z0}^2 + 2a_z(z(t) - z_0) \end{aligned}$$

Newton's Law and Weight

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

Magnitude of the Frictional Force

$$(\mu_s = \text{static coefficient of friction, } \mu_k = \text{kinetic coefficient of friction})$$

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

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

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

Projectile Motion

$$(\text{horizontal surface near Earth, } v_0 = \text{initial speed, } \theta_0 = \text{initial angle with horizontal})$$

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

Quadratic Formula

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

PHY2048 Fall 2014

PHY2048 Exam 2 Formula SheetWork (W), Mechanical Energy (E), Kinetic Energy (KE), Potential Energy (U)

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

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

Work-Energy: $W(\text{external}) = \Delta KE + \Delta U + \Delta E(\text{thermal}) + \Delta E(\text{internal})$ 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: $E = KE + U$ 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 $\vec{p} = \text{constant}$ 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: $x_{COM} = R\theta$ $v_{COM} = R\omega$ $a_{COM} = R\alpha$ $KE = \frac{1}{2}Mv_{COM}^2 + \frac{1}{2}I_{COM}\omega^2$

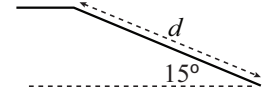
Rotational Equations of Motion (Constant Angular Acceleration α)

$$\omega(t) = \omega_0 + \alpha t$$

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

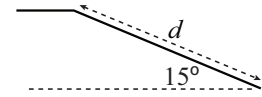
$$\omega^2(t) = \omega_0^2 + 2\alpha(\theta(t) - \theta_0)$$

1. A hill makes an angle of 15° with the horizontal. If a 50-kg jogger runs a distance of $d = 200$ m down the hill as shown in the figure, how much work is done by gravity on the jogger (in J)?



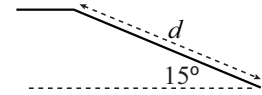
- (1) 25,364 (2) 38,046 (3) 50,729 (4) -25,364 (5) -38,046

2. A hill makes an angle of 15° with the horizontal. If a 50-kg jogger runs a distance of $d = 300$ m down the hill as shown in the figure, how much work is done by gravity on the jogger (in J)?



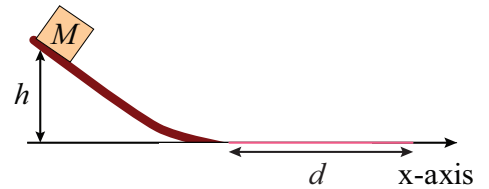
- (1) 38,046 (2) 25,364 (3) 50,729 (4) -25,364 (5) -38,046

3. A hill makes an angle of 15° with the horizontal. If a 50-kg jogger runs a distance of $d = 400$ m down the hill as shown in the figure, how much work is done by gravity on the jogger (in J)?



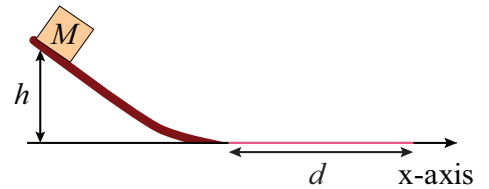
- (1) 50,729 (2) 25,364 (3) 38,046 (4) -25,364 (5) -50,729

4. Near the surface of the Earth a block of mass M is released from rest at a height $h = 10$ m on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat rough horizontal surface. If the block slides a horizontal distance $d = 50$ m along the rough surface before coming to rest, what is the kinetic coefficient of friction between the block and the horizontal surface?



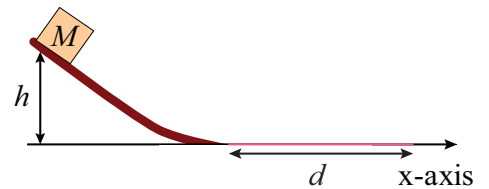
- (1) 0.2 (2) 0.4 (3) 0.5 (4) 0.3 (5) 0.6

5. Near the surface of the Earth a block of mass M is released from rest at a height $h = 10$ m on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat rough horizontal surface. If the block slides a horizontal distance $d = 25$ m along the rough surface before coming to rest, what is the kinetic coefficient of friction between the block and the horizontal surface?



