Solutions

Fall 2013 RED barcode here
Physics 105, sections 1, 2 and 3
Final Exam
Colton Please write your CID_____

No time limit. No notes. No books. Student calculators only. All problems equal weight, 100 points total.

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 = 1.496×10^{11} m
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
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
Specific heat of alum.: 900 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
Thermal conduct. of alum.: 238 J/s·m·°C
$v_{sound} = 343$ m/s at 20°C

Conversion factors

1 kg = 2.205 lb
1 inch = 2.54 cm
1 mile = 1.609 km
1 m^3 = 1000 L

1 hp = 745.7 W
1 gallon = 3.785 L
1 atm = 1.013×10^{5} Pa = 14.7 psi

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

Other equations

$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
Surface area of sphere = $4\pi r^2$
Volume of sphere = $(4/3)\pi r^3$
$v_{ave} = \dfrac{v_i + v_f}{2}$
$v = v_0 + at$
$x = x_0 + v_0 t + \frac{1}{2}at^2$
$v_f^2 = v_0^2 + 2a\Delta x$
$w = mg$, $PE_g = mgy$
$F = -kx$, $PE_s = \frac{1}{2} kx^2$
$f = \mu_k N$ (or $f \le \mu_s N$)
$P = F_{//}v = Fv\cos\theta$
$\vec{F}\Delta t = \Delta\vec{p}$
Elastic: $(v_1 - v_2)_{bef} = (v_2 - v_1)_{after}$
arc length: $s = r\theta$
$v = r\omega$
$a_{tan} = r\alpha$
$a_c = v^2/r$
$F_g = \dfrac{GMm}{r^2}$, $PE_g = -\dfrac{GMm}{r}$
$I_{pt\ mass} = mR^2$
$I_{sphere} = (2/5)\ mR^2$
$I_{hoop} = mR^2$

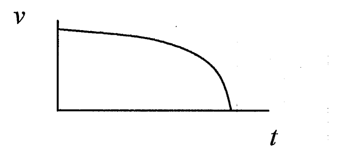
$I_{disk} = (1/2)\ mR^2$
$I_{rod}\ (center) = (1/12)\ mL^2$
$I_{rod}\ (end) = (1/3)\ mL^2$
$L = r_\perp p = rp_\perp = rp\sin\theta$
$P = P_0 + \rho gh$
$VFR = A_1 v_1 = A_2 v_2$
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$
$\Delta L = \alpha L_0 \Delta T$
$\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$
transl. $KE_{ave} = \frac{1}{2} m v_{ave}^2 = \frac{3}{2} k_B T$
$Q = mc\Delta T$; $Q = mL$
$\dfrac{\Delta Q}{\Delta t} = kA\dfrac{T_2 - T_1}{L}$
$P = e\sigma A T^4$
$|W_{on\ gas}|$ = area under P-V curve
$= |P\Delta V|$ (constant pressure)
$= |nRT\ln(V_2/V_1)|$ (isothermal)
$= |\Delta U|$ (adiabatic)
$U = \frac{3}{2}Nk_B T = \frac{3}{2}nRT$ (monatomic)

$U = \frac{5}{2}Nk_B T = \frac{5}{2}nRT$ (diatomic, around 300K)
$Q_h = |W_{net}| + Q_c$
$e = \dfrac{|W_{net}|}{Q_{added}} = 1 - \dfrac{Q_c}{Q_h}$
$e_{max} = 1 - \dfrac{T_c}{T_h}$
$\omega = \sqrt{\dfrac{k}{m}}$, $T = 2\pi\sqrt{\dfrac{m}{k}}$
$\omega = \sqrt{\dfrac{g}{L}}$, $T = 2\pi\sqrt{\dfrac{L}{g}}$
$v = \sqrt{\dfrac{T}{\mu}}$, $\mu = m/L$
$\beta = 10\log\left(\dfrac{I}{I_0}\right)$ $I_0 = 10^{-12}$ W/m^2
$f' = f\dfrac{v \pm v_0}{v \pm v_S}$
$\sin\theta = v/v_s$
o-o/c-c: $f_n = nf_1$; $n = 1,2,3,\ldots$
o-c: $f_n = nf_1$; $n = 1,3,5,\ldots$

Instructions:
- Write your CID at the top of the first page, otherwise you will not get this exam booklet back.
- Circle your answers in this booklet if you wish, but be sure to **record your answers on the bubble sheet.**
- Unless otherwise specified, **ignore air resistance, viscosity, and fluid compressibility** in all problems.
- Use $g = 9.8\ m/s^2$.

