PHYSICS 111

SPRING 2016

EXAM 2
March 8, 2016; 8:15 - 9:45 pm

Name (printed): ______________________________________________
Recitation Instructor: _________________________      Section #_______

INSTRUCTIONS:

This exam contains 20 multiple-choice questions plus 1 extra credit question, each worth 3 points. Choose one answer only for each question. Choose the best answer to each question. Answer all questions.

Allowed material: Before turning over this page, put away all materials except for pens, pencils, erasers, rulers and your calculator. There is a formula sheet attached at the end of the exam. Other copies of the formula sheet are not allowed.

Calculator: In general, any calculator, including calculators that perform graphing, is permitted. Electronic devices that can store large amounts of text, data or equations (like laptops, e-book readers, smart phones) are NOT permitted. Calculators with WiFi technology are NOT permitted. If you are unsure whether or not your calculator is allowed for the exam, ask your TA.

How to fill in the bubble sheet:
Use a number 2 pencil. Do NOT use ink. If you did not bring a pencil, ask for one.
You will continue to use the same bubble sheet you already used for Exam 1. Bubble answers 22-42 on the bubble sheet for this exam.

If you did not take the first exam, write and fill in the bubbles corresponding to:
- Your last name, middle initial, and first name.
- Your ID number (the middle 9 digits on your ISU card)
- Special codes K to L are your recitation section. Always use two digits (e.g. 01, 09, 11, 13).

Please turn over your bubble sheet when you are not writing on it.

If you need to change any entry, you must completely erase your previous entry. Also, circle your answers on this exam. Before handing in your exam, be sure that your answers on your bubble sheet are what you intend them to be. You may also copy down your answers on a piece of paper to take with you and compare with the posted answers. You may use the table at the end of the exam for this.

When you are finished with the exam, place all exam materials, including the bubble sheet, and the exam itself, in your folder and return the folder to your recitation instructor.

No cell phone calls allowed. Either turn off your cell phone or leave it at home. Anyone answering a cell phone must hand in their work; their exam is over.

Best of luck,

Dr. Soeren Prell
22. You throw a small ball straight up. Compare the sign of the work done by gravity on the ball while the ball goes up with the sign of the work done by gravity while the ball goes down.

A) The work is positive on the way up and positive on the way down.
B) The work is positive on the way up and negative on the way down.
C) The work is negative on the way up and positive on the way down.
D) The work is negative on the way up and on the way down.
E) Gravity does zero work on the way and zero work on the way down.

Solution
The work $W$ done by a force $F$ over a distance $y$ is $W = F \cdot s \cos \theta$ where $\theta$ is the angle between the displacement and the force. On the way up $\cos \theta = -1$ and $W < 0$ and on the way down $\cos \theta = +1$ and $W > 0$.

23. A truck has four times the mass of a car and is moving with twice the speed of the car. If $KE_t$ and $KE_c$ refer to the kinetic energies of truck and car respectively, it is correct to say that

A) $KE_t = 16 \cdot KE_c$
B) $KE_t = 8 \cdot KE_c$
C) $KE_t = 4 \cdot KE_c$
D) $KE_t = 2 \cdot KE_c$
E) $KE_t = KE_c$

Solution
$KE_t = \frac{1}{2} m_t v_t^2 = \frac{1}{2} (4m_c)(2v_c)^2 = 16 \left( \frac{1}{2} m_c v_c^2 \right) = 16 KE_c$
24. Which of the graphs represents the magnitude $F$ of the force you have to exert on a spring to stretch it by a distance $x$ as a function of this distance?

A) Graph a  
B) Graph b  
C) Graph c  
D) Graph d  
E) Graph e

**Solution**
According to Hook’s law $F = -kx$, the magnitude of the force $F$ is proportional to the distance $x$ the spring is stretched.

25. The figure shows a roller coaster ride. You can ignore friction. If the roller coaster leaves point Q from rest, what is its speed at the top of the 25-m peak (point S)?

A) 10 m/s  
B) 22 m/s  
C) 44 m/s  
D) 62 m/s  
E) 120 m/s

**Solution**
\[ PE_f + KE_f = PE_0 + KE_0 \rightarrow PE_0 - PE_f = KE_f \]
\[-mg\Delta y = \frac{1}{2}mv^2 \rightarrow v = \sqrt{-2g\Delta y} = \sqrt{-2(9.8 \text{ m/s}^2)(-25 \text{ m})} = 22 \text{ m/s} \]
26. A prankster drops a water balloon from the top of a building. If the balloon is traveling at 29.1 m/s when it strikes the ground, how tall is the building? Neglect air resistance.

A) 16 m  
B) 43 m  
C) 52 m  
D) 69 m  
E) 111 m  

Solution

\[ PE_0 + KE_0 = PE_f + KE_f \rightarrow mgh_0 + 0 = 0 + \frac{1}{2}mv_f^2 \rightarrow h_0 = \frac{v_f^2}{2g} = 43 \text{ m} \]

27. A force of 30 N stretches a very light ideal spring 0.73 m from equilibrium. What is the spring constant of the spring?