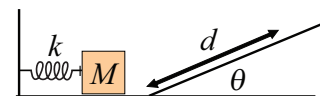
- (1) 0.4 (2) 0.2 (3) 0.5 (4) 0.3 (5) 0.6

6. Near the surface of the Earth a block of mass M is released from rest at a height $h = 10$ m on a frictionless incline as shown in the figure. The block slides down the frictionless incline to reach a flat rough horizontal surface. If the block slides a horizontal distance $d = 20$ m along the rough surface before coming to rest, what is the kinetic coefficient of friction between the block and the horizontal surface?



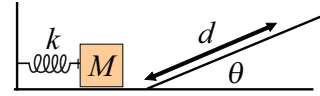
- (1) 0.5 (2) 0.2 (3) 0.4 (4) 0.3 (5) 0.6

7. Near the surface of the Earth, an ideal spring with spring constant k is on a frictionless horizontal surface at the base of a frictionless inclined plane as shown in the figure. A block with mass $M = 0.5$ kg is pressed against the spring, compressing it 6 cm from its equilibrium position. The block is then released and is not attached to the spring. If the block slides a distance $d = 2$ m up the inclined plane with $\theta = 30^\circ$ before coming to rest and then sliding back down, what is the spring constant k (in N/m)?



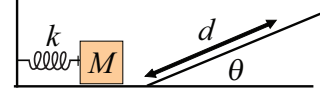
- (1) 2,722 (2) 3,267 (3) 3,811 (4) 1,958 (5) 4,611

8. Near the surface of the Earth, an ideal spring with spring constant k is on a frictionless horizontal surface at the base of a frictionless inclined plane as shown in the figure. A block with mass $M = 0.6$ kg is pressed against the spring, compressing it 6 cm from its equilibrium position. The block is then released and is not attached to the spring. If the block slides a distance $d = 2$ m up the inclined plane with $\theta = 30^\circ$ before coming to rest and then sliding back down, what is the spring constant k (in N/m)?



- (1) 3,267 (2) 2,722 (3) 3,811 (4) 1,958 (5) 4,611

9. Near the surface of the Earth, an ideal spring with spring constant k is on a frictionless horizontal surface at the base of a frictionless inclined plane as shown in the figure. A block with mass $M = 0.7$ kg is pressed against the spring, compressing it 6 cm from its equilibrium position. The block is then released and is not attached to the spring. If the block slides a distance $d = 2$ m up the inclined plane with $\theta = 30^\circ$ before coming to rest and then sliding back down, what is the spring constant k (in N/m)?



- (1) 3,811 (2) 2,722 (3) 3,267 (4) 1,958 (5) 4,611

10. The potential energy function of a point mass is given by the expression: $U(x) = 2x^2 - 8x$, where x is the coordinate of the body and U is measured in Joules. Only conservative forces are acting. Find the kinetic energy of the body (in J) at the point of stable equilibrium if the mechanical energy of the body is 20 J.

- (1) 28 (2) 30 (3) 32 (4) 12 (5) 14

11. The potential energy function of a point mass is given by the expression: $U(x) = 2x^2 - 8x$, where x is the coordinate of the body and U is measured in Joules. Only conservative forces are acting. Find the kinetic energy of the body (in J) at the point of stable equilibrium if the mechanical energy of the body is 22 J.

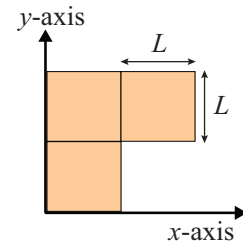
- (1) 30 (2) 28 (3) 32 (4) 12 (5) 14

12. The potential energy function of a point mass is given by the expression: $U(x) = 2x^2 - 8x$, where x is the coordinate of the body and U is measured in Joules. Only conservative forces are acting. Find the kinetic energy of the body (in J) at the point of stable equilibrium if the mechanical energy of the body is 24 J.

- (1) 32 (2) 28 (3) 30 (4) 12 (5) 16

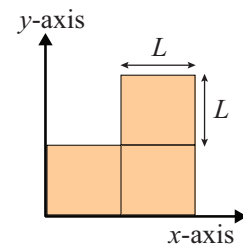
13. Three uniform square slabs are arranged in the xy -plane as shown in the figure. Each of the three squares have mass M and sides of length L . If $L = 6$ m, what are the x and y components of the center-of-mass of the three slab system?

