Instructor(s): *Woodard, Yelton*

PHYSICS DEPARTMENT

PHY 2048, Fall 2018 — Exam 2 — November 7, 2018

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.

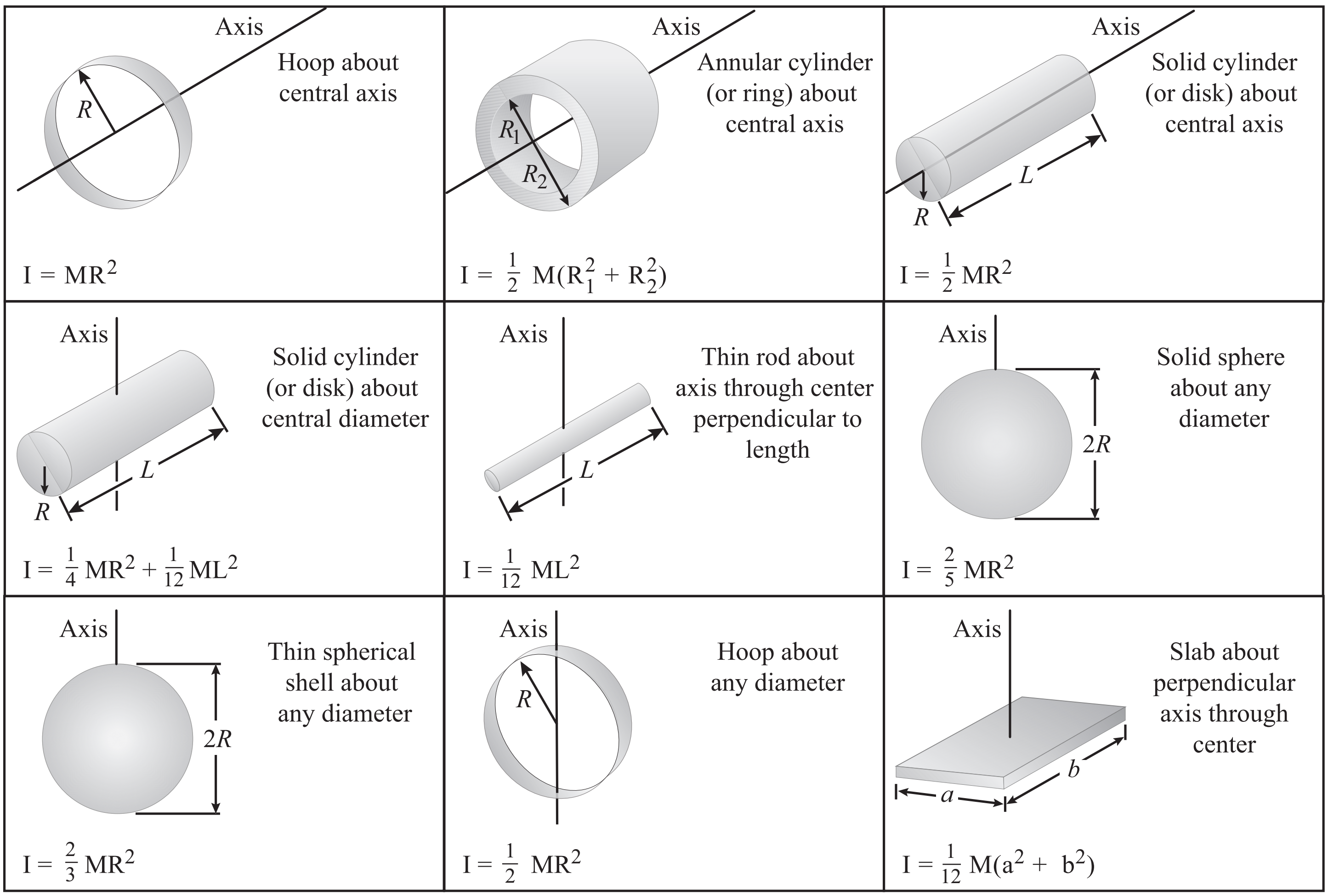
(3) Do all scratch work anywhere on this exam that you like. **Circle your answers on the test form.** At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.

(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.**

(6) Hand in the answer sheet (scantron) separately. Only the scantron is graded.