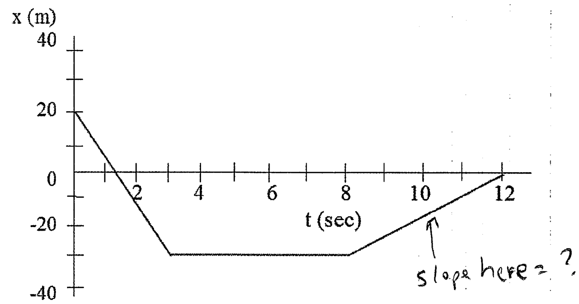
1. Consider the velocity vs time graph of a car moving along a road. The car's acceleration is:
   a. increasing in magnitude
   b. decreasing in magnitude
   c. constant

The slope is getting more and more negative



2. Consider the position vs. time graph of a car moving along a road. At t = 10 seconds, which value is closest to the car's instantaneous velocity?
   a. 5 m/s
   b. 5.5
   c. 6
   d. 6.5
   e. 7
   f. 7.5
   g. 8
   h. 8.5 m/s

V = slope of x vs t $= \frac{rise}{run} = \frac{30}{4}\frac{m}{s} = \boxed{7.5\ \frac{m}{s}}$



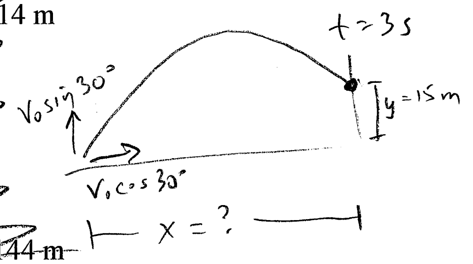
3. A car traveling at 34 m/s (76 mph) can slow down with a maximum acceleration magnitude of 8 m/s^2 as it comes to rest. What is the distance the car needs to stop?
   a. Less than 61 m
   b. 61 – 63
   c. 63 – 65
   d. 65 – 67
   e. 67 – 69
   f. 69 – 71
   g. 71 – 73
   h. More than 73 m

$V_f^{\,2} = V_0^{\,2} + 2a\,\Delta x$

$0 = (34)^2 + 2(-8)\,\Delta x$

$\Delta x = \frac{34^2}{16} = \boxed{72.25\ m}$

4. A cannonball is fired at a castle wall at a 30° angle from the horizontal, with an unknown initial speed. At exactly 3 seconds later, the ball hits the wall during the "on the way down" part of its trajectory. The ball leaves a hole in the wall 15 m off the ground. How far was the cannon from the base of the wall?
   a. Less than 114 m
   b. ~~114 – 119~~
   c. 119 – 124
   d. ~~124 – 129~~
   e. ~~129 – 134~~
   f. ~~134 – 139~~
   g. ~~139 – 144~~
   h. ~~More than 144 m~~



$t = 3s$

$x = \cancel{x_0} + V_{0x} t$

$x = (V_0 \cos 30°)(3s)$

$y = \cancel{y_0} + V_{0y} t - \frac{1}{2} g t^2$

$15 = (V_0 \sin 30°)(3s) - \frac{1}{2}(9.8\frac{m}{s^2})(3s)^2$

$V_0 = 39.4\ \frac{m}{s}$

plug into there

$x = (39.4\frac{m}{s})(\cos 30°)(3s)$

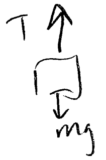
$= \boxed{102.4\ m}$

Choice F: 100–105 m

5. Consider a basketball player shooting the ball. After the ball leaves his hand, the force on the ball is:
   a. upwards and constant
   b. upwards and decreasing
   c. downwards and constant
   d. downwards and decreasing
   e. tangent to the path of the ball and constant
   f. tangent to the path of the ball and decreasing

only force is gravity, $F_g = mg$

6. A 5 kg bucket is accelerated upwards by rope at a rate of 3 m/s^2. What is the tension in the rope?
   a. Less than 50 N
   b. 50 – 53
   c. 53 – 56
   d. 56 – 59
   e. 59 – 62
   f. 62 – 65
   g. 65 – 68
   h. More than 68 N



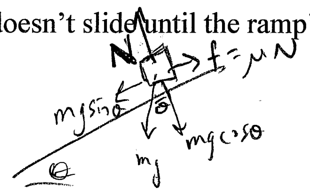
$\Sigma F = ma$

$T - mg = ma$

$T = ma + mg$

$= (5)(3) + (5)(9.8) = \boxed{64\text{ N}}$

7. A 2.3 kg block on a ramp doesn't slide until the ramp's angle is 31° from horizontal. What is μ_s?
   a. Less than 0.50
   b. 0.50 – 0.54
   c. 0.54 – 0.58
   d. 0.58 – 0.62
   e. 0.62 – 0.66
   f. 0.66 – 0.70
   g. 0.70 – 0.74
   h. More than 0.74



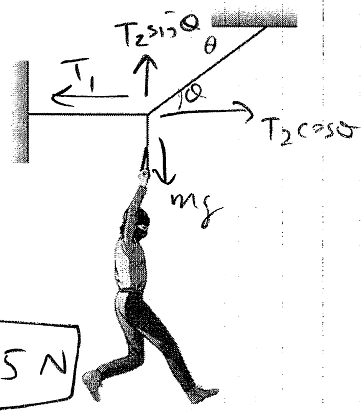
$\Sigma F_x = 0 \rightarrow \mu N = mg\sin\theta$

