(Solutions)

Fall 2014
Physics 105, sections 1 and 3
Final Exam
Colton

Write your CID here: __________
if you wish to get your exam back

3 hour time limit. A handwritten 3" x 5" note card is allowed. No books. Student calculators allowed. All problems equal weight.

Constants/Materials parameters:
$g = 9.8$ m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
$k_B = 1.381 \times 10^{-23}$ J/K
$N_A = 6.022 \times 10^{23}$
$R = k_B \cdot N_A = 8.314$ J/mol·K
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
Mass of Sun = 1.991×10^{30} kg
Mass of Earth = 5.98×10^{24} kg
Radius of Earth = 6.38×10^6 m
Radius of Earth's orbit
= 1 A.U. = 1.496×10^{11} m

Density of water: 1000 kg/m^3
Density of air (at 0°C, 1 atm): 1.29 kg/m^3
Linear exp. coeff. of alum.: 24×10^{-6} /°C
Linear exp. coeff. of copper: 17×10^{-6} /°C
Linear exp. coeff. of steel: 11×10^{-6} /°C
Specific heat of water: 4186 J/kg·°C
Specific heat of ice: 2090 J/kg·°C
Specific heat of steam: 2010 J/kg·°C
Latent heat of melting (water): 3.33×10^5 J/kg
Latent heat of boiling (water): 2.26×10^6 J/kg

Specific heat of alum.: 900 J/kg·°C
Specific heat of copper: 387 J/kg·°C
Specific heat of iron: 448 J/kg·°C
Thermal conduct. of alum.: 238 J/s·m·°C
Thermal conduct. of copper: 397 J/s·m·°C
Thermal conduct. of iron: 79.5 J/s·m·°C
v_{sound} = 343 m/s at 20°C

Conversion factors
1 inch = 2.54 cm
1 foot = 0.3048 m
1 mile = 1.609 km
1 mi/hr = 1 mph = 0.44704 m/s

1 lb = 4.448 N
1 m^3 = 1000 L
1 gallon = 3.785 L = 3785 cm^3
1 atm = 1.013×10^5 Pa = 14.7 psi

$T_F = \frac{9}{5}T_C + 32$
$T_K = T_C + 273.15$

Instructions:

- Write your CID at the top of the page, otherwise you may not get this exam booklet back.
- Circle your answers in this booklet if you wish to record them, but be sure to **mark your answers on the bubble sheet**. (You will not get the bubble sheet back.)
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use g = 9.8 m/s^2.

Some notes on the answer ranges:

If a set of answers is given like this

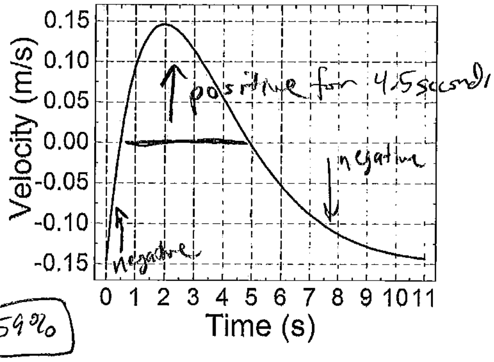
a. Less than 30 N
b. 30 – 40
c. 40 – 50
d. 50 – 60
e. More than 60 N

you can generally consider choice (a) to mean "20 – 30 N", and choice (e) to mean "60 – 70 N". I often write them like that so that if I've made a mistake when making up the answer ranges, and the answer is really less than 20 N, or larger than 70 N, then there is still an answer that is correct.

I randomize the answer choices, so the first and last choices should receive their statistical fair share of answers.

Any units and/or exponents given in the first and last answer choices also apply to the middle choices.