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



PHY2048 Exam 1 Formula Sheet

Vectors

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ $\quad \vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$ 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: $\vec{a}\cdot\vec{b} = a_xb_x + a_yb_y + a_zb_z$ 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} = (total distance)/Δt

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: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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

Kinetic Energy: $K = \frac{1}{2}mv^2$ Work: $W = \displaystyle\int_{\vec{r}_1}^{\vec{r}_2}\vec{F}\cdot d\vec{r}$ When force is constant $W = \vec{F}\cdot\vec{d}$

Power: $P = \frac{dW}{dt} = \vec{F}\cdot\vec{v}$ Work-Energy Theorem: $K_f = K_i + W$

PHY2048 Exam 2 Formula Sheet

$\Delta U = -W = -\int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r}$ $\quad F_x = -\frac{dU}{dx}$ $\quad$ Mechanical Energy: $E_{\text{mec}} = K + U$

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

Springs

Hooke's Law: $F_x = -kx$ $\quad$ Elastic Potential energy (x from spring equilibrium): $U(x) = \frac{1}{2}kx^2$

Center of Mass and Momentum

Center of Mass: $\vec{r}_{\text{com}} = \frac{1}{M_{\text{tot}}} \sum_{i=1}^{N} m_i \vec{r}_i$

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

$\vec{P}_{\text{tot}} = M_{\text{tot}}\, \vec{v}_{\text{com}}$ $\quad \vec{F}_{\text{net}} = \frac{d\vec{P}_{\text{tot}}}{dt} = M_{\text{tot}}\, \vec{a}_{\text{com}}$

Rockets: Thrust $= Ma = v_{\text{rel}} \frac{dM}{dt}$ $\quad \Delta v = v_{\text{rel}} \ln(\frac{M_i}{M_f})$

Elastic Collisions of Two Bodies, 1D

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

Rotational Variables

angular position: $\theta(t)$ $\quad$ angular velocity: $\omega(t) = \frac{d\theta(t)}{dt}$ $\quad$ angular acceleration: $\alpha(t) = \frac{d\omega(t)}{dt} = \frac{d^2\theta(t)}{dt^2}$

arc length: $s = r\theta$ $\quad$ velocity: $v = r\omega$ tangential acceleration: $a_{\text{T}} = r\alpha$ $\quad$ centripetal acceleration: $a_{\text{c}} = r\omega^2$

For constant angular acceleration α:

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

Rotational (Moment of) Inertia and Rolling

$I = \sum_{i=1}^{N} m_i r_i^2$ (discrete) $\quad I = \int r^2\, dm$ (continuous)

Parallel Axis: $I = I_{\text{com}} + M_{\text{tot}} d^2$ (d is displacement from c.o.m.)

Kinetic Energy: $K_{\text{rot}} = \frac{1}{2} I\omega^2$ $\quad K_{\text{roll}} = \frac{1}{2} M v_{\text{com}}^2 + \frac{1}{2} I_{\text{com}} \omega^2$

Torque etc.

$\vec{\tau} = \vec{r} \times \vec{F}$ $\quad \tau = rF\, \sin\theta$ $\quad$ Angular Momentum: $\vec{L} = \vec{r} \times \vec{p}$ $\quad L = I\omega$ $\quad \vec{\tau} = \frac{d\vec{L}}{dt}$

Work done by a constant torque: $W = \tau\Delta\theta = \Delta K_{\text{rot}}$

Power done by a constant torque: $P = \tau\omega$ $\quad$ For torque acting on a body with rotational inertia I: $\vec{\tau} = I\vec{\alpha}$

Precession frequency: $\Omega = \frac{mgr}{I\omega}$ (r is moment arm)

Stress and Strain(Y = Young's modulus, B = bulk modulus)

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

1. A car of mass 1500 kg is driving at 20 m/s when the driver hits the brakes, stopping the car in a distance of 25 m. What is the magnitude of the friction force?

   (1) 12000 N (2) 24000 N (3) 6000 N (4) 600 N (5) 750 N

2. You drag a box above over level ground by means of pulling a rope 37° above the horizontal, moving the box at a constant velocity of 2 m/s for a distance of 1 meter. If the box is of mass 10 kg, and the coefficient of kinetic friction between box and floor is $\mu_k = 0.7$, how much work do you do, in Joules?

   (1) 45 (2) 69 (3) 0 (4) 55 (5) 145

3. A 5.0-kg cart is moving horizontally at 6.0 m/s. In order to change its speed to 10.0 m/s, the net work done on the cart must be:

   (1) 160 J (2) 40 J (3) 90 J (4) 400 J (5) 550 J

4. A mass is at rest hanging from a spring. An extra mass m is then added and the two gently lowered by hand so that the spring is at rest at its new equilibrium point a distance h below the starting point. During this lowering process, what is the work W_h done by the hand?