$\Sigma F_y = 0 \rightarrow N = mg\cos\theta$

divide: $\mu = \tan\theta$

$\mu = \tan(31°) = \boxed{.601}$

8. A burglar hangs motionless as shown, supported by a cable that goes horizontally to the left and another cable that goes up and to the right. The burglar's mass is 70 kg. The angle θ is 40°. What is the tension in the left cable?
   a. Less than 800 N
   b. 800 – 810
   c. 810 – 820
   d. 820 – 830
   e. 830 – 840
   f. 840 – 850
   g. 850 – 860
   h. More than 860 N



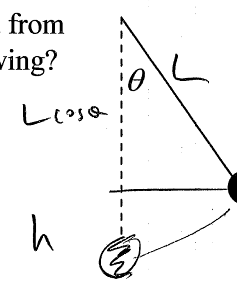
$\Sigma F_x = 0 \rightarrow T_1 = T_2\cos\theta$

$\Sigma F_y = 0 \rightarrow mg = T_2\sin\theta$

divide bottom by top: $\frac{mg}{T_1} = \tan\theta$

$T_1 = \frac{mg}{\tan\theta} = \frac{(70)(9.8)}{\tan 40°} = \boxed{817.5\text{ N}}$

9. A pendulum consisting of a string (length L) with a metal ball (mass m) on the end is released from an angle θ, measured from the vertical. How fast is the ball going at the lowest point of the swing?
   a. $\sqrt{2gL}$
   b. $\sqrt{2gL(1-\cos\theta)}$
   c. $\sqrt{2gL/\cos\theta}$
   d. $\sqrt{2gL\sin\theta}$
   e. $\sqrt{gL/\sin\theta}$
   f. $\sqrt{2mgL/\tan\theta}$
   g. $\sqrt{mg(1-\cos\theta)}$
   h. $\sqrt{mgL(1-\sin\theta)}$
   i. $\sqrt{mL(g-\cos\theta)}$



$PE = KE$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v = \sqrt{2gh}$

$= \sqrt{2g(L - L\cos\theta)}$

$\boxed{v = \sqrt{2gL(1-\cos\theta)}}$

10. Suppose a friend pushes a heavy cart (m = 20 kg) at you with a speed of 5 m/s. The cart has frictionless wheels. You try to stop the cart by applying a force of 70 N over a distance of 0.4 m. That is not enough to stop it. What is the final velocity of the cart? (It doesn't change its direction.)
   a. Less than 4.3 m/s
   b. 4.3 – 4.4
   c. 4.4 – 4.5
   d. 4.5 – 4.6
   e. 4.6 – 4.7
   f. 4.7 – 4.8
   g. 4.8 – 4.9
   h. More than 4.9 m/s

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

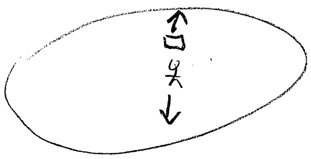
$\frac{1}{2}mv_0^2 - F\cdot d = \frac{1}{2}mv_f^2$

$v_f = \sqrt{v_0^2 - \frac{2}{m}F\cdot d} = \sqrt{5^2 - \frac{2}{20}\cdot 70\cdot .4}$

$= \boxed{4.712\text{ m/s}}$

11. A 80 kg woman stands in the middle of a frozen pond of radius 20 m. She is unable to get to the other side because of lack of friction between her shoes and the ice. To overcome this difficulty, she throws her 2 kg physics textbook horizontally towards the north shore, at a speed of 5 m/s. How long does it take her to reach the south shore? Choose the closest number. (The 80 kg number is her mass without the book.)

a. 135 s
b. 140
c. 145
d. 150
e. 155
f. 160
g. 165
h. 170 s



$\Sigma P_{bef} = \Sigma P_{aft} \rightarrow m_{book} v_{book} = m_{woman} v_{woman}$

$v_w = v_b \cdot \frac{m_b}{m_w} = .125\ m/s$

$x = vt \rightarrow t = x/v$

$= \frac{20m}{.125\ m/s} = \boxed{160s}$

12. A 6 kg block moving east at 3 m/s on a horizontal frictionless surface collides with (and bounces off of) a 9 kg block moving north at 4 m/s. Energy is not conserved. After the collision, you measure the 6 kg block moving north at 2 m/s. How fast will the second block be going after the collision?

a. Less than 3.3 m/s
b. 3.3 – 3.4
c. 3.4 – 3.5
d. 3.5 – 3.6
e. 3.6 – 3.7
f. 3.7 – 3.8
g. 3.8 – 3.9
h. More than 3.9 m/s

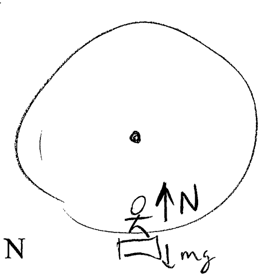
$\Sigma P_x = \Sigma P_x \rightarrow (6)(3) = (9)v_x \rightarrow v_x = 2\ m/s$

