Name

PH105 Exam 3

Key:
1) A 2) D 3) C 4) A 5) D 6) B 7) B 8) B 9) A 10) C 11) E 12) A 13) A 14) D 15) A 16) C 17) B 18) B 19) D 20) A 21) A 22) B 23) B 24) A 25) B

1) A dumbbell-shaped object is composed by two equal masses, m, connected by a rod of negligible mass and length r. If I_1 is the moment of inertia of this object with respect to an axis passing through the center of the rod and perpendicular to it and I_2 is the moment of inertia with respect to an axis passing through one of the masses, it follows that

A) $I_2 > I_1$ B) $I_1 = I_2$ C) $I_1 > I_2$

2) A uniform solid sphere of mass M and radius R rotates with an angular speed ω about an axis through its center. A uniform solid cylinder of mass M, radius R, and length $2R$ rotates through an axis running through the central axis of the cylinder. What must be the angular speed of the cylinder so it will have the same rotational kinetic energy as the sphere? See the formula sheet for moments of inertia.

A) $2\omega/5$ B) $\omega/\sqrt{5}$ C) $\sqrt{2/5}\omega$ D) $2\omega/\sqrt{5}$ E) $4\omega/5$

3) A machinist turns the power on to a grinding wheel, which is at rest at time $t = 0.00$ s. The wheel accelerates uniformly for 10 s and reaches the operating angular velocity of 25 rad/s. The wheel is run at that angular velocity for 37 s and then power is shut off. The wheel decelerates uniformly at 1.5 rad/s^2 until the wheel stops. In this situation, the time interval of angular deceleration (slowing down) is closest to:

A) 23 s B) 15 s C) 17 s D) 19 s E) 21 s

4) Future space stations will create an artificial gravity by rotating. Consider a cylindrical space station 195 m radius rotating about its central axis. Astronauts walk on the inside surface of the space station. What rotation period will provide “normal” gravity?

A) 28 s B) 4.4 s C) 6.3 s D) 40 s

5) A new roller coaster contains a loop-the-loop in which the car and rider are completely upside down. If the radius of the loop is 13.2 m, with what minimum speed must the car traverse the loop so that the rider does not fall out while upside down at the top? Assume the rider is not strapped to the car.

A) 12.5 m/s B) 14.9 m/s C) 10.1 m/s D) 11.4 m/s

6) A turbine blade rotates with angular velocity $\omega(t) = 2.00\text{rad/s} - 2.10\text{rad/sec}^3 t^2$. What is the angular acceleration of the blade at t = 9.10 s?

A) -172 rad/s^2 B) -38.2 rad/s^2 C) -36.2 rad/s^2 D) -19.1 rad/s^2 E) -86.0 rad/s^2

7) A 4.50-kg wheel that is 34.5 cm in diameter rotates through an angle of 13.8 rad as it slows down uniformly from 22.0 rad/s to 13.5 rad/s. What is the magnitude of the angular acceleration of the wheel?

A) 111 rad/s^2 B) 10.9 rad/s^2 C) 0.616 rad/s^2 D) 5.45 rad/s^2 E) 22.5 rad/s^2

8) A 1000-kg car is slowly picking up speed as it goes around a horizontal curve whose radius is 100 m. The coefficient of static friction between the tires and the road is 0.350. At what speed will the car begin to skid sideways?

A) 35.0 m/s B) 18.5 m/s C) 9.25 m/s D) 34.3 m/s E) 23.6 m/s

9) A satellite orbits the earth a distance of 1.50×10^7 m above the planet's surface and takes 8.65 hours for each revolution about the earth. The earth's radius is 6.38×10^6 m. The acceleration of this satellite is closest to

A) 0.870 m/s^2 B) 2.72 m/s^2 C) 1.91 m/s^2 D) 0.0690 m/s^2 E) 9.80 m/s^2

10) A tire is rolling along a road, without slipping, with a velocity v. A piece of tape is attached to the tire. When the tape is opposite the road (at the top of the tire), its velocity with respect to the road is

A) 1.5v B) zero C) 2v D) v E) The velocity depends on the radius of the tire.

11) A uniform disk, a uniform hoop, and a uniform solid sphere are released at the same time at the top of an inclined ramp. They all roll without slipping. In what order do they reach the bottom of the ramp?

A) disk, hoop, sphere B) sphere, hoop, disk C) hoop, disk, sphere
D) hoop, sphere, disk E) sphere, disk, hoop

12) A 72.0-kg person pushes on a small doorknob with a force of 5.00 N perpendicular to the surface of the door. The doorknob is located 0.800 m from axis of the frictionless hinges of the door. The door begins to rotate with an angular acceleration of 2.00 rad/s^2. What is the moment of inertia of the door about the hinges?