   (1) $-mgh < W_h < 0$ (2) $W_h =$ -mgh (3) $W_h =$ mgh (4) $W_h = 0$ (5) $0 < W_h < mgh$

5. A bowling ball of mass 5 kg hangs from the ceiling attached to the end of a rope of length 4 meters. It is displaced to one side so that the rope is at 20° to the vertical, and released. What is its maximum kinetic energy in its subsequent motion, in Joules?

   (1) 12 (2) 188 (3) 68 (4) 17 (5) 38

6. The potential energy function of a point mass is given by the expression: $U(x) = 1 - 4x + x^2$, where x is the position coordinate in meters, and U is measured in Joules. Only conservative forces are acting. A point mass is placed at x=0 and released. What is its maximum kinetic energy in its subsequent motion?

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

7. At t=0 s, an exploding shell of mass M is propelled straight up in the air from ground level, 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

8. A baseball of mass 0.15 kg is pitched horizontally at 40 m/s. After being hit it travels back over the pitcher's head with an initial speed of 40 m/s and initial direction 30° above the horizontal. What is the magnitude of the change of momentum of the ball due to the hit, in kg·m/s?

   (1) 12 (2) 21 (3) 95 (4) 55 (5) 0

9. Two objects of mass m_1 and m_2 have the same kinetic energies. Find the ratio of the magnitude of their momenta, p_1/p_2.

   (1) $\sqrt{m_1/m_2}$ (2) m_1/m_2 (3) $(m_1/m_2)^2$ (4) m_2/m_1 (5) 1

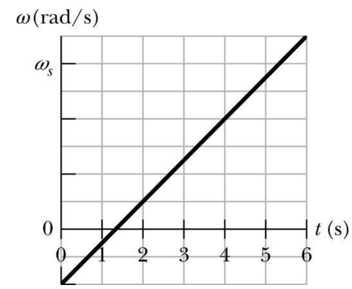
10. A 10 g bullet moving at speed v strikes a 250 g wooden block at rest on a frictionless surface. The bullet emerges, traveling in the same direction with its speed reduced to $v/2$. What is the resulting speed of the block?

    (1) $v/50$ (2) $v/100$ (3) $v/500$ (4) $v/2$ (5) $v/200$

11. A merry-go-round rotates from rest with an angular acceleration of 1.5 rad/s^2. How long does it take to rotate through the first two revolutions?

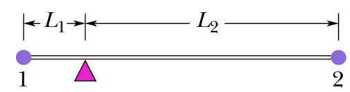
(1) 4.09 s (2) 3.14 s (3) 2.89 s (4) 2.31 s (5) 2.05 s

12. The Figure gives angular speed versus time for a thin rod that rotates around one end. The scale on the ω axis is set by $\omega_s = 6$ rad/s. At $t = 4$ s, the rod has a rotational kinetic energy of 1.6 J. What is its kinetic energy at $t = 0$?



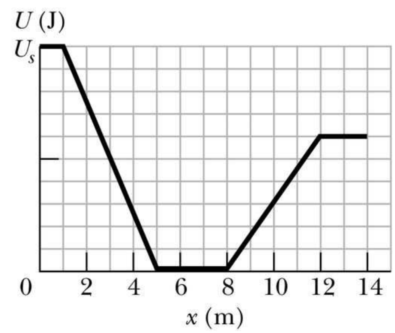
(1) 0.4 J
(2) 0.8 J
(3) 1.2 J
(4) 1.6 J
(5) 2.0 J

13. The Figure shows particles 1 and 2, each of mass m, fixed to the ends of a rigid massless rod of length $L_1 + L_2$, with $L_1 = 20$ cm and $L_2 = 80$ cm. The rod is held horizontally on the fulcrum and then released. What is the magnitude of the initial (linear) acceleration of particle 1?



(1) 0.18 g (2) 0.50 g (3) 0.60 g (4) 0.67 g (5) 0.37 g

14. The Figure shows the potential energy $U(x)$ of a solid ball that can roll along an x axis. The scale on the U axis is set by $U_s = 100$ J. The ball is uniform, rolls smoothly, and has a mass of 0.4 kg. It is released at $x = 7$ m headed in the positive direction of the x axis with a mechanical energy of 75 J. If the ball can reach $x = 13$ m, what is its speed there?