A) 41 N/m  
B) 22 N/m  
C) 34 N/m  
D) 46 N/m  
E) 52 N/m  

Solution

\[ F = -k\Delta x \rightarrow k = \frac{F}{\Delta x} = \frac{30 \text{ N}}{0.73 \text{ m}} = 41 \text{ N/m} \]

28. A railroad car collides with and sticks to an identical railroad car that is initially at rest. After the collision, the total kinetic energy of the two cars is

A) the same as before.  
B) half as much as before.  
C) one third as much as before.  
D) one fourth as much as before.  
E) twice as much as before.  

Solution

\[ mv_0 = 2mv_f \rightarrow v_f = \frac{v_0}{2} \]

\[ KE_f = \frac{1}{2}(2m)\left(\frac{v_0}{2}\right)^2 = \frac{1}{2}\left(\frac{1}{2}mv_o^2\right) = \frac{1}{2}KE_0 \]
29. Three objects are moving along a straight line as shown in the figure. Taking the positive direction to be to the right, what is the total momentum of this system?

A) +106 kg · m/s  
B) −106 kg · m/s  
C) +14.0 kg · m/s  
D) −14.0 kg · m/s  
E) −286 kg · m/s

Solution

\[ p_{\text{total}} = \sum p = p_1 + p_2 + p_3 = m_1v_1 + m_2v_2 + m_3v_3 \]
\[ = (8 \text{ kg})(5 \text{ m/s}) + (15 \text{ kg})(-4 \text{ m/s}) + (3 \text{ kg})(2 \text{ m/s}) \]
\[ = 40 \text{ kg m/s} - 60 \text{ kg m/s} + 6 \text{ kg m/s} \]
\[ = -14 \text{ kg m/s} \]

30. A 3.0-kg mass is located at \((x = 0.0 \text{ m}, y = 8.0 \text{ m})\), and a 1.0-kg mass is located at \((x = 12 \text{ m}, y = 0.0 \text{ m})\). You want to add a 4.0-kg mass so that the center of mass of the three-mass system will be at the origin. What should be the \(y\) coordinate of the 4.0-kg mass?

A) −6.0 m  
B) −8.0 m  
C) −12 m  
D) −3.0 m  
E) −4.0 m

Solution

\[ y_{\text{cm}} = \frac{m_1y_1 + m_2y_2 + m_3y_3}{m_1 + m_2 + m_3} = \frac{(3 \text{ kg})(8 \text{ m}) + (1 \text{ kg})(0 \text{ m}) + (4 \text{ kg})x}{m_1 + m_2 + m_3} = 0 \]
\[ \rightarrow (3 \text{ kg})(8 \text{ m}) + (1 \text{ kg})(0 \text{ m}) + (4 \text{ kg})x = 0 \]
\[ \rightarrow x = \frac{(3 \text{ kg})(8 \text{ m})}{(-4 \text{ kg})} = -6 \text{ m} \]
31. A very light ping-pong ball moving east at a speed of 4 m/s collides with a very heavy stationary bowling ball. The ping-pong ball bounces back to the west, and the bowling ball moves very slowly to the east. Which object experiences the greater magnitude impulse during the collision?

A) Neither; both experienced the same magnitude impulse.
B) the ping-pong ball
C) the bowling ball
D) It is impossible to tell since the actual mass values are not given.
E) It is impossible to tell since the velocities after the collision are unknown.

Solution
According to Newton’s third law the ping-pong balls exerts the same magnitude force on the bowling ball as the bowling ball on the ping-pong ball, but the forces have opposite direction. The average force \( F \) acts for the time \( \Delta t \) the two balls are in contact. Since the impulse \( J = F/\Delta t \), the impulses experienced by the two balls have opposite direction and same magnitude.

32. In an amusement park ride, a small child stands against the wall of a cylindrical room that is rotating counterclockwise around its center with constant angular speed. She finds herself stuck with her back to the wall, when the bottom of the room drops down. Which diagram correctly shows the forces acting on the child while she is enjoying the ride?

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

Solution
The net force has to point to the center of the circle, since it provides the centripetal force. The weight of the person is balanced by the friction with the wall. The centripetal force is the normal force by the wall on the child.
33. Two children, Ahmed and Jacques, ride on a merry-go-round at constant angular speed. Ahmed is at a greater distance from the axis of rotation than Jacques. Which of the following is a true statement?

A) Ahmed has a greater angular acceleration than Jacques.
B) Ahmed has a larger centripetal acceleration.
C) Jacques has a smaller tangential acceleration than Ahmed.
D) Jacques has a larger tangential acceleration than Ahmed.
E) Jacques and Ahmed have the same tangential speed.

Solution
Since Ahmed and Jacques ride the same rotating object they move at the same constant angular speed $\omega$ and thus have the same zero angular acceleration ($\alpha = \Delta \omega / \Delta t = 0$). Ahmed’s tangential speed ($v_T = \omega R$) is larger than Jacques since he rides at a larger radius. Both have the same zero tangential acceleration ($a_T = R \alpha = 0$). Ahmed has a larger centripetal acceleration ($a_C = \omega^2 R$) since he rides at a larger radius.

