

PHY 121: Mechanics: Final Examination

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Monday, June 20, 2011

Duration: 3 hours

Total :140 points

1. (a) A sound wave in air produces a pressure variation given by
$$p(x, t) = 0.75 \cos \frac{\pi}{2}(x - 340t)$$
Where p is in pascals, x is in meters, and t is in seconds. Find (1) the pressure amplitude of the sound wave, (2) the wave-length, (3) the frequency, and (4) the speed.

[5 points]

- (b) The frequency of a car horn is 400 Hz . If the horn is honked as the car moves with a speed $u_s = 34 \text{ m/s}$ through still air toward a stationary receiver, find (1) the wavelength of the sound passing the receiver and (2) find the frequency received. Take the speed of sound in air to be 340 m/s . (3) Find the frequency of the sound received if the car is stationary as the horn is honked and a receiver moves with a speed $u_r = 34 \text{ m/s}$ toward the car. (4) Are the frequencies you found in (2) and (3) same or different?

[10 points]

2. We want to support a thin hoop by a horizontal nail and have the hoop make one complete small-angle oscillation in 2.0 s . Write down the differential equation describing the motion. What is the moment of inertia of the hoop about the pivot. What must the hoop's radius be?

[10 points]

3. A nonuniform bar is suspended at rest in a horizontal position by two massless cords as shown in figure 1. One cord makes an angle $\theta = 36.9^\circ$ with the vertical and the other makes an angle $\phi = 53.1^\circ$ with the vertical. If the length L of the bar is 6.10 m , compute the distance d from the right end of the bar to the center of mass.

[10 points]

4. (a) A steel bridge is 1000 m long. By how much does it expand when the temperature rises from 0 to $30\text{ }^\circ\text{C}$. Use coefficient of thermal expansion (α) for steel to be $11 * 10^{-6}\text{ K}^{-1}$. What stress would be required to cause this change in length, if the Young's modulus for steel is 200 GN/m^2 ?

[5 points]

- (b) While working in the laboratory, you fill a 1 L glass flask to the brim with water at $10\text{ }^\circ\text{C}$. You heat the flask, raising the temperature of the water and flask to $30\text{ }^\circ\text{C}$. How much water spills out of the flask? Use coefficient of volume expansion for water as $0.207 * 10^{-3}\text{ K}^{-1}$ and coefficient of linear expansion for glass as $9 * 10^{-6}\text{ K}^{-1}$.

[5 points]

5. A copper bar is heated to $300\text{ }^\circ\text{C}$. Then it is clamped rigidly between two fixed points so that it can neither expand nor contract. If the breaking stress of copper is 230 MN/m^2 , the coefficient of linear expansion of copper is $17 * 10^{-6}\text{ K}^{-1}$, and Young's modulus for copper is 110 GN/m^2 , at what temperature will the bar break as it cools ?

[10 points]

6. Four bodies of identical mass M form the vertices of a square of side l and rotate in circular orbits about an axis passing through the center of the square and perpendicular to the plane containing the center of mass of the four bodies. They are held in place by their mutual gravitation. What is the speed of each? What is the moment of inertia of the system about this axis, if the dimension of the bodies are negligible compared to the separation distance?

[10 points]

7. You have a summer job at a music shop, helping the owner build musical instruments. He asks you to test a new wire he bought, for possible use in guitars. He tells you that the 3 m long wire has a linear mass density of 0.0025 kg/m , and he has found that the n 'th harmonic has a frequency 252 Hz and the next harmonic has frequency 336 Hz . He wants you to figure out n . And use that to determine the fundamental frequency of the wire and determine whether or not the wire is a good choice for guitar strings. You know that safety issues start to arise if the tension in the wire gets above 700 N .

[15 points]

8. A disk of mass m and radius r is rotating with an initial velocity ω_i about a frictionless shaft through its symmetry axis as shown in figure 2. It drops onto another disk of radius R and mass M that is initially at rest on the same shaft. Because of surface friction, the two disks eventually attain a common angular velocity ω_f . Find ω_f and the ratio of Kinetic energies $(\frac{K_f}{K_i})$.

[10 points]

9. Block A in figure 3 hangs by a cord from a spring balance D and is submerged in a liquid C contained in a beaker B. The mass of the beaker is 1.00 kg , the mass of the liquid is 1.80 kg . Balance D reads 3.50 kg and balance E reads 7.50 kg . The volume of block A is $3.80 \times 10^{-3}\text{ m}^3$
(a) What is the density of the liquid? (b) What will each balance read if block A is pulled up out of the liquid?

[15 points]

10. A thin rod of mass M and length L is attached to a pivot at the top. A piece of clay of mass m and speed v hits the rod at a distance d from the pivot and sticks to it (figure 4).
- (a) Find the ratio of the system's kinetic energy just after the collision to the kinetic energy just before the collision.
 - (b) Determine the position of the center of mass of the new system at the instant of collision.
 - (c) If the new system undergoes small oscillations, find the time period (T) of the oscillating system.

[15 points]

11. You are watching a baseball game with a stopwatch. The batter hits a high fly ball (the baseball is hit high in the air, towards the out field). You time the ball to be in the air for $t_{fly} = 8.0$ s before it is caught by the outfielder. Find the maximum height the baseball attained. (neglect air friction)

[10 points]

12. A block of mass m slides along a frictionless table at speed v toward a wall. A spring of spring constant k is attached to the wall in such a way that it will be compressed when struck by the moving block (see figure 5). Ignore the mass of the spring and calculate
- (a) what will be the maximum compression of the spring, x_{max} ?
 - (b) What will be the instantaneous speed of the block when the spring is compressed by an amount x , $x < x_{max}$?

[10 points]