$\Sigma P_y = \Sigma P_y \rightarrow (9)(4) = (6)(2) + (9)(v_y) \rightarrow v_y = 2.667\ m/s$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{2^2 + 2.667^2} = \boxed{3.33\ m/s}$

13. Chuck (mass 90 kg) is on a Ferris Wheel (radius 12 m). He is going at a constant speed of 4.2 m/s around the circle without stopping. When he rounds the bottom of the circle, what is the normal force on him from the chair?

a. Less than 950 N
b. 950 – 960
c. 960 – 970
d. 970 – 980
e. 980 – 990
f. 990 – 1000
g. 1000 – 1010
h. More than 1010 N



$\Sigma F = ma_c = \frac{mv^2}{r}$

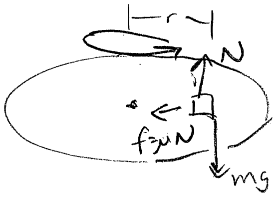
$N - mg = \frac{mv^2}{r}$

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

$= (90)(9.8) + \frac{(90)(4.2)^2}{12} = \boxed{1014.3N}$

14. A small block (mass m) rests on a rotating turntable a distance r from the center. The coefficient of static friction between the two objects is μ_s. How fast can the turntable spin before the block starts to slip?

a. $(1/\mu)\sqrt{rg}$
b. $\mu\sqrt{rg}$
c. $\sqrt{\mu rg}$
d. $\sqrt{rg/\mu}$
e. $(1/(\mu m))\sqrt{rg}$
f. $\mu m\sqrt{rg}$
g. $\sqrt{\mu mrg}$
h. $\sqrt{rg/(\mu m)}$



$\Sigma F_y = 0 \rightarrow N = mg$

$\Sigma F_x = ma_c = \frac{mv^2}{r}$

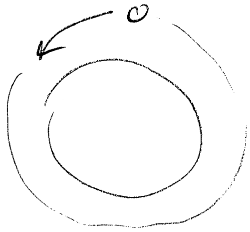
$\mu \cdot N = \frac{mv^2}{r}$

$\mu(\cancel{m}g) = \frac{\cancel{m}v^2}{r}$

$\boxed{v = \sqrt{\mu \cdot rg}}$

15. A 200 kg satellite is in a circular orbit 9000 km (9×10^6 m) from the center of the Earth. What is its speed?

a. Less than 6.5 km/s
b. 6.5 – 6.6
c. 6.6 – 6.7
d. 6.7 – 6.8
e. 6.8 – 6.9
f. 6.9 – 7.0
g. 7.0 – 7.1
h. More than 7.1 km/s



$$\Sigma F = ma_c = mv^2/r$$

$$\frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{(6.67\cdot10^{-11})(5.98\cdot10^{24})}{9\cdot10^6}} = \boxed{6657\ \tfrac{m}{s}}$$

16. Object A is initially rotating at a certain angular speed. A torque is applied to stop it, and it stops after N_A revolutions (not necessarily an integer). Object B undergoes the same situation, with everything being exactly the same except it has twice the moment of inertia of object A. How does N_B (the number of revolutions for the second situation) compare to N_A? $N_B =$ _____ N_A

a. 1/4 ×
b. 1/2 ×
c. $\frac{1}{\sqrt{2}}\times$
d. same as
e. $\sqrt{2}\times$
f. 2 ×
g. 4 ×

$\Sigma \tau = I\alpha \Rightarrow$ if $\tau =$ same and $I = \times 2$, then $\alpha = \times \frac{1}{2}$

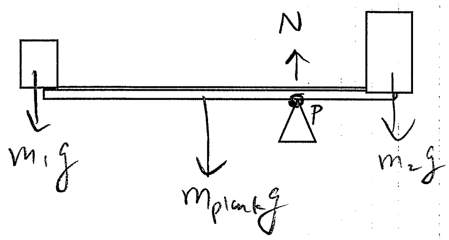
$\cancel{\omega_f^2} = \omega_0^2 + 2\alpha\Delta\theta \Rightarrow$ if $\omega_0 =$ same and $\alpha = \times\frac{1}{2}$

then $\Delta\theta = \times 2$

$\Delta\theta =$ proportional to # revs, so

revs $= \times 2$

17. Two boxes are balanced on a plank as shown. The plank is 4 meters long, and has a mass of 20 kg. The left and right boxes are balanced 3 m and 1 m away from the fulcrum (triangle), respectively. If the box on the right is 40 kg, what must be the mass of the box on the left? (Hint: the plank's own mass is significant, don't neglect it.)



a. Less than 4 kg
b. 4 – 5
c. 5 – 6
d. 6 – 7
e. 7 – 8
f. 8 – 9
g. 9 – 10
h. More than 10 kg