1. On the right is a velocity vs time graph of a car moving along a road for 11 seconds. Positive means "to the right". During the time shown, what fraction of the time did the car spend moving to the left? (Choose the closest answer.)



   a. 10 %
   b. 20
   c. 30
   d. 40
   e. 50
   f. 60 → = negative velocity
   g. 70
   h. 80
   i. 90 %

Velocity is positive for 4.5 s = 41%

negative for 6.5 s = $\boxed{59\%}$

2. An airplane is flying at a constant altitude. Which of the following is true about the lift force on the airplane relative to the force of gravity?
   → not accelerating up or down so $\Sigma F = 0$

   a. $F_{lift} < F_{gravity}$
   b. $F_{lift} = F_{gravity}$
   c. $F_{lift} > F_{gravity}$

So $F_{lift} = mg$

3. The sun's gravitational force on the Earth keeps the Earth in orbit. Which of the following must be equal and opposite to that force according to Newton's Third Law?
   a. the action of the Earth around its orbit → $\vec{F}_{12} = -\vec{F}_{21}$
   b. the Earth's force on the sun
   c. the moon's force on the Earth
   d. the net centrifugal force on the Earth
   e. the net centripetal force on the Earth

$\vec{F}_{sun-earth} = -\vec{F}_{earth-sun}$

4. A 10,000 kg airplane lands with a speed of 50 m/s and friction provides a stopping force of 60,000 N. What is the minimum distance needed to stop?
   a. Less than 150 m
   b. 150 – 160
   c. 160 – 170
   d. 170 – 180
   e. 180 – 190
   f. 190 – 200
   g. 200 – 210
   h. More than 210 m

$\Sigma F = ma$

$a = \frac{F_{stop}}{m}$

$a = \frac{-60000\,N}{10000\,kg}$

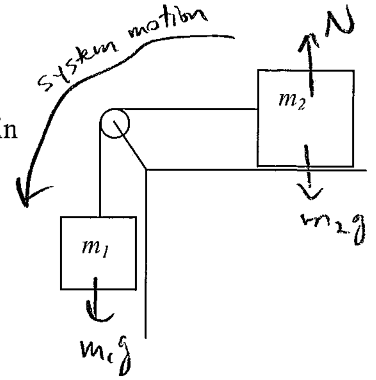
$a = -6\ m/s^2$

$v_f^2 = v_0^2 + 2a\Delta x$

$0 = (50\frac{m}{s})^2 + 2(-6\frac{m}{s^2})\Delta x$

$\Delta x = \frac{50^2}{(2)(6)}\ m = \boxed{208.3\,m}$

5. A hanging mass, m_1, is attached via a pulley to another mass, m_2, which is resting on a horizontal frictionless table as shown in the figure. Find the acceleration of the masses in terms of m_1, m_2, and g.



   a. g
   b. m_1g
   c. m_2g
   d. $\frac{m_1}{m_1+m_2}g$
   e. $\frac{m_2}{m_1+m_2}g$
   f. $\frac{m_1+m_2}{m_1}g$
   g. $\frac{m_1+m_2}{m_2}g$

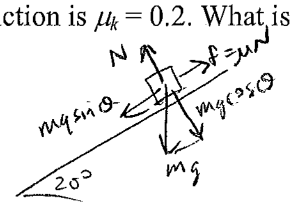
$\Sigma F_{system} = m_{system}a_{system}$

$m_1g = (m_1+m_2)a$

$\boxed{a = \frac{m_1}{m_1+m_2}g}$

6. A 3 kg block slides down a ramp with friction. The ramp is tilted up at an angle of 20°, measured relative to the horizontal. The coefficient of friction is $\mu_k = 0.2$. What is the block's acceleration?

   a. Less than 0.4 m/s^2
   b. 0.4 – 0.6
   c. 0.6 – 0.8
   d. 0.8 – 1.0
   e. 1.0 – 1.2
   f. 1.2 – 1.4
   g. 1.4 – 1.6
   h. More than 1.6 m/s^2



