Instructor(s): *Matcheva/Yelton*

PHYSICS DEPARTMENT

PHY 2048 | Exam 2 | November 7th, 2017

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

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(1) **Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number).** Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your UFID number on your answer sheet.

(2) Print your name on this sheet and sign it also.

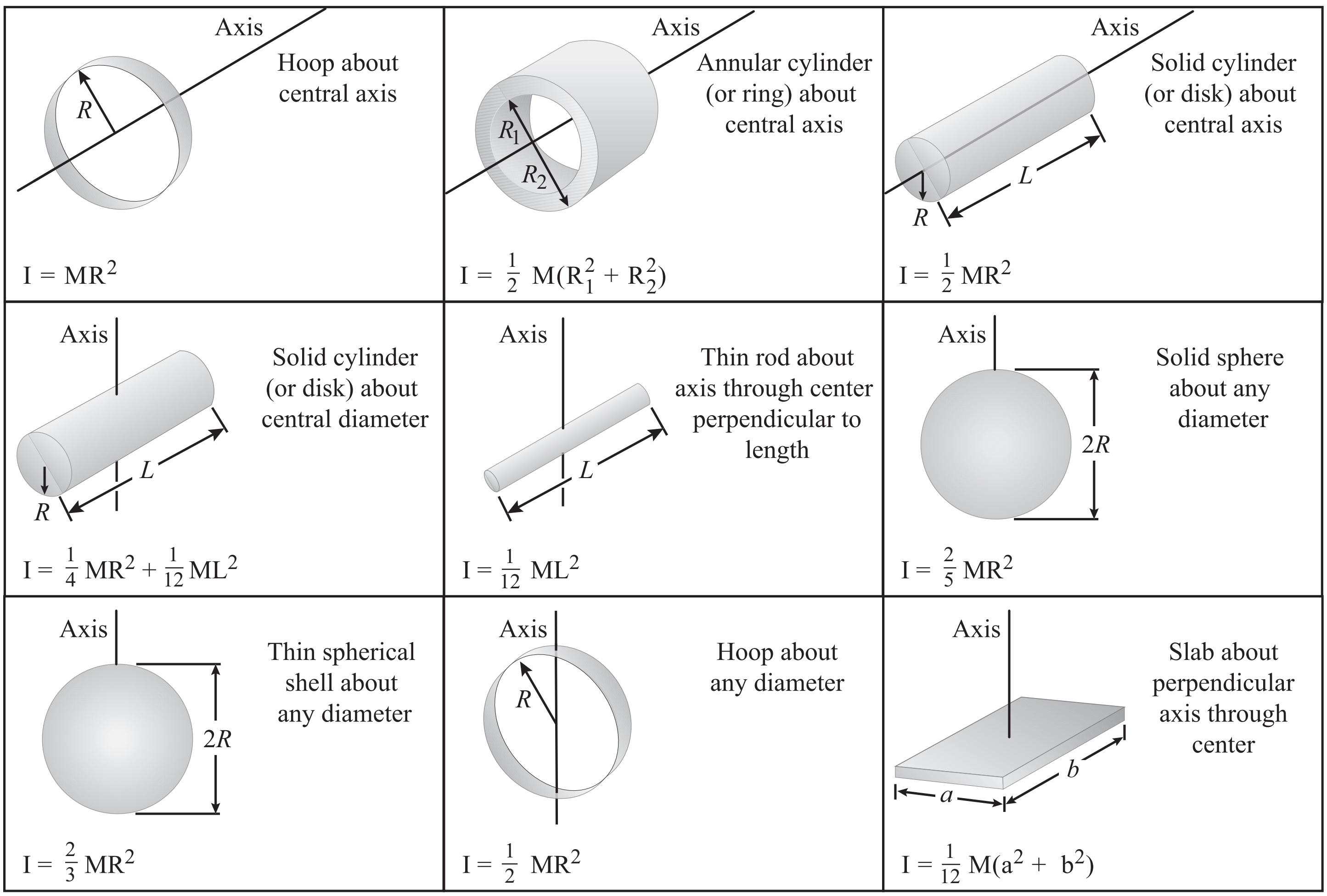
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.

