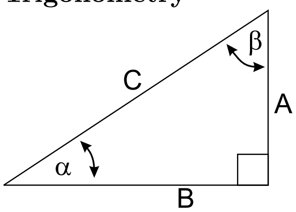
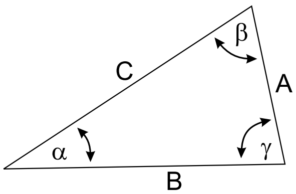
Scott Pratt

Do not open exam until instructed to do so.

Quadratic Formula
$ax^2 + bx + c = 0,$
$x = [-b \pm \sqrt{b^2 - 4ac}]/(2a)$
Geometry
Circle: circumference=$2\pi R$, area=πR^2
Sphere: area=$4\pi R^2$, volume=$4\pi R^3/3$
Trigonometry



$$\sin\alpha = \frac{A}{C}, \quad \cos\alpha = \frac{B}{C}$$
$$\tan\alpha = \frac{A}{B}$$



$$\frac{\sin\alpha}{A} = \frac{\sin\beta}{B} = \frac{\sin\gamma}{C}$$
$$A^2 + B^2 - 2AB\cos\gamma = C^2$$

Polar Coordinates
$x = r\cos\theta, \quad y = r\sin\theta$
$r = \sqrt{x^2 + y^2}, \quad \tan\theta = y/x$
SI Units and Constants

quantity	unit	abbreviation
Mass m	kilograms	kg
Distance x	meters	m
Time t	seconds	s
Force F	Newtons	N=kg m/s^2
Energy E	Joules	J=N m
Power P	Watts	W=J/s
Temperature T	°C, °K or °F	$T_{\circ F} = 32 + (9/5)T_{\circ C}$
Pressure P	Pascals	Pa=N/m^2

1 cal=4.1868 J, 1 hp=745.7 W
$g = 9.81$ m/s^2, G=6.67×10^{-11} Nm^2/kg^2
0°C=273.15°K, $N_A = 6.023 \times 10^{23}$
$R = 8.31$ J/(mol°K), $k_B = R/N_A = 1.38 \times 10^{-23}$ J/°K
$\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4)
$v_{\rm sound} = 331\sqrt{T/273}$ m/s
H_20: $c_{\rm ice,liq.,steam}$=$\{0.5, 1.0, 0.48\}$ cal/g°C
$L_{F,V}$=$\{80, 540\}$ cal/g, $\rho = 1.0$ g/cm^3.

1-d motion, constant a
$x = (1/2)(v_0 + v_f)t$
$v_f = v_0 + at$
$x = v_0 t + (1/2)at^2$
$x = v_f t - (1/2)at^2$
$(1/2)v_f^2 - (1/2)v_0^2 = ax$
Momentum, Force and Impulse
$p = mv, \ F = ma = \Delta p/\Delta t$
$I = F\Delta t = \Delta p$
Friction: $F_{\rm fric} = \mu N$
Spring: $F = -kx$

Work, Energy and Power
$W = Fx\cos\theta, KE = (1/2)mv^2, \ P = \Delta E/\Delta t = Fv$
Spring: $PE = (1/2)kx^2$
Rotational Motion
$v = \omega r = 2\pi r/T, \quad \omega = \Delta\theta/\Delta t = 2\pi f = 2\pi/T, f = 1/T$
$\alpha = (\omega_f - \omega_0)/t = \frac{a}{r}$
$L = I\omega = mvr\sin\theta$, ($\theta$= angle between v and r)
$KE = (1/2)I\omega^2 = L^2/(2I)$
$\tau = rF\sin\theta, \ I\alpha = \tau, \ I_{\rm point} = mR^2$
$I_{\rm cyl.shell} = MR^2, \ I_{\rm sphere} = (2/5)MR^2$
$I_{\rm solid\ cyl.} = (1/2)MR^2, \ I_{\rm sph.\ shell} = (2/3)MR^2$
$a = v^2/r = \omega v = \omega^2 r$
Gravity and circular orbits
$PE = -G\frac{Mm}{r}, \ \Delta PE = mgh(\text{small } h)$
$$F = G\frac{Mm}{r^2}, \quad \frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$
Gases, liquids and solids
$P = F/A, \ PV = NRT, \ \Delta P = \rho gh$
$\langle (1/2)mv^2 \rangle = (3/2)k_B T$
$F_{\rm bouyant} = \rho_{\rm displaced\ liq.} V_{\rm displaced\ liq.} g$
Stress $= F/A$, Strain $= \Delta L/L$, Y = Stress/Strain
$\frac{\Delta L}{L} = \frac{F/A}{Y}, \frac{\Delta V}{V} = \frac{-\Delta P}{B}, Y = 3B$
Bernoulli: $P_a + \frac{1}{2}\rho_a v_a^2 + \rho_a g h_a = P_b + \frac{1}{2}\rho_b v_b^2 + \rho_b g h_b$
Heat
$\Delta L/L = \alpha\Delta T, \ \Delta V/V = 3\alpha\Delta T$
$Q = mC_v\Delta T + mL$(if phase trans.)
Conduction and Radiation
$P = kA(T_b - T_a)/\Delta x = A(T_b - T_a)/R,$
$R \equiv \Delta x/k, \ P = e\sigma AT^4$
Thermodynamics
$\Delta U = Q + W, \quad W = -P\Delta V$, ideal gas: $\Delta U = nC_V\Delta T$
Adiabatic exp: pV^γ =const, $TV^{\gamma-1}$ =const
$\gamma = C_p/C_V$=5/3 (monotonic), =7/5 (diatomic)
$Q = T\Delta S, \ \Delta S > 0$
Engines: $W = |Q_H| - |Q_L|$
$\epsilon = W/Q_H < (T_H - T_L)/T_H < 1$
Refrigerators and heat pumps: $W = |Q_H| - |Q_L|$
$\epsilon = Q_L/W < T_L/(T_H - T_L)$
Simple Harmonic Motion and Waves
$f = 1/T, \omega = 2\pi f$
$x(t) = A\cos(\omega t - \phi), \ v = -\omega A\sin(\omega t - \phi)$
$a = -\omega^2 A\cos(\omega t - \phi)$
Spring: $\omega = \sqrt{k/m}$
Pendulum: $T = 2\pi\sqrt{L/g}$
Waves: $y(x,t) = A\sin[2\pi(ft - x/\lambda + \delta)], \ v = f\lambda$
$I = {\rm const}A^2 f^2, \ I_2/I_1 = R_1^2/R_2^2$
Standing waves: $\lambda_n = 2L/n$
Strings: $v = \sqrt{T/\mu}$
Solid/Liquid: $v = \sqrt{B/\rho}$
Sound: $I = {\rm Power}/A = I_0 10^{\beta/10}, \ I_0 \equiv 10^{-12}$ W/m^2
Decibels: $\beta = 10\log_{10}(I/I_0)$
Beat freq.=$|f_1 - f_2|$
Doppler: $f_{\rm obs} = f_{\rm source}(V_{\rm sound} \pm v_{\rm obs})/(V_{\rm sound} \pm v_{\rm source})$
Pipes: same at both ends: $L = \lambda/2, \lambda, 3\lambda/2$
Pipes: open at only one end: $L = \lambda/4, 3\lambda/4, 5\lambda/4 \cdots$