- (1) $x_{com} = 5$ m, $y_{com} = 7$ m
 (2) $x_{com} = 7$ m, $y_{com} = 5$ m
 (3) $x_{com} = 5$ m, $y_{com} = 5$ m
 (4) $x_{com} = 7$ m, $y_{com} = 7$ m
 (5) $x_{com} = 4$ m, $y_{com} = 7$ m

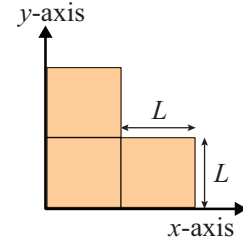


14. Three uniform square slabs are arranged in the xy -plane as shown in the figure. Each of the three squares have mass M and sides of length L . If $L = 6$ m, what are the x and y components of the center-of-mass of the three slab system?

- (1) $x_{com} = 7$ m, $y_{com} = 5$ m
 (2) $x_{com} = 5$ m, $y_{com} = 7$ m
 (3) $x_{com} = 5$ m, $y_{com} = 5$ m
 (4) $x_{com} = 7$ m, $y_{com} = 7$ m
 (5) $x_{com} = 4$ m, $y_{com} = 7$ m

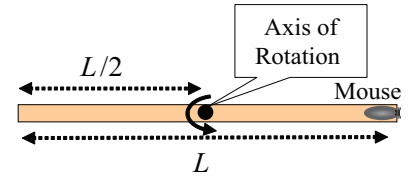


15. Three uniform square slabs are arranged in the xy -plane as shown in the figure. Each of the three squares have mass M and sides of length L . If $L = 6$ m, what are the x and y components of the center-of-mass of the three slab system?



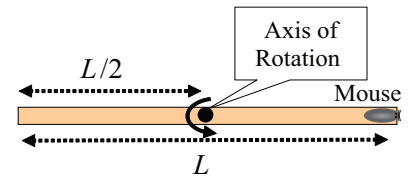
- (1) $x_{com} = 5$ m, $y_{com} = 5$ m
 (2) $x_{com} = 5$ m, $y_{com} = 7$ m
 (3) $x_{com} = 7$ m, $y_{com} = 5$ m
 (4) $x_{com} = 7$ m, $y_{com} = 7$ m
 (5) $x_{com} = 4$ m, $y_{com} = 7$ m

16. A small piece of cheese is placed at the center of a thin horizontal 2 kg rod of length L . The rod rotates horizontally around its center of mass with an angular velocity 10 rad/sec as shown in the figure. A 0.5 kg mouse originally standing at the edge of the rod runs towards the cheese. What is the angular velocity (in rad/s) of the rod when the mouse reaches the cheese?



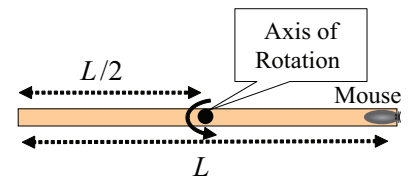
- (1) 17.5 (2) 21.0 (3) 24.5 (4) 5.7 (5) 6.9

17. A small piece of cheese is placed at the center of a thin horizontal 2 kg rod of length L . The rod rotates horizontally around its center of mass with an angular velocity 12 rad/sec as shown in the figure. A 0.5 kg mouse originally standing at the edge of the rod runs towards the cheese. What is the angular velocity (in rad/s) of the rod when the mouse reaches the cheese?



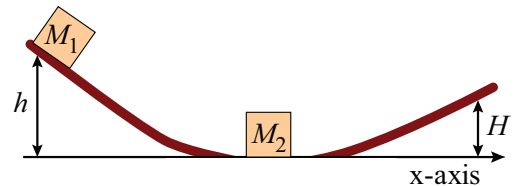
- (1) 21.0 (2) 17.5 (3) 24.5 (4) 5.7 (5) 6.9

18. A small piece of cheese is placed at the center of a thin horizontal 2 kg rod of length L . The rod rotates horizontally around its center of mass with an angular velocity 14 rad/sec as shown in the figure. A 0.5 kg mouse originally standing at the edge of the rod runs towards the cheese. What is the angular velocity (in rad/s) of the rod when the mouse reaches the cheese?



