General Physics I-A

Final Exam

Version 1

May 5, 2006

Acceleration of Gravity: $g = 9.8\,\mathrm{m/s^2}$
Gravitational Force Constant: $G = 6.67 \times 10^{-11}\,\mathrm{N{\cdot}m/^2/kg^2}$
1 liter = 1000 $\mathrm{cm^3} = 1 \times 10^{-3}\,\mathrm{m^3}$
1 atm = $1.013 \times 10^5\,\mathrm{N/m^2}$
Density of water: 1.00 $\mathrm{g/cm^3}$ = 1000 $\mathrm{kg/m^3}$
Density of air: 1.25 $\mathrm{kg/m^3}$
Speed of sound in air: 343 m/s (at 20°C)
1 cal = 4.186 J
Specific heat of water: 1.00 cal/g
Heat of fusion of water: 79.7 cal/g
Heat of vaporization of water: 539 cal/g
Avogadro's number: $N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Absolute zero: 0 K = -273.15°C
Boltzmann's Constant: $k = 1.38 \times 10^{-23}$ J/K
Ideal Gas Constant: $R = N_A k = 8.315$ J/(mol K)
Stefan-Boltzmann Constant: $\sigma = 5.67 \times 10^{-8}\,\mathrm{W/m^2{\cdot}K^4}$
Moments of Inertia about CM:

Thin Hoop: MR^2, Solid Cylinder: $\frac{1}{2}MR^2$,
Solid Sphere: $2MR^2/5$, Rod: $ML^2/12$.

---

1. [1pt] You are throwing a ball straight up in the air. At the highest point, the ball's

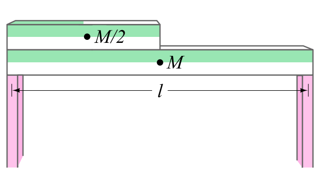
A) acceleration is nonzero, but its velocity is zero.
B) velocity and acceleration are zero.
C) velocity is nonzero but its acceleration is zero.
D) velocity and acceleration are both nonzero.

`A`

Explanation:
The gravitational acceleration is always 9.8 meters per second squared downward, at every point on the ball's trajectory. The velocity is positive while the ball moves upward, and negative while it is falling, so the velocity becomes zero at the highest point.

---

2. [1pt] A uniform steel beam has a mass of 888 kg. On it is resting half of an identical beam, as shown in the figure below.



What is the vertical support force at each end?

A) 8.7 kN on the left and 4.4kN on the right.
B) 10.9 kN on the left and 2.2kN on the right.
C) 7.6 kN on the left and 5.4kN on the right.
D) 9.8 kN on the left and 3.3kN on the right.

`C`

Explanation:
The mass of the long beam is $M = 888\,\mathrm{kg}$. Balancing forces on the beams shows that the total weight of the two beams is $3Mg/2 = F_1 + F_2$, where F_1 and F_2 are the vertical support forces at the left and right ends of the long beam. The torques must also balance. Let L denote the unspecified length of the longer beam. The weights of the beams can be treated as if they are concentrated at the centers of mass as shown in the figure. Calculating them about the left end of the beams, we find a clockwise torque $MgL/8$ due to the short beam, a clockwise torque $MgL/2$ due to the long beam, and a counterclockwise torque F_2L due to the vertical support force at the right end of the beam. Therefore, balancing the torques about the left end of the beams gives

$$F_2L = MgL/8 + MgL/2 = 5MgL/8.$$

The factors of the length L cancel, giving $F_2 = 0.625$ $(888\,\mathrm{kg})(9.8\,\mathrm{m/s^2}) = 5.4\,\mathrm{kN}$. Then F_1 can be found from the balance of forces equation,

$$F_1 = 3Mg/2 - F_2 = 13.1\,\mathrm{kN} - 5.4\,\mathrm{kN} = 7.6\,\mathrm{kN}.$$

---

3. [1pt] The left end of a see-saw accelerates downward, as you view it. By the right-hand rule, the torque vector acting on the see-saw points (Select one)

A) toward you.
B) down.
C) away from you.
D) counterclockwise.