A) 1.88 kg·m^2 B) 2.74 kg·m^2 C) 7.52 kg·m^2 D) 4.28 kg·m^2 E) 0.684 kg·m^2

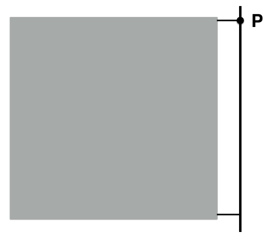
13) A string is wrapped around a pulley with a radius of 2.0 cm and no appreciable friction in its axle. The pulley is initially not turning. A constant force of 50 N is applied to the string, which does not slip, causing the pulley to rotate and the string to unwind. If the string unwinds 1.2 m in 4.9 s, what is the moment of inertia of the pulley?

A) 0.20 kg·m^2 B) 17 kg·m^2 C) 0.017 kg·m^2 D) 14 kg·m^2 E) 0.17 kg·m^2

Name

Name

14) A uniform sign is supported against a wall at point P as shown in the figure below. If the sign is a square 0.40 m on a side and its mass is 4.0 kg, what is the magnitude of the horizontal force that the wall at P experiences?



A) 7.8 N B) 98 N C) 0.00 N D) 20 N

15) A 5.0-m long, 12-kg uniform ladder rests against a smooth vertical wall with the bottom of the ladder 3.0 m from the wall. The coefficient of static friction between the floor and the ladder is $\mu_s = 0.28$. What distance, measured along the ladder from the bottom, can a 60-kg person climb before the ladder starts to slip?
A) 1.7 m B) 3.7 m C) 3.3 m D) 4.0 m E) 1.3 m

16) A solid, uniform sphere of mass 2.0 kg and radius 1.7 m rolls from rest without slipping down an inclined plane of height 7.0 m. What is the angular velocity ω of the sphere at the bottom of the inclined plane?

A) 11 rad/s B) 9.9 rad/s C) 5.8 rad/s D) 7.0 rad/s

17) A mass M is attached to an ideal massless spring. When this system is set in motion with amplitude A, it has a period T. What is the period if the amplitude of the motion is increased to $2A$?

A) $4T$ B) T C) $2T$ D) $\sqrt{2}T$ E) $T/2$

18) A restoring force of magnitude F acts on a system with a displacement of magnitude x. In which of the following cases will the system undergo simple harmonic motion? Do not worry about the sign of the force, only its dependence on x.

A) $F \propto 1/x$ B) $F \propto x$ C) $F \propto x^2$ D) $F \propto \sqrt{x}$ E) $F \propto \sin x$

19) If we double only the amplitude of a vibrating ideal mass-and-spring system, the mechanical energy of the system

A) increases by a factor of $\sqrt{2}$. B) increases by a factor of 2. C) increases by a factor of 3.
D) increases by a factor of 4. E) does not change.

Name ____

20) A sewing machine needle moves up and down in simple harmonic motion with an amplitude of 1.27 cm and a frequency f of 2.55 Hz. What is the maximum speed of the needle?

A) 20.3 cm/s B) 3.24 cm/s C) 7.94 cm/s D) 0.633 cm/s

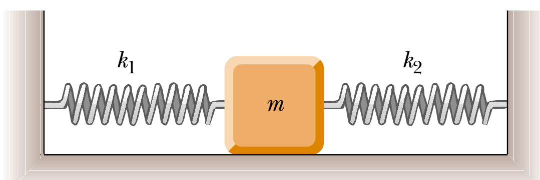
21) Referring to the previous question, what is the maximum acceleration of the needle?

A) 326 cm/s^2 B) 8.26 cm/s^2 C) 10.5 cm/s^2 D) 47.6 cm/s^2

22) An object of mass 8.0 kg is attached to an ideal massless spring and allowed to hang in the Earth's gravitational field. The spring stretches 3.6 cm before it reaches its equilibrium position. If this system is allowed to oscillate, what will be its frequency f?

A) 0.0045 Hz B) 2.6 Hz C) 0.67 Hz D) 2.1 Hz

23) A 2.0 kg block on a frictionless table is connected to two ideal massless springs with spring constants k_1 and k_2 whose opposite ends are fixed to walls, as shown in the figure below. What is angular frequency of the oscillation if $k_1 = 7.6$ N/m and $k_2 = 5.0$ N/m?



A) 0.56 rad/s B) 2.5 rad/s C) 0.40 rad/s D) 3.5 rad/s

24) A 0.25 kg ideal harmonic oscillator has a total mechanical energy of 4.0 J. If the oscillation amplitude is 20.0 cm, what is the oscillation frequency?

A) 4.5 Hz B) 2.3 Hz C) 1.4 Hz D) 3.2 Hz

25) An object that **weighs** 2.450 N is attached to an ideal massless spring and undergoes simple harmonic oscillations with a period of 0.640 s. What is the spring constant of the spring?