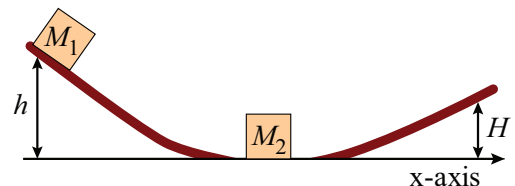
- (1) 24.5 (2) 17.5 (3) 21.0 (4) 5.7 (5) 8.0

19. A block of mass M_1 starts from rest at a height $h = 9$ m above the level surface and slides down a smooth ramp as shown in the figure. The block slides down the ramp, across the level surface, and collides with a block of mass M_2 which is at rest. The two blocks stick together and travel up a smooth ramp. If the maximum height that the combined 2-block reaches $H = 4$ m and all the surfaces are smooth and frictionless, what is the mass M_2 ?



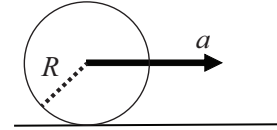
- (1) $\frac{1}{2}M_1$ (2) $\frac{1}{3}M_1$ (3) $\frac{2}{3}M_1$ (4) M_1 (5) $2M_1$

20. A block of mass M_1 starts from rest at a height $h = 16$ m above the level surface and slides down a smooth ramp as shown in the figure. The block slides down the ramp, across the level surface, and collides with a block of mass M_2 which is at rest. The two blocks stick together and travel up a smooth ramp. If the maximum height that the combined 2-block reaches $H = 9$ m and all the surfaces are smooth and frictionless, what is the mass M_2 ?



- (1) $\frac{1}{3}M_1$ (2) $\frac{1}{2}M_1$ (3) $\frac{2}{3}M_1$ (4) M_1 (5) $2M_1$

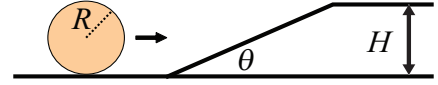
27. Starting from rest at time $t = 0$, a circular wheel with radius $R = 3$ m is pulled to the right along a horizontal surface at a constant acceleration of $a = 2$ m/s² as shown in the figure. If the wheel rolls without slipping, how long (in s) does it take the wheel to make 10 revolutions?



- (1) 13.7 (2) 10.6 (3) 12.3 (4) 5.3

(5) 15.1

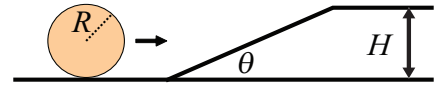
28. Near the surface of the Earth a solid sphere of mass M , radius $R = 0.5$ m, and moment of inertia $I = 2MR^2/5$ rolls along a horizontal surface and up a ramp of height $H = 0.7$ m that makes an angle of $\theta = 20^\circ$ with the horizontal surface as shown in the figure. If the ball rolls without slipping on both the horizontal surface and the ramp, what is the minimum number of revolutions per second the ball must have while rolling on the horizontal surface in order to reach the top of the ramp?



- (1) 1.0 (2) 1.2 (3) 1.5 (4) 0.5

(5) 2.0

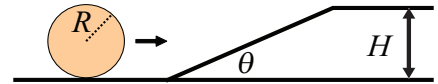
29. Near the surface of the Earth a solid sphere of mass M , radius $R = 0.5$ m, and moment of inertia $I = 2MR^2/5$ rolls along a horizontal surface and up a ramp of height $H = 1.0$ m that makes an angle of $\theta = 20^\circ$ with the horizontal surface as shown in the figure. If the ball rolls without slipping on both the horizontal surface and the ramp, what is the minimum number of revolutions per second the ball must have while rolling on the horizontal surface in order to reach the top of the ramp?



- (1) 1.2 (2) 1.0 (3) 1.5 (4) 0.5

(5) 2.0

30. Near the surface of the Earth a solid sphere of mass M , radius $R = 0.5$ m, and moment of inertia $I = 2MR^2/5$ rolls along a horizontal surface and up a ramp of height $H = 1.5$ m that makes an angle of $\theta = 20^\circ$ with the horizontal surface as shown in the figure. If the ball rolls without slipping on both the horizontal surface and the ramp, what is the minimum number of revolutions per second the ball must have while rolling on the horizontal surface in order to reach the top of the ramp?



- (1) 1.5 (2) 1.0 (3) 1.2 (4) 0.5

(5) 2.0

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