`A`

Explanation:
The acceleration of the see-saw could be caused by a force pushing down on the left end, one pulling up on the right end, or a combination of these. The right-hand rule says that if you put the fingers of your right hand along the see-saw so that they point from the center toward the end where the force acts, and then curl them toward the force, the torque vector points along your thumb. In either of the cases that could cause the rotation in this problem, you will find that your thumb points toward you, so the torque is toward you.

---

4. [1pt] The following expression gives the resistive force on a sphere of radius r moving with speed v through air:

$$R(v) = 3.1 \times 10^{-4} rv + 0.87 r^2 v^2,$$

where R is in Newtons, r is in meters, and v is in m/s. Estimate the terminal speed of fall (in air) of an air-filled toy balloon, with a diameter of 50 cm and a mass (not counting the air inside) of 0.59 g.

A) 0.46 m/s
B) 75 m/s
C) 0.33 m/s
D) 37 m/s

C

Explanation:
The terminal velocity is obtained by setting the resistive force $R(v)$ equal to the weight of the balloon, $mg = 5.8 \times 10^{-3}$ N. Normally, air resistance is dominated by the term quadratic in v, so we will estimate the terminal velocity v neglecting the linear term, and then verify that the linear term is small. Then $mg = C_2 r^2\ v^2$ determines the terminal velocity, with $r = 2.5 \times 10^{-1}$ m and $C_2 = 0.87\ \mathrm{N\,s^2/m^4}$. This gives

$$v = [(5.8 \times 10^{-3}/0.87)\ \mathrm{m^4/s^2}]^{1/2}\ /\ 2.5 \times 10^{-1}\,\mathrm{m} = 3.3 \times 10^{-1}\,\mathrm{m/s}.$$

The neglected linear term in $R(v)$ is $C_1 r\ v$, with $C_1 = 3.1 \times 10^{-4}\,\mathrm{N\,s/m^2}$. For the terminal velocity found, the ratio of the linear term to the quadratic term in $R(v)$ is

$$C_1/(C_2 r\ v) = 4.4 \times 10^{-3}$$

which is less than 1%, justifying its neglect compared to the quadratic term.

---

5. [1pt] The springs of a car of mass 1780 kg give it a period when empty of 0.77 s for small vertical oscillations. How much further does the car sink down when the driver and three passengers, each of mass 84 kg, get into the car?

A) 1.4 cm
B) 2.1 cm
C) 2.8 cm
D) 0.7 cm

C

Explanation:
The period of oscillation of the empty car can be used to determine the spring constant k, since the angular velocity is determined by $\omega^2 = k/M$ where M is the mass of the empty car., and $\omega = 2\pi/T$ determines the period T. Combining these relations gives

$$k = 4\pi^2 M/T^2 = 1.19 \times 10^5\,\mathrm{N/m}.$$

Once the spring constant is known, Hooke's law determines the distance y the car sinks down when four people of mass m enter the car: $4mg = ky$. Using the given mass of the people and the value of k just found shows that the car's springs are compressed an additional distance $y = 2.8$ cm.

---

6. [1pt] What mass of steam at 100°C must be added to 1.10 kg of ice at 0°C to yield liquid water at 35.0°C?

A) 5.79 kg
B) 3.00 kg
C) 0.21 kg
D) 0.52 kg

C

Explanation:
An unknown mass m_s of steam at the boiling point 100°C is added to a mass $m_\mathrm{i} = 1.10$ kg of ice at the freezing point 0°C, yielding liquid water at temperature $T_\mathrm{w} = 35$°C. The latent heat of fusion for ice is $L_\mathrm{f} = 79.7$ cal/g and the latent heat of vaporization for steam is $L_\mathrm{v} = 539$ cal/g, so energy conservation gives

$$m_\mathrm{i} L_\mathrm{f} + m_\mathrm{i} c_\mathrm{w}(T_\mathrm{w} - 0°\mathrm{C}) = m_\mathrm{s} L_\mathrm{v} + m_\mathrm{s} c_\mathrm{w}(100°\mathrm{C} - T_\mathrm{w})\ .$$

The specific heat of water is $c_\mathrm{w} = 1.00$ cal/g. Therefore, solving for the mass of steam gives

$$\begin{aligned} m_S &= m_I \left[\frac{L_f - c_w T_w}{Lv + c_w(100°C - T_w)}\right] \\ &= 1.10\,\mathrm{kg}\ \left[\frac{79.7 + 35}{539 + 65}\right] = 0.209\,\mathrm{kg}. \end{aligned} \tag{1}$$

---

7. [1pt] How much work would be required to move a satellite of mass 4990 kg from a circular orbit of radius $r_1 = 4r_E$ about the Earth to another circular orbit of radius $r_2 = 8r_E$? (r_E is the radius of the Earth, 6380 km.)