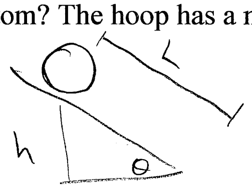
$$\Sigma \tau_p = 0$$

$$(m_1\cancel{g})(3m) + (m_{plank}\cancel{g})(1m) = (m_2\cancel{g})(1m)$$

$$m_1 = \frac{m_2 - m_{plank}}{3} = \frac{40-20}{3}\ kg = \boxed{6.67\ kg}$$

18. A hoop rolls without slipping down a ramp that is 2.2 m long, with an angle of 20° from horizontal. How fast will the hoop be going at the bottom? The hoop has a mass of 13 kg and a radius of 30 cm.

a. Less than 2.2 m/s
b. 2.2 – 2.4
c. 2.4 – 2.6
d. 2.6 – 2.8
e. 2.8 – 3.0
f. 3.0 – 3.2
g. 3.2 – 3.4
h. More than 3.4 m/s



$h = L\sin\theta$

$$PE = KE$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$I = mr^2$ for hoop, $\omega^2 = v^2/r^2$

$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2 + \frac{1}{2}\cancel{m}v^2$$

$$gh = v^2$$

$$v = \sqrt{gh} = \sqrt{(9.8)(2.2\sin 20^\circ)} = \boxed{2.716\ m/s}$$

19. A student sits on a rotating stool holding two weights at arm's length. He rotates with a certain angular velocity, ω_1. By bringing in his arms, he then reduces the moment of inertia of himself & weights to one half the original value. How does his new angular velocity (ω_2) compare to the original one? $\omega_2 =$ _____ ω_1

a. $1/4 \times$
b. $1/2 \times$
c. $1/\sqrt{2} \times$
d. same as
e. $\sqrt{2} \times$
f. $2 \times$
g. $4 \times$

$L_{bef} = L_{aft}$

$I_1 w_1 = I_2 w_2$

if $I = \times \frac{1}{2}$, then $\underline{w = \times 2}$

20. T/F: Same situation. The student & weights have more kinetic energy at the end than at the beginning.

a. True
b. False

It requires work to bring in the weights, so KE has increased

21. Water flows from a little pipe into a big pipe while also decreasing in height. That is, the water is flowing downhill. The volume flow rate (m^3/s) in the little pipe will be ______ in the big pipe.

a. greater than
b. the same as
c. less than
d. cannot be determined from the information given

VFR = constant

22. Same situation. The pressure in the little pipe will be ______ in the big pipe.

a. greater than
b. the same as
c. less than
d. cannot be determined from the information given

$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

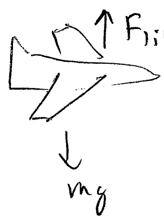
$P_1 = P_2 + \rho g(h_2 - h_1) + \frac{1}{2}\rho(v_2^2 - v_1^2)$

negative negative

$P_1 = P_2 -$ stuff

23. A certain model airplane (m = 4 kg) is being tested in a wind tunnel; it's hovering in mid air. It has two wings (as usual), and each wing has a horizontal area of 0.10 m^2. The wings are shaped so that the air is traveling faster above the wing than below in order to generate lift (as usual). Suppose the air above each wing is moving at 50 m/s. If all of the lift is explained by the Bernoulli effect, how fast must the air below the wing be moving? Use 1.29 kg/m^3 as the density of air, and neglect the $\rho g h$ terms in the equation.

a. Less than 45.8 m/s
b. 45.8 – 46.0
c. 46.0 – 46.2
d. 46.2 – 46.4
e. 46.4 – 46.6
f. 46.6 – 46.8
g. 46.8 – 47.0
h. More than 47.0 m/s



$\Sigma F = 0$

$mg = F_{lift} = P_{bottom}\,\text{area} - P_{top}\cdot\text{area}$

1 = top
2 = bottom

$mg = (P_2 - P_1)\cdot\text{area}$

from Bernoulli this $= \frac{1}{2}\rho(v_1^2 - v_2^2)$

$mg = \frac{1}{2}\rho(v_1^2 - v_2^2)\cdot\text{area}$

$v_2 = \sqrt{v_1^2 - \frac{2mg}{\rho}\frac{1}{\text{area}}} = \sqrt{50^2 - \frac{2(4)(9.8)}{1.29}\cdot\frac{1}{2(.10)}}$

$= \boxed{46.86 \text{ m/s}}$

24. How much energy does the Earth lose due to radiation, each second? The average temperature of the Earth is 15°C, and Wikipedia says its average emissivity is 0.612.

288 K

Side note: the Earth also gains about that same amount of energy from the sunlight it absorbs, so that (neglecting global warming) there is no net energy gain or loss.

a. Less than 1.2×10^{10} J
b. 1.2 – 1.4
c. 1.4 – 1.6
d. 1.6 – 1.8
e. 1.8 – 2.0
f. 2.0 – 2.2
g. 2.2 – 2.4
h. More than 2.4×10^{10} J

$P = \varepsilon\sigma A\cdot T^4$

$= (.612)(5.67\cdot 10^{-8})(4\pi(6.38\cdot 10^6)^2)(288)^4$

$= \boxed{1.221\cdot 10^{17}\ \text{J/sec}}$

Sorry about the poor answer choices!