Tilted axes: $\Sigma F_x = ma$ $\qquad \Sigma F_y = 0$

$mg\sin\theta - \mu N = ma$ $\qquad N - mg\cos\theta = 0$

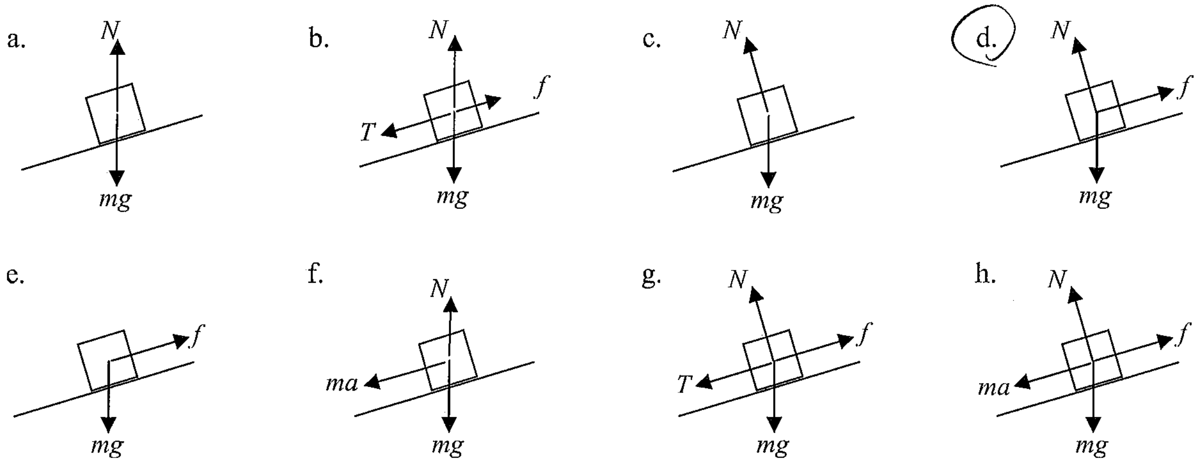
$N = mg\cos\theta$

$\cancel{m}g\sin\theta - \mu \cancel{m}g\cos\theta = \cancel{m}a$

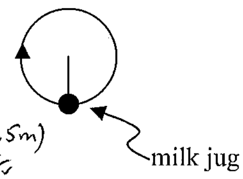
$a = (9.8\,\frac{m}{s^2})\sin 20° - (.2)(9.8\,\frac{m}{s^2})\cos 20°$

$\boxed{a = 1.51\,m/s^2}$

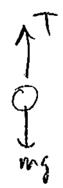
7. Same situation. Which of the following would be the proper free body diagram for the block?



8. Danielle swings a gallon of milk (3.91 kg) around in a clockwise vertical circle, see the figure. The milk jug moves around at a constant speed, at a rate of 1.2 revolutions per second, and her arm is 0.5 m long. What is the tension in her arm when the milk is at its lowest point? (Choose the closest answer.)



   a. 10 N
   b. 20
   c. 30
   d. 40
   e. 50
   f. 80
   g. 110
   h. 150
   i. 190 N



$v = 1.2\,\frac{rev}{s} \times \frac{2\pi(.5m)}{1\,rev}$

$v = 3.77\,m/s$

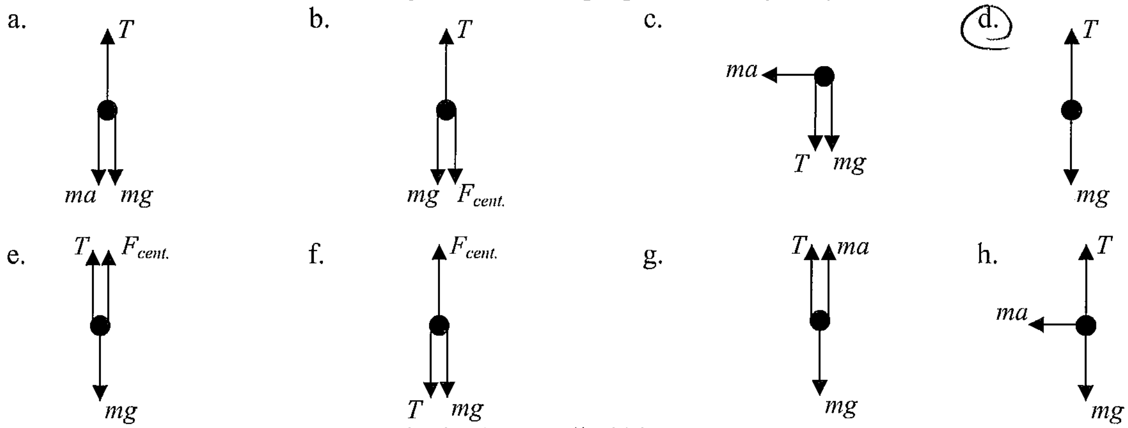
$\Sigma F = ma_c$

$T - mg = \frac{mv^2}{r}$

$T = mg + \frac{mv^2}{r}$

$T = (3.91\,kg)(9.8\,\frac{m}{s^2}) + \frac{(3.91\,kg)(3.77\,\frac{m}{s})^2}{.5\,m} = \boxed{149.46\,N}$