A) $1.95{\times}10^{10}$ J
B) $1.73{\times}10^{10}$ J
C) $3.90{\times}10^{10}$ J
D) $3.47{\times}10^{10}$ J

A

Explanation:
The work is the difference in the total mechanical energy for the satellite in two orbits. The potential energy of a statellite of mass m in a circular orbit of radius r about the Earth is $U =$ - $GM_E m/r$. The kinetic energy is $K = \frac{1}{2}\ mv^2$. The centripetal acceleration is equal to the gravitational attraction to Earth, so $mv^2/r = GM_E m/r^2$. This implies that $K = \frac{1}{2}\ GM_E m/r =$

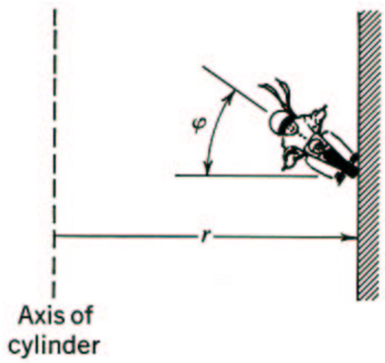
$-\frac{1}{2}\,U$. The total mechanical energy is then $E = \frac{1}{2}\,GM_E m/r$. It is convenient to use the fact that $g = GM_E/r_E{}^2$ to rewrite the satellite's energy as $E = \frac{1}{2}\,mgr_E{}^2/r$. The work needed to move the satellite from an orbit of radius $r_1 = 4r_E$ to $r_2 = 8r_E$ is then

$$W = E_2 - E_1 = \frac{mgr_E^2(r_2 - r_1)}{2r_1r_2} = \frac{4mgr_E}{2 \times 32} = 1.95 \times 10^{10}\ \mathrm{J} \quad (2)$$

for the orbits given.

---

8. [1pt] A trick cyclist rides his bike around a "wall of death" in the form of a vertical cylinder (see the figure). The maximum frictional force parallel to the surface of the cylinder is equal to a fraction μ of the normal force exerted on the bike by the wall.



If $\mu = 0.54$ and the radius of the cylinder is 6.3 m, what minimum speed must the cyclist ride to avoid slipping down?

A) 10.7 m/s
B) 15.1 m/s
C) 5.3 m/s
D) 7.6 m/s

A

Explanation:
The contact force between the cycle and the cylinder can be expressed as the sum of a normal force $F_{\rm N}$ pointing inward and a tangential frictional force $F_{\rm f}$ pointing upward. The remaining force is the weight mg of the cycle and rider pointing downward through the center of gravity. Balancing the forces in the y (vertical) direction gives $F_{\rm f} = mg$. The forces in the x (horizontal) direction are not balanced, because there is centripetal acceleration. The net force is the mass m times the centripetal acceleration $a_{\rm c} = v^2/r$. In this case, the net horizontal force is simply the normal force, so $F_{\rm N} = mv^2/r$. When the cycle is about to slip, the frictional force is related to the normal force by $F_{\rm f} = \mu F_{\rm N}$, where $\mu = 0.54$ is the coefficient of static friction. Then the vertical equation determines $F_{\rm N} = mg/\mu$. Substituting this into the horizontal equation gives

$$mg/\mu = mv^2/r.$$

The unknown mass m cancels, and this equation can be solved to find $v^2 = gr/\mu$. Substituting the given values and taking the square root gives $v = 10.7$ m/s.

---

9. [1pt] A train traveling east at 64 mph collides a baseball thrown at it head-on with a speed of 87 mph. If the collision is elastic, how fast will the ball be moving after it bounces off the front of the moving train? (All speeds are relative to the ground.)