25. An old-fashioned 1 liter glass milk jug is "empty" (still has air inside at 1 atm), at 300 K. You seal it, then put it into a fire at 700 K. The jug does not burst. What is the final pressure in the jug?

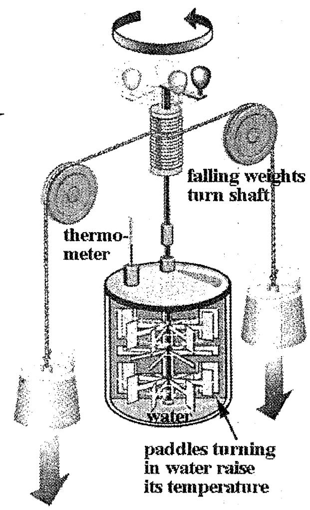
a. Less than 1.8 atm
b. 1.8 – 2.0
c. 2.0 – 2.2
d. 2.2 – 2.4
e. 2.4 – 2.6
f. 2.6 – 2.8
g. 2.8 – 3.0
h. More than 3.0 atm

$P_1 V_1 = \cancel{nR}T_1$
$P_2 V_2 = \cancel{nR}T_2$

$P_2 = P_1 \cdot \frac{T_2}{T_1} = (1\,atm)\left(\frac{700\,k}{300\,k}\right) = \boxed{2.333\ atm}$

26. As mentioned in class, Joule used falling weights to churn water with paddles, thus turning gravitational potential energy into random kinetic energy that could be measured as an increase in temperature. See the figure. Suppose the two weights are ~~5~~ 2.5 kg each, start 1 m off the ground, and there is 3 kg of water inside the churn. When the weights hit the ground, they are moving at 2 m/s. How much has the temperature of the water increased? Assume that only the water changes in temperature.

Side note: Joule would not have been able to measure such a small increase in temperature, but he potentially could have lifted the weights back up and repeated the experiment several times until the total temperature change was large enough for him to measure.



a. Less than 0.0020°C
b. 0.0020 – 0.0022
c. 0.0022 – 0.0024
d. 0.0024 – 0.0026
e. 0.0026 – 0.0028
f. 0.0028 – 0.0030
g. 0.0030 – 0.0032
h. More than 0.0032°C

PE = KE + heat energy

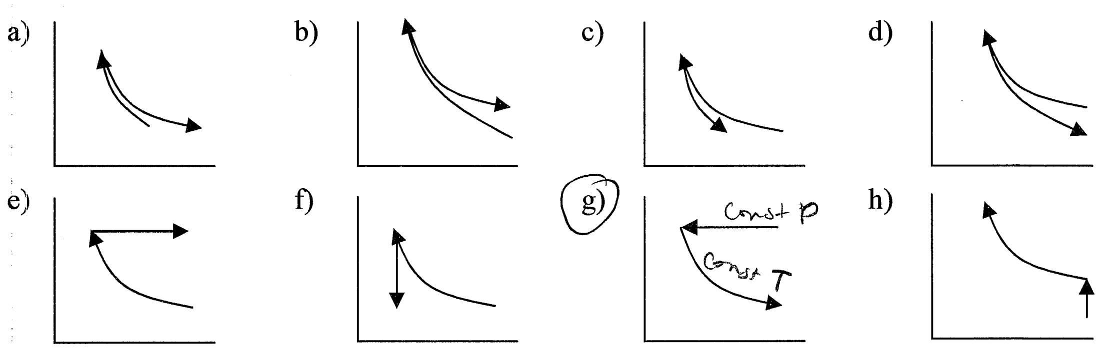
heat = PE − KE

$m_{water} c \Delta T = m_{weights} g h - \frac{1}{2} M_{weights} v^2$

$\Delta T = \frac{mgh - \frac{1}{2} m v^2}{m_{water} \cdot c} = \frac{(5)(9.8)(1) - \frac{1}{2}(5)(2)^2}{(3)(4186)}$

$= \boxed{.003106\ °C}$

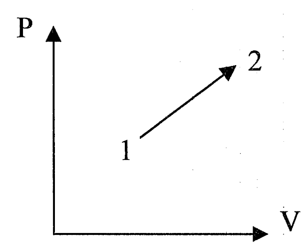
27. First, a monatomic ideal gas (initial volume of 1.50 m^3) is compressed to 0.50 m^3 via a constant pressure process. Next, the gas is expanded again back to its original volume while keeping its temperature constant. Which of the following diagrams best represents the two processes on a standard P-V diagram?