(1) 7.32 m/s
(2) 14.1 m/s
(3) 19.4 m/s
(4) 10.4 m/s
(5) The ball cannot reach there

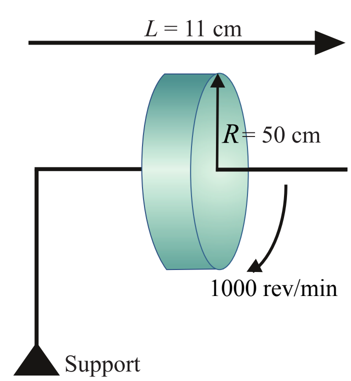
15. A force (in Newtons) $\vec{F} = 2\hat{i} - 3\hat{k}$ acts on a pebble with position vector (in meters) $\vec{r} = 0.5\hat{j} - 2\hat{k}$ relative to the origin. What is the resulting torque (in Newton-meters) about the origin?

(1) $-1.5\hat{i} - 4\hat{j} - \hat{k}$ (2) $-1.5\hat{i} + 4\hat{j} + \hat{k}$ (3) $1.5\hat{i} - 4\hat{j} + \hat{k}$ (4) $1.5\hat{i} + 4\hat{j} - \hat{k}$ (5) $-1.5\hat{i} - 4\hat{j} + \hat{k}$

16. At time t, the vector $\vec{r} = 4t^2\hat{i} - (2t + 6t^2)\hat{j}$ gives the position of a 3 kg particle relative to the origin of an xy coordinate system ($\vec{r}$ is in meters and t is in seconds). What is the torque (in Newton-meters) acting on the particle relative to the origin?

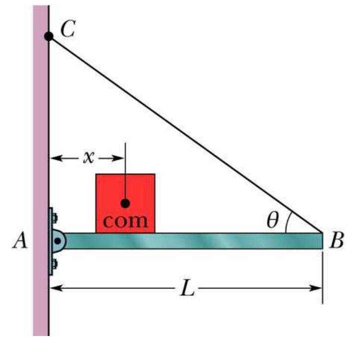
(1) $48t$ (2) $144t^2$ (3) $48t + 144t^2$ (4) $48t + 288t^2$ (5) Insufficient information

17. A certain gyroscope consists of a uniform disk with a 50 cm radius mounted at the center of an axle that is 11 cm long and of negligible mass. The axle is horizontal and supported at one end. If the spin rate is 1000 rev/min, what is the precession rate?



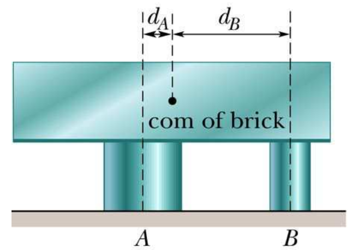
(1) 0.041 rad/s
(2) 0.082 rad/s
(3) 0.13 rad/s
(4) 0.26 rad/s
(5) 16 rad/s

18. In the Figure, suppose the length L of the uniform bar is 3 m and its weight is 200 N. Also, let the block's weight $W = 300$ N and the angle $\theta = 30°$. The wire can withstand a maximum tension of 500 N. What is the maximum possible distance x before the wire breaks?



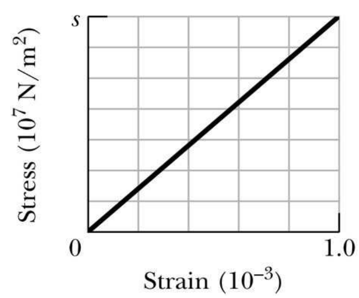
(1) 1.5 m
(2) 2.0 m
(3) 2.5 m
(4) 3.0 m
(5) 1.0 m

19. In the Figure, a lead brick rests horizontally on cylinders A and B. The areas of the top faces of the cylinders are related by $A_A = 2A_B$; the Young's moduli of the cylinders are related by $E_A = 2E_B$. The cylinders had identical lengths before the brick was placed on them. What fraction of the brick's mass is supported by cylinder A?



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

20. The Figure shows the stress versus strain plot for an aluminum wire that is stretched by a machine pulling in opposite directions at the two ends of the wire. The scale of the stress axis is set by $s = 7$, in units of 10^7 N/m^2. The wire has an initial length of 0.8 m and an initial cross-sectional area of 2×10^{-6} m^2. How much work does the force from the machine do on the wire to produce a strain of 10^{-3}?



(1) 0.056 J
(2) 0.070 J
(3) 0.084 J
(4) 0.098 J
(5) 0.112 J