A) 238 mph
B) 192 mph
C) 215 mph
D) 261 mph

C

Explanation:
In an elastic collision, the relative speed of the objects is the same before and after the collision. The relative speed before the collision is 151 mph, since the ball and train are headed toward one another. After the collision, the train will still be moving with speed 64 mph, since it is much more massive than the ball. Therefore, the ball will be moving with speed (64 + 151) mph = 215 mph relative to the ground.

---

10. [1pt] A fire hose delivers 12 liters per second with a speed of 23 m/s. If the hose is aimed directly at a wall, what is the force of water on the wall? (Assume it all runs down the wall without splashing.)

A) 221 N
B) 331 N
C) 386 N
D) 276 N

D

Explanation:
The force of the water on the wall is equal to the change in momentum (impulse) per unit time of the water: $F = \mu v$, where $v = 23$ m/s is the water's velocity and μ is the rate at which the water's mass leaves the nozzle. Since one liter has a mass of 1 kg, $\mu = 12$ kg/s. This gives a force of

$$F = \mu v = (12\,\mathrm{kg/s})(23\,\mathrm{m/s}) = 276\,\mathrm{N}$$

one the wall.

---

11. [1pt] The temperature of 1.55 mol of an ideal diatomic gas goes from 26.7°C to 43.5°C at a constant volume. What is the change in entropy?

A) 15.7 J/K
B) -1.76 J/K
C) 1.76 J/K
D) -15.7 J/K

C

Explanation:

The change in entropy at constant volume is $\Delta S = \int dQ/T = nC_V \int dT/T = nC_V \ln(T_2/T_1)$. The molar specific heat at constant volume for an ideal diatomic gas in this temperature range is $5R/2$, with ideal gas constant $R = 8.315$ J/mol K and $T_1 = 299.8$ K and $T_2 = 316.65$ K are the beginning and ending absolute temperatures needed in the entropy equation. There are $n = 1.55$ moles of gas, so the change in entropy is

$$\Delta S = 1.55\ (2.5)\ (8.315\ \text{J/K})\ \ln\ (316.6/299.8) = 1.76\,\text{J/K}.$$

---

12. [1pt] You are given two carts, A and B. They look identical, and you are told that they are made of the same material. You place A at rest on an air track and give B a constant velocity directed to the right so that it collides elastically with A. After the collision, both carts move to the right, the velocity of B being smaller than what it was before the collision. What do you conclude?

A) The two carts are identical.
B) need more information
C) Cart A is hollow.
D) Cart B is hollow.

C

Explanation:

If the carts had the same mass, and had an elastic collision, cart B would come to rest when it struck car A, and car A would then move to the right with the same velocity as B originally had. If cart B is more massive than A, then it will move to the right as well, while if cart B is less massive than A, it will bounce back to the left. In the case given, we can conclude that cart B must be more massive than A, so that A must be hollow.

---

13. [1pt] Starting from a point that can be taken as the origin, a ship travels 47.2 miles northeast in a straight line, and then 24.8 miles on a course that heads in a direction making a counterclockwise angle of 66.0° with a reference line drawn eastward. Find the x and y coordinates of its final position (x eastward, y northward).

A) x = 23.3 mi, y = 43.5 mi
B) x = 43.5 mi, y = 56.0 mi
C) x = 23.3 mi, y = 56.0 mi
D) x = 43.5 mi, y = -10.7 mi

B

Explanation:

The ship's first displacement can be represented as a vector **A** of magnitude $A = 47.2$ mi at an angle of $\theta_A = 45°$ counterclockwise from the x axis, which we take to point eastward. The components of **A** are $A_x = A \cos \theta_A = 33.4$ mi and $A_y = A \sin \theta_A = 33.4$ mi. The ship's second displacement is a vectore **B** of magnitude $B = 24.8$ mi at an angle of $\theta_B = 66.0°$ counterclockwise from the x axis. The components of **B** are $B_x = B \cos \theta_B = 10.1$ mi and $B_y = B \sin \theta_B = 22.7$ mi. The components of the total displacement **C** = **A** + **B** are then $C_x = A_x + B_x = 43.5$ mi and $C_y = A_y + B_y = 56.0$ mi.