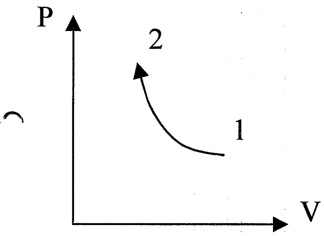
28. A diatomic ideal gas undergoes the process shown in the figure. For this process is $W_{on\ gas}$ positive, negative, or zero?

a. Positive
b. Negative
c. Zero

Volume increasing
→ $W_{by\ gas}$ = positive
$W_{on\ gas}$ = negative



29. A diatomic ideal gas is compressed isothermally from state 1 (100 kPa, 0.008 m^3, 300 K) to state 2 (200 kPa, 0.004 m^3, 300 K), as in the figure. Was heat added or taken away from the gas?



a. Added
b. Taken away
c. Neither ($Q_{added} = 0$)

If no heat added/taken away, then the temp. would have increased.

30. A large power plant takes in steam at 550°C (823K) to power turbines and then exhausts the steam at 140°C (413K). Each second the fuel powering the turbines produces 90 megajoules of heat energy, which is then used to produce work. If the power plant operates at the theoretical maximum possible efficiency (according to the Carnot theorem), what will its power output be?

a. Less than 44 MW
b. 44 – 46
c. 46 – 48
d. 48 – 50
e. 50 – 52
f. 52 – 54
g. 54 – 56
h. More than 56 MW

$e_{max} = 1 - \frac{T_c}{T_h} = 1 - \frac{413}{823} = 49.82\%$

Also $e = \frac{W}{Q_h} \rightarrow W = e \cdot Q_h$

$= (.4982)(90\text{ MJ})$

$= \boxed{44.84\text{ MJ}}$ every second

31. The second law of thermodynamics (remember the song: "Heat cannot of itself pass from one body to a hotter body") is a statement of:

a. conservation of energy
b. conservation of linear momentum
c. conservation of angular momentum
d. conservation of mass and/or volume
e. probability

think of the card example from class

32. A 0.2 kg mass hangs on a spring (spring constant 5 N/m) and oscillates. What will be the frequency of the oscillation?

a. Less than 0.60 Hz
b. 0.60 – 0.63
c. 0.63 – 0.66
d. 0.66 – 0.69
e. 0.69 – 0.72
f. 0.72 – 0.75
g. 0.75 – 0.78
h. More than 0.78 Hz

$\omega = \sqrt{k/m}$

$f = \omega/2\pi = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

$= \frac{1}{2\pi}\sqrt{\frac{5}{.2}} = \boxed{.7958\text{ Hz}}$

33. A 3 kg mass on a frictionless horizontal surface is attached to a horizontal spring and oscillates with an amplitude of 8 cm. If the spring constant is 70 N/m what will be the maximum speed of the mass?

a. Less than 0.10 m/s
b. 0.10 – 0.15
c. 0.15 – 0.20
d. 0.20 – 0.25
e. 0.25 – 0.30
f. 0.30 – 0.35
g. 0.35 – 0.40
h. More than 0.40 m/s

$PE_{spring} = KE_{max}$

$\cancel{\tfrac{1}{2}} kx^2 = \cancel{\tfrac{1}{2}} mv^2$

$v = \sqrt{\frac{kx^2}{m}}$

$= \sqrt{\frac{70 \cdot (.08)^2}{3}} = \boxed{.3864\text{ m/s}}$

34. Suppose you want to know the height of a tower. You climb to the top and set up a pendulum extending all the way down to the ground with a large weight on the end. You then measure the period of this pendulum to be 7.8 s. How tall is the tower?

a. Less than 11 m
b. 11 – 12
c. 12 – 13
d. 13 – 14
e. 14 – 15
f. 15 – 16
g. 16 – 17
h. More than 17 m

$T = 2\pi\sqrt{\frac{L}{g}} \rightarrow L = g\left(\frac{T}{2\pi}\right)^2$

$= (9.8\,\frac{m}{s^2})\left(\frac{7.8\,s}{2\pi}\right)^2$

$= \boxed{15.10\,m}$

35. A clock pendulum made out of aluminum keeps perfect time at 20°C. If the temperature in the room falls to -12.5°C, will the clock run fast (gain time) or slow (lose time)?

a. Fast
b. Slow

length will shrink so period will decrease. Clock runs fast.

36. A rubber cord is 4 m long and has a mass of 0.2 kg. A transverse wave pulse is produced by plucking one end of the taut cord. That pulse makes three round trips (down and back) along the cord in 0.7 s. What is the tension in the cord?

a. Less than 59 N
b. 59 – 61
c. 61 – 63
d. 63 – 65
e. 65 – 67
f. 67 – 69
g. 69 – 71
h. More than 71 N

$v = \frac{\text{distance}}{\text{time}} = \frac{4\,m \times 6}{.7\,sec} = 34.29\,m/s$

v also $= \sqrt{\frac{T}{\mu}} \rightarrow T = \mu v^2$

$T = \left(\frac{.2\,kg}{4\,m}\right)(34.29\,\frac{m}{s})^2$

$= \boxed{58.78\,N}$

37. A firecracker goes off and produces a sound of 98 dB where Sarah is standing. What is the intensity of the sound wave? Choose the closest number.