A) 12.1 N/m B) 24.1 N/m C) 0.610 N/m D) 2.45 N/m E) 0.102 N/m

$$g = 9.81\,\mathrm{m/s^2}$$

$$\text{sphere} \quad V = \frac{4}{3}\pi r^3 \quad A = 4\pi r^2$$

$$ax^2 + bx^2 + c = 0 \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$c^2 = a^2 + b^2 - 2ab\cos\theta_{ab}$$

$$\sin\theta \approx \theta \qquad \cos\theta \approx 1 - \frac{1}{2}\theta^2 \qquad \text{small } \theta$$

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} \equiv \frac{dv_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

$$\Delta v_x = \int_{t_i}^{t_f} a_x(t)\,dt \qquad \Delta x = \int_{t_i}^{t_f} v_x(t)\,dt$$

$$x(t) = x_i + v_{x,i}t + \frac{1}{2}a_x t^2$$

$$v_x(t) = v_{x,i} + a_x t$$

$$v_{x,f}^2 = v_{x,i}^2 + 2a_x\Delta x$$

$$a_{x,\text{ramp}} = g\sin\theta$$

$$\Delta U^G = mg\Delta x$$

$$\frac{a_{1x}}{a_{2x}} = -\frac{m_2}{m_1}$$

$$E_{\text{mech}} = K + U \quad K = \frac{1}{2}mv^2$$

$$\Delta E = \Delta K + \Delta U = 0 \quad \text{non-dissipative, closed}$$

$$\Delta E = W$$

$$\Delta U_{\text{spring}} = \frac{1}{2}k\,(x - x_o)^2$$

$$P = \frac{dE}{dt}$$

$$P = F_{\text{ext,x}}\,v_x \quad \text{one dimension}$$

Rotation: we use radians

$$s = \theta r \quad \leftarrow \text{arclength}$$

$$\omega = \frac{d\theta}{dt} = \frac{v_t}{r} \qquad \alpha = \frac{d\omega}{dt}$$

$$a_t = \alpha r \quad \text{tangential}$$

$$a_r = -\frac{v^2}{r} = -\omega^2 r \quad \text{radial}$$

$$v_t = r\omega \qquad v_r = 0$$

$$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2 \quad \text{const } \alpha$$

$$\omega_f = \omega_i + \alpha t \quad \text{const } \alpha$$

$$\Delta x = r\theta \quad v = r\omega \quad a = r\alpha \quad \text{no slipping}$$

$$I = \sum_i m_i r_i^2 \Rightarrow \int r^2\,dm = cmr^2 \qquad I = mr^2 \quad \text{point particle}$$

$$I_z = I_{com} + md^2 \quad \text{axis } z \text{ parallel, dist } d$$

$$\vec{\mathbf{L}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}} = I\vec{\boldsymbol{\omega}} \qquad L = I\omega = mvr$$

$$K = \frac{1}{2}I\omega^2 = L^2/2I$$

$$\Delta K = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2 = W = \int \tau\,d\theta$$

$$P = \frac{dW}{dt} = \tau\omega$$

$$\tau = rF\sin\theta_{rF} = r_\perp F = rF_\perp$$

$$\tau_{net} = \sum \vec{\boldsymbol{\tau}} = I\vec{\boldsymbol{\alpha}} = \frac{d\vec{\mathbf{L}}}{dt}$$

$$K_{\text{tot}} = K_{cm} + K_{rot} = \frac{1}{2}mv_{cm}^2 + \frac{1}{2}I\omega^2$$

Oscillations:

$$T = \frac{1}{f} = \frac{2\pi}{\omega} \quad \omega = \frac{2\pi}{T} = 2\pi f$$

$$x(t) = A\sin(\omega t + \varphi_i) = A\sin\varphi(t)$$

$$v(t) = \frac{dx}{dt} = \omega A\cos(\omega t + \varphi_i)$$

$$a(t) = \frac{d^2x}{dt^2} = -\omega^2 A\sin(\omega t + \varphi_i) = -\omega^2 x(t)$$

$$\varphi(t) = \omega t + \varphi_i$$

$$a = -\omega^2 x = \frac{d^2x}{dt^2} \qquad \frac{d^2\theta}{dt^2} = -\omega^2\theta$$

$$E = \frac{1}{2}kA^2 = \frac{1}{2}m\omega^2 A^2$$

$$\omega = \sqrt{k/m} \quad \text{spring.}$$

$$T = \begin{cases} 2\pi\sqrt{m/k} & \text{spring} \\ 2\pi\sqrt{L/g} & \text{simple pendulum} \\ 2\pi\sqrt{I/mgl_{cm}} & \text{physical pendulum} \end{cases}$$

Derived unit	**Symbol**	**equivalent to**
newton	N	kg·m/s^2
joule	J	kg·m^2/s^2 = N·m
watt	W	J/s=m^2·kg/s^3

Moments of inertia of things of mass M

Object	axis	**dimension**	**I**
solid sphere	central axis	radius R	$\frac{2}{5}MR^2$
hollow sphere	central axis	radius R	$\frac{2}{3}MR^2$
solid disc/cylinder	central axis	radius R	$\frac{1}{2}MR^2$
hoop	central axis	radius R	MR^2
point particle	pivot point	distance R to pivot	MR^2
rod	center	length L	$\frac{1}{12}ML^2$
rod	end	length L	$\frac{1}{3}ML^2$
solid regular octahedron	through vertices	side a	$\frac{1}{10}ma^2$