---

14. [1pt] A heat pump is used to keep a house warm at 22.5°C. How much work is required of the pump to deliver 2760 J of heat into the house if the outdoor temperature is 0°C. Assume ideal (Carnot) behavior.

A) 227 J
B) 2760 J
C) 210 J
D) 195 J

C

Explanation:

If $Q_H = 2760$ J is delivered to a house at temperature 22.5°C = 296 K, the work required can be found from the relation $W = Q_H/\text{CP}$, where CP is the coefficient of performance of the heat pump. (Remember that the heat delivered to the house is what matters for a heat pump, so the definition is different than for a refrigerator.) For an ideal heat pump, CP = $T_H/(T_H - T_C)$. In this case, T_C = 0°C = 273 K and T_H = 296 K, so the coefficient of performance is 13.13. Therefore, the work required is W = 2760 J/13.13 = 210 J.

---

15. [1pt] You open the refrigerator in your room and put in a case of room-temperature root beer. After an hour, the root beer is ice cold. If your room air did not exchange any heat with the outdoor air during that time, the room air will be (Select one)

A) colder because the refrigerator reverses natural heating, so that things get colder rather than hotter.

B) warmer because some of the heat from the root beer inevitably leaks out into the room as the result of imperfect insulation.

C) warmer because the refrigerator will have pumped heat out of the root beer and into the room air.

D) colder because as the refrigerator struggles to cool the root beer, some of the cold it produces inevitably leaks out into the room as the result of imperfect insulation.

C

Explanation:
The first law of thermodynamics says that the heat exhausted into the room is the sum of the heat taken out of the root beer and the energy used to run the refrigerator. Therefore, the room will become warmer as the refrigerator runs.

---

16. [1pt] Consider two identical glasses. Glass 1 contains only water. Glass 2 is filled to the same level with water, but also contains a large floating ice cube. Which glass is heavier?

A) Glass 1.

B) It is impossible to say without more information.

C) Glass 2.

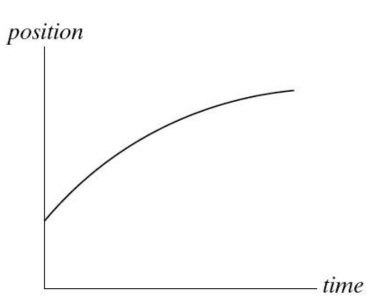
D) They have the same weight.

D

Explanation:
The mass of a floating ice cube is equal to the mass of water it displaces.This is equal to the mass of water that would occupy the space containing the underwater part of the ice cube if it weren't there. This means that when the water levels are the same, the mass of ice plus water is the same as the mass of just the water.

---

17. [1pt] A train car moves along a long straight track. The graph shows the position as a function of time for this train.



The graph shows that the train:

A) moves at a constant velocity.

B) slows down all the time.

C) speeds up all the time.

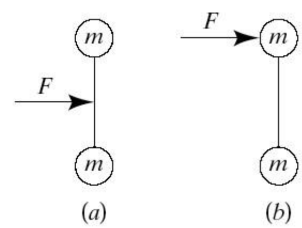
D) speeds up part of the time and slows down part of the time.

B

Explanation:
Since the slope of the graph is decrasing with time, the train is slowing down.

---

18. [1pt] A force F is applied to a dumbbell for a time interval Δt, first as in (a) and then as in (b).



Which statement is true?

A) Dumbbell a moves faster but b has more energy.

B) The speeds are the same but dumbbell a has more energy.

C) The speeds are the same but dumbbell b has more energy.

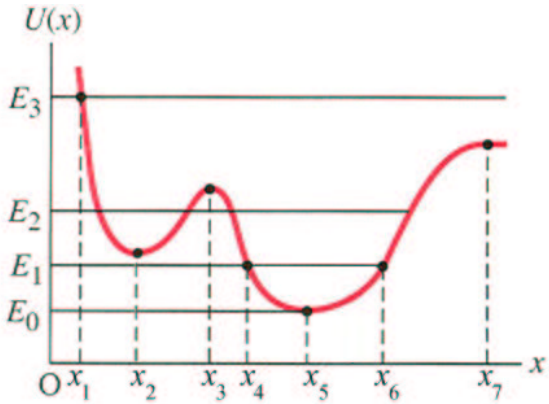
D) Dumbbell a moves faster and has more energy than b.