9. Same situation. Which of the following would be the proper free body diagram for the milk container?



10. A car having a mass of 1,000 kg and going 12 m/s drives up a hill that is 4 m high. Gravity slows it down but at the same time the car's engine does 50,000 J of work to help it get up the hill. What will the car's speed be at the top of the hill?
   a. Less than 3 m/s
   b. 3 – 5
   c. 5 – 7
   d. 7 – 9
   e. 9 – 11
   f. 11 – 13
   g. 13 – 15
   h. More than 15 m/s

$E_{bef} + W = E_{aft}$

$\frac{1}{2}mv_0^2 + W_{eng} = mgh + \frac{1}{2}mv_f^2$

$v_f = \sqrt{\frac{2}{m}\left(\frac{1}{2}mv_0^2 + W_{eng} - mgh\right)}$

$v_f = \sqrt{\frac{2}{1000}\left(\frac{1}{2}\cdot 1000\cdot 12^2 + 50000 - 1000\cdot 9.8\cdot 4\right)}$ m/s

$= \boxed{12.87 \text{ m/s}}$

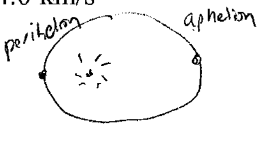
11. Pluto orbits the sun in an elliptical orbit, with the farthest distance ("aphelion") being 48.87 A.U. and the nearest distance ("perihelion") being 29.66 A.U. (1 A.U. = the radius of the Earth's orbit, see page 1.) Pluto's speed is 3.71 km/s when it's at aphelion. How fast will it be traveling at perihelion? (Hint: this is a conservation of energy problem. Consider its potential energy relative to the sun.)

$\to 7.311\cdot 10^{12}$ m

$\to 4.437\cdot 10^{12}$ m

$3710 \frac{m}{s}$

   a. Less than 4.0 km/s
   b. 4.0 – 4.5
   c. 4.5 – 5.0
   d. 5.0 – 5.5
   e. 5.5 – 6.0
   f. 6.0 – 6.5
   g. 6.5 – 7.0
   h. More than 7.0 km/s



$E_{bef} + \cancel{W} = E_{aft}$

$PE_i + KE_i = PE_f + KE_f$

$-\frac{GM\cancel{m}}{r_0} + \frac{1}{2}\cancel{m}v_0^2 = -\frac{GM\cancel{m}}{r_f} + \frac{1}{2}\cancel{m}v_f^2$

$v_f = \sqrt{2GM\left(\frac{1}{r_f} - \frac{1}{r_0}\right) + v_0^2}$

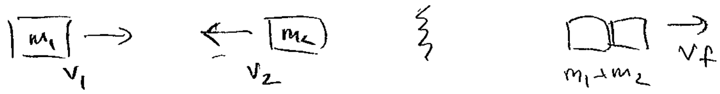
$= \sqrt{2(6.67\cdot 10^{-11})(1.991\cdot 10^{30})\left(\frac{1}{4.437\cdot 10^{12}} - \frac{1}{7.311\cdot 10^{12}}\right) + 3710^2}$ $\frac{m}{s}$

$= 6107$ m/s $= \boxed{6.107 \text{ km/s}}$

12. Which of the following is true about the units of watts?
   a. 1 W = 1 N
   b. 1 W = 1 N·m
   c. 1 W = 1 N/m
   d. 1 W = 1 N·s
   e. 1 W = 1 N/s
   f. 1 W = 1 J
   g. 1 W = 1 J·m
   h. 1 W = 1 J/m
   i. 1 W = 1 J·s
   j. 1 W = 1 J/s

$\text{Power} = \frac{\text{energy}}{\text{time}}$

13. A train car of mass 6000 kg moving at 3 m/s to the right attaches to another car (7000 kg) that is moving at 2 m/s to the left. How much kinetic energy gets lost in the collision? (Choose the closest answer.)
   a. 600 J
   b. 4000
   c. 14000
   d. 18000
   e. 40400
   f. 41000
   g. 50000
   h. 83000 J



Cons. mom.: $\Sigma P_{bef} = \Sigma P_{aft}$

$(6000 \text{ kg})(3 \text{ m/s}) - (7000 \text{ kg})(2 \text{ m/s}) = (13000 \text{ kg})\, v_f$