(4) **Blacken the circle of your intended answer completely, using a #2 pencil or <u>blue</u> or <u>black</u> ink**. Do not make any stray marks or some answers may be counted as incorrect.

(5) **The answers are rounded off. Choose the closest to exact. There is no penalty for guessing. If you believe that no listed answer is correct, leave the form blank.**

(6) Hand in the answer sheet separately.

Use $g = 9.80$ m/s^2



PHY2048 Exam 1 Formula Sheet

Vectors

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

Scalar Product: $\vec{a} \cdot \vec{b} = a_xb_x + a_yb_y + a_zb_z$ Magnitude: $\vec{a} \cdot \vec{b} = |\vec{a}||\vec{b}|\cos\theta$ (θ = angle between $\vec{a}$ and $\vec{b}$)

Vector Product: $\vec{a} \times \vec{b} = (a_yb_z - a_zb_y)\hat{i} + (a_zb_x - a_xb_z)\hat{j} + (a_xb_y - a_yb_x)\hat{k}$

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

Motion

Displacement: $\Delta\vec{r} = \vec{r}(t_2) - \vec{r}(t_1)$

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

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

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

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

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

Instantaneous Acceleration: $\vec{a} = \dfrac{d\vec{v}}{dt} = \dfrac{d^2\vec{r}}{dt^2}$

Equations of Motion for Constant Acceleration

$\vec{v} = \vec{v}_0 + \vec{a}t$

$\vec{r} - \vec{r}_0 = \vec{v}_0t + \frac{1}{2}\vec{a}t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$ (in each of 3 dim)

Newton's Laws

$\vec{F}_{net} = 0 \Leftrightarrow \vec{v}$ is a constant (Newton's First Law)

$\vec{F}_{net} = m\vec{a}$ (Newton's Second Law)

"Action = Reaction" (Newton's Third Law)

Force due to Gravity

Weight (near the surface of the Earth) = mg (**use g=9.8** m/s^2)

Magnitude of the Frictional Force

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

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

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

Period: $T = \dfrac{2\pi R}{v} = \dfrac{2\pi}{\omega}$

Projectile Motion

Range: $R = \dfrac{v_0^2\sin(2\theta_0)}{g}$

Quadratic Formula

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

PHY2048 Exam 2 Formula Sheet

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

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

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

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

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

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

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

Linear Momentum, Angular Momentum, Torque

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

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

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

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

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

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

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

Rotational Variables

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

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

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

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

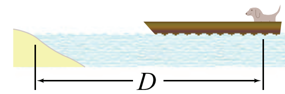
Rotational Equations of Motion (Constant Angular Acceleration α)

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

Elastic Collisions of Two Bodies, 1D

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

1. A 2.0 kg dog stands at one end of a 4.0 meter long boat of mass 12.0 kg, a total distance of D=6.0 meters from the shore. He then walks to the other end of the boat. Assuming no friction between the boat and the water, how far is the dog now from the shore.



(1) 2.6 m (2) 2.0 m (3) 1.0 m (4) 1.7 m (5) 3.0 m

2. A bowling ball of mass 5 kg hangs from the ceiling attached to the end of a rope displaced to one side so that the rope is at 37 degrees to the vertical, and released. What is the maximum speed, in m/s, of its subsequent motion?

(1) 4.4 (2) 6.2 (3) 7.7 (4) 0.9 (5) 3.1

3. A uniform stick of length L and mass M has a rotational inertia around an axis through its mid-point and perpendicular to the stick, of I_1. A piece is broken off one end leaving it to be of length 3L/4. What is the rotational inertia of this shortened stick, around an axis through its midpoint and perpendicular to it?