C

Explanation:
The center-of-mass speed is determined by the center-of-mass momentum of the dumbbell, which is equal to the impulse (the product of the force times the time over which it acts). Since both dumbbells receive the same impulse, they have the same linear momentum , and therefore the same center-of-mass velocity. Dumbbell b will have more energy, since it has rotational energy in addition to translational energy, while dumbbell a only has translational energy.

---

19. [1pt] A particle moves in one dimension under the influence of a force with potential energy $U(x)$ as shown in the graph.



A particle with total energy E_2

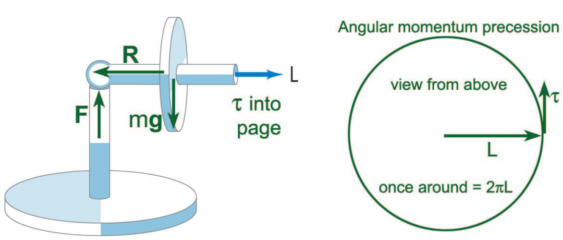
A) must oscillate about point x_2.
B) may oscillate about point x_2 or x_5.
C) may oscillate about any of the points x_2, x_3 or x_5.
D) must oscillate about point x_5.

B

Explanation:
A particle with the specified energy can oscillate about either of the two possible local minima of the potential, depending on where it starts out. It cannot oscillate about a local maximum, especially one where the potential energy is greater than the total energy.

---

20. [1pt] A toy gyroscope consists of a disk mounted at the center of an axle as shown. One end of the axle is attached to a pivot which is free to turn. The angular momentum vector of the spinning disk is as shown in the figure.



Seen from above, the gyroscope will precess about the pivot

A) in a clockwise direction with a period inversely proportional to L
B) in a counterclockwise direction with a period proportional to L
C) in a clockwise direction with a period proportional to L
D) in a counterclockwise direction with a period inversely proportional to L

B

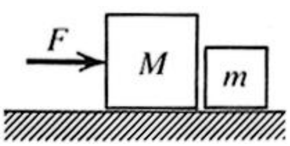
Explanation:
The torque about the gyroscope's center of mass causes a change in its angular momentum vector: $\tau = d\mathbf{L}/dt$. The torque about the center of mass is due to the support pushing up on the axis, at a distance R from the center of mass. When the gyroscope is as shown, the torque has magnitude $\tau = MgR$, and is pointing into the page by the right-hand rule. Since the change in $\mathbf{L}$ is perpendicular to $\mathbf{L}$, the magnitude of $\mathbf{L}$ is constant, but it rotates into the page, making a counterclockwise uniform motion as seen from above. Thus, the angular momentum vector goes in a circle of radius L at a uniform rate, going through a circumference of $2\pi L$ in a time T which can be calculated from the torque: $2\pi L = T\tau$. Therefore, the time to precess around once is

$$T = 2\pi L/\tau,$$

and the precession period is proportional to L.

---

21. [1pt] Two blocks, of masses $M = 4.50\,\text{kg}$ and $m = 1.16\,\text{kg}$, are in contact on a horizontal table. A constant horizontal force $F = 6.31\,\text{N}$ is applied to block M as shown). There is a *constant* frictional force of 1.66 N between the table and the block m, but *no* frictional force between the table and the first block M.



Calculate the acceleration of the two blocks.

A) $0.82\,\text{m/s}^2$
B) $1.11\,\text{m/s}^2$
C) $1.41\,\text{m/s}^2$
D) $4.01\,\text{m/s}^2$

A

Explanation:
Consider the two blocks as a unit with total mass $M + m = 5.66\,\text{kg}$, and denote the frictional force by $F_\text{f} = 1.66\,\text{N}$. Newton's law shows that the acceleration a is determined by $(M + m)a = F$ - $F_\text{f} = 4.65\,\text{N}$. Therefore, the acceleration is $a = 0.82\,\text{m/s}$.