$v_f = .3077$ m/s

$KE_{bef} = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$= \frac{1}{2}(6000 \text{ kg})(3\frac{m}{s})^2 + \frac{1}{2}(7000 \text{ kg})(2\frac{m}{s})^2$

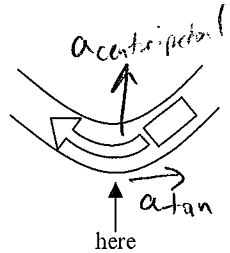
$= 41000$ J

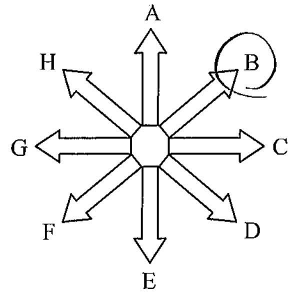
$KE_{aft} = \frac{1}{2}m_{tot}v_f^2$

$= \frac{1}{2}(13000 \text{ kg})(.3077\frac{m}{s})^2$

$= 615$ J

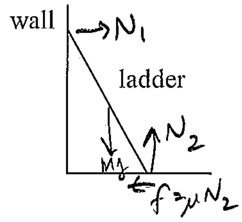
$E_{lost} = 41000 \text{ J} - 615 \text{ J} = \boxed{40385 \text{ J}}$



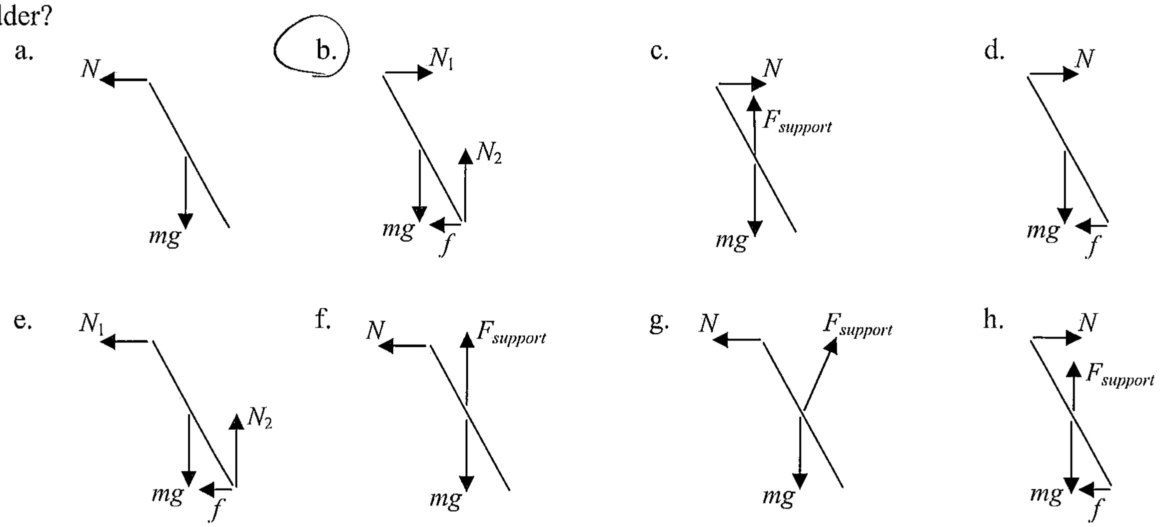


14. A car goes around a corner as shown above, <u>while slowing down</u>. At the point labeled “here”, in what general direction is the car’s acceleration, as indicated by the arrows on the right?

a. A
b. B
c. C
d. D
e. E
f. F
g. G
h. H
i. None; the car is not accelerating.



15. A ladder rests against a wall as shown in the figure. There is no friction on the wall, but there is friction on the ground. Which of the following would be the proper free body diagram for the ladder?



16. Same situation. What is true about the torque supplied by the wall compared to the torque supplied by gravity, using the point where the ladder touches the ground as the “pivot point” (considering magnitudes only)?

a. $\tau_{wall} < \tau_{gravity}$
b. $\tau_{wall} = \tau_{gravity}$
c. $\tau_{wall} > \tau_{gravity}$
d. No specific relationship between the two torques can be established without more information.