a. 0.000019 W/m^2
b. 0.000063
c. 0.00019
d. 0.00063
e. 0.0019
f. 0.0063
g. 0.019
h. 0.063
i. 0.19
j. 0.63 W/m^2

$\beta = 10 \log I/I_0$

$\beta/10 = \log I/I_0$

$I = I_0\, 10^{\beta/10}$

$= (10^{-12}\,\frac{W}{m^2})\, 10^{9.8} = \boxed{0.00631\,W/m^2}$

38. Same situation. Suppose Casey is standing twice as far away from the firecracker as Sarah. How many decibels get produced at Casey's location? You may assume the sound travels away from the firecracker in spherical waves.

a. 90 dB
b. 91
c. 92
d. 93
e. 94
f. 95
g. 96
h. 97
i. 98 dB

$I \sim \frac{1}{r^2} \rightarrow$ 2x as far = $\frac{1}{4}$ the intensity

$\frac{1}{4} = \frac{1}{2} \times \frac{1}{2}$

$= -3\,dB \;\; -3\,dB$

$= -6\,dB$, i.e. 6 dB less than Sarah's 98 dB value

$= \boxed{92\,dB}$

39. A car drives very fast at 70 m/s toward a hill, and honks its horn with a frequency of 670 Hz. What frequency will a man on the hill hear? Use 343 m/s for the speed of sound. Choose the closest number.

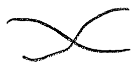
a. 443 Hz
b. 533
c. 556
d. 670
e. 807
f. 842
g. 1014 Hz

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

$= (670\,Hz) \frac{343}{343-70} = \boxed{841.8\,Hz}$

40. The fundamental frequency (first harmonic) of the trumpet I brought to class is very close to 150 Hz. How long would the trumpet's uncoiled length be (not including valves)? Take the speed of sound in air to be 343 m/s. Hint: a trumpet is like an open-open pipe.

a. Less than 1.12 m
b. 1.12 – 1.15
c. 1.15 – 1.18
d. 1.18 – 1.21
e. 1.21 – 1.24
f. 1.24 – 1.27
g. 1.27 – 1.30
h. More than 1.30 m

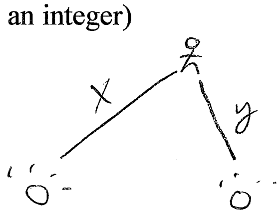
Fundamental:  $L = \frac{1}{2}\lambda$

also $v = \lambda f \rightarrow \lambda = \frac{v}{f}$

$L = \frac{1}{2}\frac{v}{f} = \frac{1}{2}\frac{343\,m/s}{150\,1/s} = \boxed{1.143\,m}$

41. 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. $x-y=(n+\frac{1}{2})\lambda$

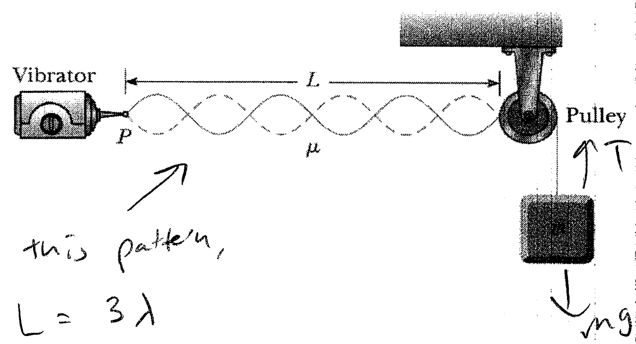


max when $\Delta PL = n\lambda$

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

42. In the arrangement shown in the figure, an object of mass m = 4.4 kg hangs from a cord around a light pulley. The length of the cord between point P and the pulley is L = 2 m. When the vibrator is set to a frequency of 275 Hz, a standing wave with six antinodes is formed. What must be the cord's linear mass density μ?

a. Less than 1.14 g/m
b. 1.14 – 1.17
c. 1.17 – 1.20
d. 1.20 – 1.23
e. 1.23 – 1.26
f. 1.26 – 1.29
g. 1.29 – 1.32
h. More than 1.32 g/m



For this pattern,

$L = 3\lambda$

$L = 3\left(\frac{v}{f}\right)$

$\underline{T = mg}$

also $v = \sqrt{\frac{T}{\mu}}$ so $L = \frac{3}{f}\sqrt{\frac{T}{\mu}}$

solve for μ ... $\left(\frac{fL}{3}\right)^2 = \frac{T}{\mu}$

$\mu = \frac{T \cdot 9}{f^2 L^2}$

$\mu = \frac{(4.4 \cdot 9.8) \times 9}{(275)^2 (2)^2} = 1.283 \cdot 10^{-3}\,\frac{kg}{m}$

$= \boxed{1.283\,\frac{g}{m}}$