(1) 0.42 I_1 (2) 0.56 I_1 (3) 0.75 I_1 (4) 0.87 I_1 (5) 0.375 I_1

4. At t=0 s, a hand grenade of mass M is thrown straight up in the air with a speed of 15 m/s. At t = 1 s it explodes into two equal pieces. At t = 2 s, one of the pieces hits the ground. At the moment it hits the ground, how far off the ground, in m, is the other piece?

(1) 20.8 (2) 0 (3) 10.4 (4) 5.2 (5) 15.6

5. The potential energy function of a point mass is given by the expression: $U(x) = x^2 - 3x + 3$, where x is the position coordinate in meters, and U is measured in Joules. Only conservative forces are acting. The point mass is placed at x=0 and released. What is the force on the mass after it has traveled one meter?

(1) 1 N (2) -1 N (3) 3 N (4) 4 N (5) 6 N

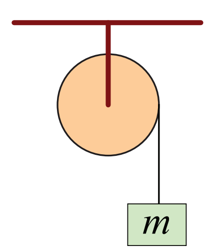
6. A 0.5 kg ball is dropped from a 2 m height, strikes a horizontal sidewalk. The average force of the concrete on the ball is 50 N, and the time of the collision is 0.1 seconds. How high does the ball reach on its rebound?

(1) 0.71 m (2) 2.0 m (3) 1.4 m (4) 1.0 m (5) 0.5 m

7. A fan blade with a center-to-tip length 0.5 m starts from rest and then speeds up with a uniform angular acceleration of 0.3 rad/s^2. Calculate the magnitude of the total linear acceleration of the tip of the blade, at $t = 2\,\mathrm{s}$.

(1) 0.23 m/s^2 (2) 0.18 m/s^2 (3) 0.15 m/s^2 (4) 0.33 m/s^2 (5) 0.60 m/s^2

8. A block of mass m is attached to a cord that is wrapped around the rim of a pulley, of radius R and hangs vertically, as shown. The pulley is a uniform disk and has mass M. When the block is released and the mass m accelerates down, what is the tension in the cord?



(1) mgM/(M+2m) (2) mgM/(M-2m) (3) Mgm/(M-m) (4) mgM/(m+M) (5) 0

9. A sleigh (including load) weighs 5000 N. It is pulled on level snow by a dog team exerting a horizontal force on it. The coefficient of kinetic friction between sleigh and snow is 0.05. How much work (in J) is done by the dog team pulling the sleigh 1000 m at constant speed?

(1) 2.5×10^5 (2) 0 (3) 5.0×10^5 (4) 2.5×10^6 (5) 5.0×10^6

10. A block of mass M sliding down an incline at constant speed is initially at a height h above the ground. The coefficient of kinetic friction between the mass and the incline is μ and the angle of the incline is θ. If the mass continues to slide down the incline at constant speed, how much energy is dissipated by friction by the time the mass reaches the bottom of the incline.

(1) Mgh (2) μMgh (3) μMghcos$\,\theta$ (4) μMgh/sin$\,\theta$ (5) 0

11. An object is constrained to move on a straight line along the x-axis pulled by a force $\vec{F} = 2x\hat{i} + 3y\hat{j}$. Find the work (in J) done on the object by the force $\vec{F}$ while the object moves from position x=2m to x=4m along x.

(1) 12 (2) 4 (3) 6 (4) 10 (5) 2

12. You push a 2.0 kg block against a horizontal spring, compressing the spring by 10 cm. Then you release the block, and the spring sends it sliding across a horizontal tabletop. It stops 40 cm from where you released it. The spring constant is 200 N/m. What is the block-table coefficient of kinetic friction?