$\Sigma\tau_p = 0 \rightarrow \tau_{mg} - \tau_{N_1} = 0$

$\tau_{mg} = \tau_{N_1}$

17. Andrew spins a top. In 0.5 seconds he is able to get the top spinning at 3 revolutions per second by exerting a constant tangential force of 0.5 N at a radius of 0.7 cm. What is the top’s moment of inertia?

$\rightarrow 6\pi$ rad/s

a. Less than 8.4×10^{-5} kg·m^2
b. 8.4 – 8.6
c. 8.6 – 8.8
d. 8.8 – 9.0
e. 9.0 – 9.2
f. 9.2 – 9.4
g. 9.4 – 9.6
h. More than 9.6×10^{-5} kg·m^2

F_{Andrew}

kinematics to find α: $\omega_f = \omega_0 + \alpha t \rightarrow \alpha = \frac{\omega_f - \omega_0}{t}$

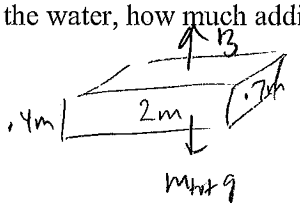
$\alpha = \frac{6\pi \text{ rad/s} - 0}{.5 s} = 12\pi \frac{rad}{s^2}$

$\Sigma\tau = I\alpha$

$\rightarrow I = \frac{\tau_{Andrew}}{\alpha} = \frac{(.5N)(.007m)}{12\pi \text{ rad/s}^2}$

$\boxed{I = 9.284 \cdot 10^{-5} \text{ kg m}^2}$

18. Jane makes a 40 kg canoe out of a rectangular form: 2.0 m long by 0.7 m wide by 0.4 m deep. Assuming it doesn't tilt as it rests in the water, how much additional mass can she put in the canoe before it sinks? (Choose the closest answer.)



a. 40 kg
b. 390
c. 520
d. 560
e. 930
f. 2500
g. 5100
h. 5500 kg

$\Sigma F = 0 \rightarrow m_{tot} g = B$

$m_{tot} g = \rho_{fl} V_{obj} g$

$m_{tot} = (1000\ kg/m^3)(2m \times .7m \times .4m)$

$m_{tot} = 560\ kg$

So $\boxed{m_{extra} = 520\ kg}$

19. Will smoke get "sucked" up a chimney better on a windy day or on a calm day?
a. windy day
b. calm day
c. same

→ causes low pressure at top of chimney due to Bernoulli effect

20. Clara takes a 100 g piece of ice out of her freezer (at -10 °C) and adds it to 300 g of water in an insulated cup (at 30 °C). The insulated cup itself has negligible mass. How cold does the ice get the water?
a. Less than 0.5 °C
b. 0.5 – 1.0
c. 1.0 – 1.5
d. 1.5 – 2.0
e. 2.0 – 2.5
f. 2.5 – 3.0
g. 3.0 – 3.5
h. More than 3.5 °C

$Q_{gained\ by\ ice} = Q_{lost\ by\ water}$

$m c_i \Delta T + mL + m c_w \Delta T = m c_w \Delta T$

$(.1)(2090)(10) + (.1)(333000) + (.1)(4186)(T_f - 0) = (.3)(4186)(30 - T_f)$

$35390 + 418.6\ T_f = 37674 - 1255.8\ T_f$

$1674.4\ T_f = 2284$

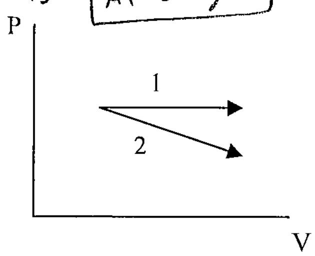
$\boxed{T_f = 1.36\ °C}$

21. Which would be able to more efficiently conduct thermal energy, a 1 cm long rod made of aluminum or a 2 cm long rod made of copper? (The two rods have the same diameter.)
a. the aluminum rod
b. the copper rod
c. same

$\frac{Q}{t} = k \frac{A\, \Delta T}{l}$ if A and ΔT are the same, heat transfer is set by $\frac{k}{l}$

Al: $\frac{k}{l} = \frac{238}{1}$ [units]   Cu: $\frac{k}{l} = \frac{387}{2} = 193.5$ [units] $\boxed{\text{Al is larger}}$