---

22. [1pt] If you double the absolute temperature of a light bulb filament, its power output increases by a factor of (Select one)

A) 8
B) 16
C) 2
D) 4

B

Explanation:
The radiated power is proportional to the fourth power of the absolute temperature, by the Stefan-Boltzmann law. Doubling the absolute temperature therefore increases the power output by a factor of 16.

---

23. [1pt] A particular organ pipe can resonate at 216 Hz, 360 Hz, and 504 Hz, but not at any other intermediate frequencies. The organ pipe is

A) open on both ends with fundamental frequency 72 Hz.
B) open on one end with fundamental frequency 72 Hz.
C) open on both ends with fundamental frequency 216 Hz.
D) open on one end with fundamental frequency 216 Hz.

`B`

Explanation:
In terms of the fundamental frequency f_1, the harmonics of an open pipe are $f_n = n\, f_1$, while the harmonics of a closed pipe are $f_n = (2n$ - $1)\ f_1$. For the open pipe, the difference between successive harmonics is $\Delta f = f_1$, while for the closed pipe, the difference between successive harmonics is $2f_1$. To find the fundamental frequency f_1, we first must decide whether the pipe is open or closed. To decide, we can form the ratios $f_n/\Delta f$ for successive harmonics f_n. If these ratios are consecutive integers, the pipe is open, while if they are consecutive half-odd-integers, the pipe is closed on one end. For the harmonics given, $\Delta f = 144$ Hz, and the values of $f_n/\Delta f$ are $216/144 = 1.5$, $360/144 = 2.5$, and $504/144 = 3.5$. Any of these suffices to show that the pipe is closed on one end, so that the fundamental is $\Delta f\ /\ 2 = 72.0$ Hz.

---

24. [1pt] If one drum has a loudness of 95 dB, how loud would 100 identical drums be?

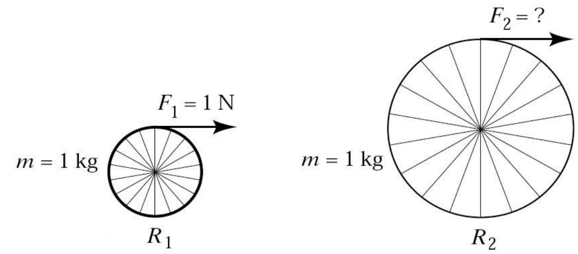
A) 195 dB
B) 115 dB
C) 125 dB
D) 105 dB

`B`

Explanation:
One hundred drums would have 100 times the intensity of a single drum. Each factor of 10 in intensity adds 10 decibels to the loudness, so 100 drums are 20 decibels louder than a single drum.

---

25. [1pt] Two wheels with fixed hubs, each having a mass of 1 kg, start from rest, and forces are applied as shown. The first wheel has radius $R_1 = 0.5$ m, and the second wheel has radius $R_2 = 1.0$ m.



Assume the hubs and spokes are massless, so that the rotational inertia is $I = mR^2$. In order to impart identical angular accelerations, how large must F_2 be?

A) 0.5 N
B) 1 N
C) 4 N
D) 2 N

`D`

Explanation:
The torque equals the moment of inertia times the angular acceleration, so

$$RF = I\alpha = mR^2\alpha.$$

Therefore, $F = mR\alpha$. Comparing two wheels with the same mass and angular acceleration gives $F_2/F_1 = R_2/R_1$. Since $R_2/R_1 = 2$ and $F_1 = 1$ N, we find that $F_2 = 2$ N.

---

26. [1pt] Which of the following statements is **not** explained by Bernoulli's principle?

A) A narrow horizontal pipe of constant cross-section will have a greater pressure difference between the ends than a wide one, assuming the same volume rate of flow.
B) If a pipe becomes narrower, the pressure drops in the narrow part.
C) If holes are punched in a can full of water, the water will flow faster from holes near the bottom than holes near the top.
D) A fast wind can lift the roof off a house.