34. The L-shaped object shown in the figure consists of three small masses connected by extremely light rods. Assume that the masses shown are accurate to three significant figures. What is the moment of inertia of this object about the y-axis?

A) 43.6 kg · m²
B) 32.7 kg · m²
C) 49.6 kg · m²
D) 5.0 kg · m²
E) 6.5 kg · m²

Solution
$$I_y = \sum (mx^2) = (1 \text{ kg})(0 \text{ m})^2 + (1 \text{ kg})(3.3 \text{ m})^2 + (2 \text{ kg})(3.3 \text{ m})^2$$
$$= (3 \text{ kg})(3.3 \text{ m})^2 = 32.7 \text{ kg } \text{m}^2$$
35. As shown in the figure, a given force with magnitude $F$ is applied to a rod in several different ways. In which case is the torque about the pivot P due to this force the greatest?

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

**Solution**
The torque is magnitude of the force $F$ times the component of the distance between the pivot point and the point where force applies perpendicular to the force. Thus, the largest torque is achieved when the force $F$ applies at the right edge of the rod perpendicular to the distance between the pivot point and the point where force applies.

36. At a certain instant, a compact disc is rotating at 210 rpm (revolutions per minute). What is its angular speed?

A) 11 rad/s
B) 22 rad/s
C) 45 rad/s
D) 69 rad/s
E) 660 rad/s

**Solution**
\[
\omega = \left(210 \text{ rev/min}\right)\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 22 \text{ rad/s}
\]

37. When a fan is turned off, its angular speed decreases from 10 rad/s to 6.3 rad/s in 5.0 s. What is the magnitude of the average angular acceleration of the fan?

A) 0.86 rad/s²
B) 0.74 rad/s²
C) 0.37 rad/s²
D) 11 rad/s²
E) 1.2 rad/s²

**Solution**
\[
\alpha = \frac{\omega - \omega_0}{\Delta t} = \frac{(6.3 \text{ rad/s}) - (10 \text{ rad/s})}{5.0 \text{ s}} = 0.74 \text{ m/s}^2
\]
38. An electrical motor spins at a constant 2695 rpm (revolutions per minute). If the rotor radius is 7.165 cm, what is the centripetal acceleration of the edge of the rotor?

A) 5707 m/s²
B) 281.6 m/s²
C) 572,400 m/s²
D) 28.20 m/s²
E) 0 m/s²

Solution
\[ a_c = \omega^2r = \left( \left( \frac{2695 \text{ rev}}{\text{min}} \right) \left( \frac{2\pi \text{ rad}}{1 \text{ rev}} \right) \left( \frac{1 \text{ min}}{60 \text{ s}} \right) \right)^2 (0.07165 \text{ m}) = 5706 \text{ m/s}^2 \]

39. A Ferris wheel with a diameter of 25 m rotating at 20 rad/s slows down with a constant angular acceleration of magnitude 5.0 rad/s². How many revolutions does it make while slowing down before coming to rest?

A) 40
B) 20
C) 10
D) 6.4
E) 3.2

Solution
\[ \omega_f^2 - \omega_0^2 = 2\alpha\Delta\theta \rightarrow \Delta\theta = \frac{\omega_f^2 - \omega_0^2}{2\alpha} = \frac{0 - (20 \text{ rad/s})^2}{2(-5 \text{ rad/s}^2)} = 40 \text{ rad} \left( \frac{1 \text{ rev}}{2\pi \text{ rad}} \right) = 6.4 \text{ rev} \]

40. A 50-N force is exerted on a lever at a point 0.40-m from the supporting hinge. The angle between the lever and the force is 60 deg as shown in the figure. What is the torque applied to the lever?

A) 17 Nm
B) 10 Nm
C) 20 Nm
D) 40 Nm
E) 23 Nm

Solution
\[ \tau = Fr\sin\theta = (50 \text{ N})(0.4 \text{ m})\sin(60^\circ) = 17 \text{ Nm} \]
41. The torque required to turn the crank on an ice cream maker is 4.50 N \cdot m. How much work does it take to turn the crank through 300 full turns?

A) 4240 J  
B) 8480 J  
C) 2120 J  
D) 1350 J  
E) 2700 J  

**Solution**  
\[ W = \tau \Delta \theta = (4.5 \text{ Nm})(300 \times 2 \times \pi) = 8480 \text{ J} \]

42. A 50-kg box is being pushed along a horizontal surface. The coefficient of static friction between the box and the ground is 0.65, and the coefficient of kinetic friction is 0.35. What horizontal force must be exerted on the box for it to accelerate at 1.2 m/s²?

A) 60 N  
B) 120 N  
C) 170 N  
D) 230 N  
E) 490 N  

**Solution**  
\[ F_{\text{net}} = F - f_k = F - \mu_K mg = ma \]  
\[ \rightarrow F = m(a + \mu_K g) = (50 \text{ kg}) \left(1.2 \text{ m/s}^2\right) + 0.35 \left(9.8 \text{ m/s}^2\right) = 230 \text{ N} \]
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