22. Processes 1 and 2 are indicated on the PV diagram, see the figure. They both begin at the same pressure and same volume. They also end at the same volume. In which process will the gas do more work?



a. process 1
b. process 2
c. same

$W = P_{ave} \Delta V$
↑ larger for 1   ↑ same

or: think of area under the path
→ also larger for 1

23. Air can be thought of as a diatomic gas having a molar mass of 28.97 g/mol. That is basically a weighted average of the molar masses of all of molecules found in air (primarily N_2 and O_2). Use that molar mass to find the density of air at 320 K. The air is at 1 atm. Hint: in the ideal gas law, the "n" can be replaced by "mass/molar mass", and you can then solve for mass/volume, which is density. Choose the closest answer.
a. 0.5 kg/m^3
b. 0.6
c. 0.7
d. 0.8
e. 0.9
f. 1.0
g. 1.1
h. 1.2 kg/m^3

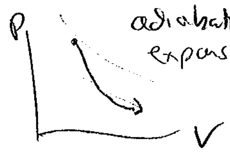
$PV = nRT \rightarrow PV = \left(\frac{m}{MM}\right) RT$

$\frac{m}{V} = \frac{P \cdot MM}{RT} = \frac{(1.01 \cdot 10^5\ Pa)(.02897\ kg/mol)}{(8.31\ \frac{J}{mol\,K})(320\ K)}$

$= \boxed{1.10\ kg/m^3}$

24. A monatomic ideal gas (3 moles) occupying an initial volume of 0.80 m^3 and having a temperature of 350 K are rapidly expanded to 1.20 m^3. The process occurs so quickly that no heat has time to enter the gas. This cools the gas to 267.1 K. How much work was done by the gas during this process? (Incidentally, to calculate the final temperature, I used the equation $TV^{\gamma-1}$ = constant, that you derived in a homework problem.)

a. Less than 2800 J
b. 2800 – 3000
c. 3000 – 3200
d. 3200 – 3400
e. 3400 – 3600
f. 3600 – 3800
g. 3800 – 4000
h. 4000 – 4200



adiabatic expansion

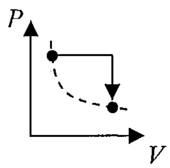
$\Delta U = \cancel{Q} + W_{on}$

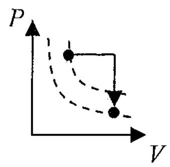
$W_{on} = \Delta U = \frac{3}{2} nR\Delta T$ for monatomic

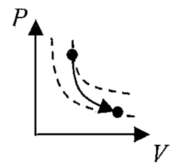
$W_{by} = -W_{on} = \frac{3}{2}(3\,\text{moles})(8.31\,\frac{\text{J}}{\text{mol K}})(350\,\text{K} - 267.1\,\text{K})$

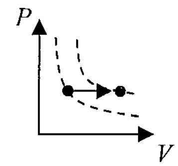
$= \boxed{3100\,\text{J}}$

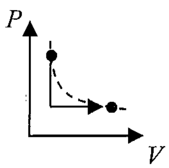
25. Same situation. Which of the following would be the proper P-V diagram for the gas? (The dashed lines indicate isothermal contours.)

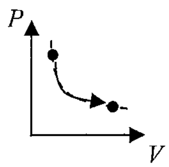
a.


b.


c.


d.


e.


f.


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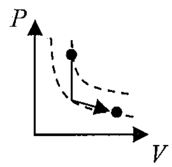

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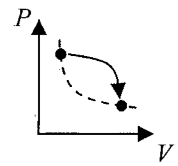
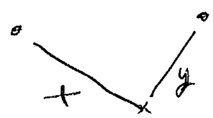


26. A student sits a distance of x from one speaker and a distance of y from another speaker. Both speakers are playing the same tone, in phase. (This is like the demo we did in class.) Under what conditions will the student hear a maximum in the sound level? (n = an integer)

a. $x + y = n\lambda$
b. $x - y = n\lambda$
c. $x + y = (n + \frac{1}{2})\lambda$
d. $x - y = (n + \frac{1}{2})\lambda$



For max, $\Delta PL = n\lambda$

$\boxed{x - y = n\lambda}$

27. In the "ladies belt demo" where the belt was like a "closed-closed" string, suppose the fundamental frequency was seen at 400 Hz. What frequency will have five antinodes?