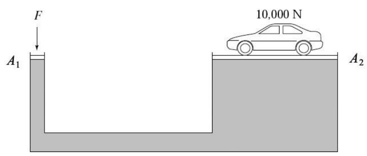
`A`

Explanation:
In short, Bernoulli's principle states that energy is conserved in a fluid flow. One consequence is that when a fluid speeds up, the pressure drops. This explains why pressure drops in narrow parts of a pipe (where the flow must be faster, by continuity), or why low pressure can develop over a house in a high wind. The fact that water flows faster from holes further down in a can of water also is a special case of Bernoulli's principle. However, Bernoulli's principle predicts that there will never be a pressure difference between the ends of a horizontal pipe of constant

cross section. This requires viscosity, and the statement about the dependence on the width of the pipe is due to Poiseuille's equation.

---

27. [1pt]



A container is filled with oil and fitted on both ends with pistons. The area of the left piston is 23.0 mm^2; that of the right piston 27600 mm^2. What force must be exerted on the left piston to keep the 10,000- N car on the right at the same height?

A) 10000 N
B) 6.94×10^{-3} N
C) 8.33 N
D) 289 N

C

Explanation:
Pascal's principle says that the increase in pressure is the same at both pistons, so that the force is proportional to the area of the piston. The area of a cylindrical piston is proportional to the square of its diameter, so the output force is related to the input force by $F_2/F_1 = A_2/A_1$, with $F_2 = mg$ = 10000 N the weight of the car. Solving for the applied force gives

$$F_1 = mg\ (A_1/A_2) = mg/1200 = 8.33\ \text{N}.$$

---

28. [1pt] You are in the kitchen with three mixing bowls in front of you. One bowl is metal, the second is glass, and the third is plastic. All three are at exactly the same temperature: the 68° F (20° C) temperature of the room. If you touch the three bowls together, (Select one)

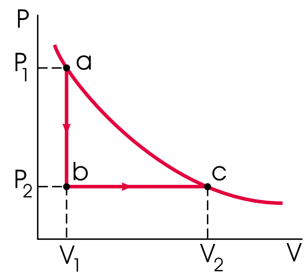
A) heat will flow from the metal bowl to the glass bowl, and from the glass bowl to the plastic bowl.
B) no heat will flow between the bowls.
C) heat will flow from the glass bowl to both the plastic bowl and the metal bowl.
D) heat will flow from the plastic bowl to the glass bowl, and from the glass bowl to the metal bowl.

B

Explanation:
If objects in contact are at the same temperature, they will be in thermal equilibrium, which means that no heat will flow between them, regardless of what they are made of.

---

29. [1pt] Consider the following cyclic process. An ideal gas enclosed in a piston starts at point a and is cooled at constant volume so that its pressure drops from P_1 to P_2 at point b. Then the gas expands at constant pressure, from a volume of V_1 to V_2, where the temperature reaches its original value at point c. Then the gas is compressed at constant temperature back to its original pressure P_1 and volume P_2, returning to point a.



Which of these statements is true for the complete cycle $abca$?

A) The net work done by the gas is zero.
B) The net work done by the gas is positive.
C) The sign of the net work cannot be determined without more information about the heat added to the system.
D) The net work done by the gas is negative.

D

Explanation:
The work done in any process on a PV diagram is the area under the curve representing the process, positive for expansion and negative for compression. In this case, the work done while expanding is the area below the line bc, while the work done while compressing the gas is the area under the curve ac, with a minus sign. The net work is therefore negative in this process.

---

30. [1pt] Suppose that in the diagram for the previous problem, P_1 = 2.27 atm, P_2 = 1.41 atm, V_1 = 7.03 L, and V_2 = 12.9 L. How much work is done by the gas in going from point a to b and then to c?

A) 511 J
B) 226 J
C) 1350 J
D) 838 J

D

Explanation:
The work done when the gas expands at constant pressure P_2 = 1.41 atm is $W = P_2(V_2 - V_1)$ = 1.41 atm × 5.87 L =

8.28 atm· L. The units can be converted to Joules using 1 atm $= 1.013 \times 10^5$ N/ m^2 and 1 L $= 1 \times 10^{-3}$ m^3, which implies that 1 atm· L = 101.3 J. The work done in Joules is therefore 838 J.