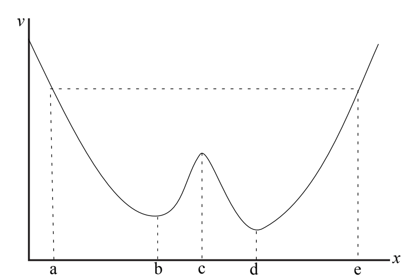
(1) 0.13 (2) 0.72 (3) 0.54 (4) 0.65 (5) 0.32

13. A motor lifts a block at constant speed. Which of the statements below is NOT correct.

A : The upward force of the cable attached to the block is constant.
B : The acceleration of the block is zero.
C : The net work done on the block is zero.
D : The mechanical energy of the Earth-block system is constant.
E : The kinetic energy of the block is constant.

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

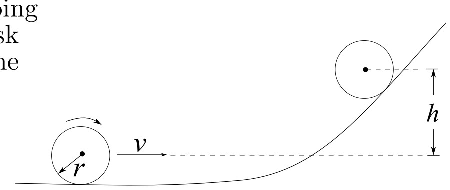
14. A particle is released from rest at the point x = e and moves along the x axis subject only to the potential energy function U(x) shown in the figure. How many of the statements below are correct?



A) The particle moves back and forth between points e and a.
B) The particle comes momentarily to rest at point a.
C) The particle comes permanently to rest at point b.
D) The particle changes direction of motion at point c.
E) The acceleration of the particle is 0 at point d.

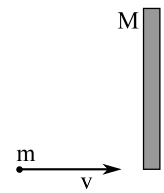
(1) 3 (2) 1 (3) 2 (4) 4 (5) 5

15. A uniform disk with a mass of m and a radius of r rolls without slipping along a horizontal surface and ramp, as shown in the figure. The disk has an initial velocity of v. What is the maximum height h to which the center of mass of the disk rises?



(1) $3v^2/(4g)$ (2) $v^2/(2g)$ (3) v^2/g (4) $3v^2/(2g)$ (5) $2v^2/g$

16. A uniform stick of length L and mass M lies on a frictionless horizontal surface. A point particle of mass m = M/18 approaches the stick with speed v on a straight line perpendicular to the stick that intersects the stick at one end, as shown in the figure. After the collision the particle is at rest. The angular velocity of the stick after the collision is:

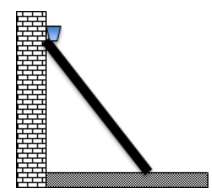


(1) v/3L (2) v/2L (3) 2v/L (4) 3v/L (5) 6v/L

17. A cockroach of mass M lies on the rim of a uniform disk of mass 4M that can rotate freely about its center like a merry-go-round. Initially the cockroach and disk rotate together with an angular velocity of 0.26 rad/s. Then the cockroach walks halfway to the center of the disk. What is the ratio K/K_0 of the new kinetic energy of the system to its initial kinetic energy?

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

18. A 200 N ladder leans against a vertical, frictionless wall at an angle of 60 degrees with respect to the horizontal floor. The static friction coefficient of the ladder with the floor is 0.5. A bucket is placed at the top of the ladder. What is the maximum weight of the bucket (in Newtons), which the ladder can support without the ladder falling down?



(1) 546 N (2) 0 N (3) 86 N (4) 200 N (5) 172 N

19. A 0.1 kg meter stick is supported at both ends by strings, and there is a 200 g mass attached to it at the 70 cm mark. It is in static equilibrium. What is the force exerted by the string connected to the 0 cm mark?

(1) 1.1 N (2) 1.5 N (3) 1.9 N (4) 2.5 N (5) 2.9 N

20. A cannon shoots a cannon ball straight up at an initial speed of 50 m/s. Find the angular momentum of the ball (in kg.m^2/s) 2 seconds after the shot was fired with respect to an observer on the ground that is 10 m away west from the cannon. The mass of the ball is 5 kg. Neglect the air resistance.

(1) 1520 South (2) 1520 North (3) 2500 South (4) 2500 North (5) 2500 East