a. 800 Hz
b. 1000
c. 1200
d. 1600
e. 2000
f. 2400 Hz

→ fifth harmonic $f_5 = 5f_1$

$f_5 = 5(400\,\text{Hz})$

$= \boxed{2000\,\text{Hz}}$

28. A certain pendulum consists of a 1 kg weight at the end of a light string. What will happen to its period if the weight is doubled to 2 kg? Express your answer in terms of a ratio: new period / old period = _______

a. 1/4
b. 1/2
c. 1/√2
d. 1 → doesn't depend on m, so stays the same
e. √2
f. 2
g. 4

$T = 2\pi\sqrt{\frac{L}{g}}$

29. On the surface of a pond, a particular set of waves travels at a speed of 0.6 m/s. Kim observes the waves moving past her and counts 14 waves go past in 5 seconds. What is the period of the wave oscillations?
    a. Less than 0.40 s
    b. 0.40 – 0.45
    c. 0.45 – 0.50
    d. 0.50 – 0.55
    e. 0.55 – 0.60
    f. 0.60 – 0.65
    g. 0.65 – 0.70
    h. More than 0.7 s

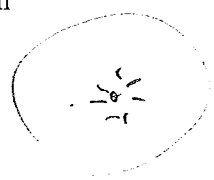
$\text{period } T = \frac{\text{seconds}}{\text{wave}} = \frac{5\ s}{14\ \text{wave}} = \boxed{.357\ s}$

$\left(\text{freq} = \frac{\text{waves}}{\text{sec.}} = \frac{14\ \text{waves}}{5\ s} = 2.8\ Hz \right)$

30. Same situation. What is the wavelength of the wave oscillations?
    a. Less than 0.05 m
    b. 0.05 – 0.10
    c. 0.10 – 0.15
    d. 0.15 – 0.20
    e. 0.20 – 0.25
    f. 0.25 – 0.30
    g. 0.30 – 0.35
    h. More than 0.35 m

$v = \lambda f \rightarrow \lambda = \frac{v}{f} = \frac{.6\ m/s}{2.8\ Hz} = \boxed{.214\ m}$

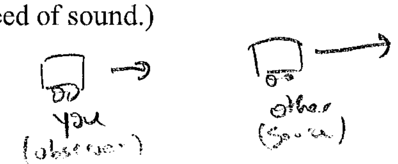
31. A stereo speaker emits sound waves with a power output of 100 W. What is the intensity 10 m from the source? (Assume that the sound is emitted uniformly in all directions from the speaker.)
    a. Less than 0.01 W/m^2
    b. 0.01 – 0.02
    c. 0.02 – 0.03
    d. 0.03 – 0.04
    e. 0.04 – 0.05
    f. 0.05 – 0.06
    g. 0.06 – 0.07
    h. More than 0.07 W/m^2



$I = \frac{P}{A} = \frac{P}{4\pi r^2}$

$I = \frac{100\ W}{4\pi (10m)^2} = \boxed{.0796\ \frac{W}{m^2}}$

32. A car goes past you at 20 m/s. It blows its horn, having a frequency of 1 kHz. You are driving at 12 m/s in the same direction as the other car. What frequency do you hear as the car drives away from you? Choose the closest answer. (Use 343 m/s as the speed of sound.)
    a. 912 Hz
    b. 945
    c. 965
    d. 978
    e. 1025
    f. 1035
    g. 1062
    h. 1099 Hz



$f' = f_0 \frac{v \pm v_o}{v \mp v_s}$

+ because obs. is moving towards source

$= (1000\ Hz)\left(\frac{343\ m/s + 12\ m/s}{343\ m/s + 20\ m/s}\right)$

+ because source is moving away from observer

$= \boxed{978\ Hz}$

33. Which of the following statements explain why musical tones played by different instruments sound different to your ear even when they play the same musical pitch?
    I. The various waves are not all sinusoidal True – they have different shapes
    II. The various waves do not contain the same harmonics True – different shapes mean different harmonics
    III. The various waves have different fundamental frequencies False – same pitch so same fundamental freq.

    a. I only
    b. II only
    c. III only
    d. I and II
    e. II and III
    f. I and III
    g. I, II, and III