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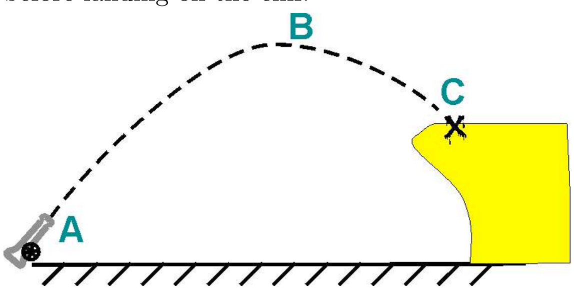
3 pt Consider a projectile which strikes a target as shown below. Ignore all forces except gravity. Point A refers to a point just beyond the muzzle of the cannon, B refers to the highest point in the trajectory and C refers to a point just before landing on the cliff.



▷ The acceleration at B is ____ the acceleration at C.

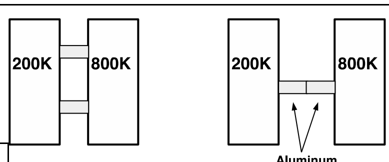
1. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The magnitude of the vertical component of the velocity at A is ____ the magnitude of the vertical component of the velocity at C

2. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The horizontal component of the velocity at A is ____ than the horizontal component of the velocity at C.

3. **A**◯ greater than **B**◯ less than
C◯ equal to



2 pt
A hot (800 °K) and a cold (200 °K) object are connected by two aluminum bars as shown.

▷ Considering the left configuration only, lowering the temperature of the 800 °K block to 400 °K will reduce the rate of heat transfer by a factor of ________________.

4. **A**◯ one fourth **B**◯ one half
C◯ one third

▷ Compared to the configuration on the left, the rate of heat transferred in configuration shown the right is __________ as high.

5. **A**◯ one fourth **B**◯ one half
C◯ one third

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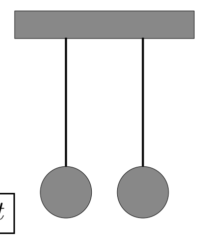
2 pt Dumb Dora slides a bumper car down an icy frictionless hill of height h. At the bottom of the hill, she collides head-on with her lifetime companion Brainless Billy, who is at rest in his bumper car. The two cars, including their dimwitted passengers, have equal mass. After the collision the two cars stick together. Their speed after the collision is 20 mph.

▷ If the collision is repeated, but they bounce off each other elastically, Billy's final speed will be ________.

6. **A**◯ 20 mph **B**◯ 28.284 mph **C**◯ 40 mph
D◯ 80 mph

▷ Just before the collision, Dora's speed was ________.

7. **A**◯ 20 mph **B**◯ 28.284 mph **C**◯ 40 mph
D◯ 80 mph



1 pt
Identical spheres are suspended by light strings. If air is blown between the spheres, the spheres will ____________.

▷

8. **A**◯ move toward one another
B◯ move away from one another
C◯ stay the same distance apart

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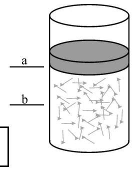
1 pt A train passes a station at constant speed, blowing its whistle twice: once while approaching the station and again after passing the station. To an observer standing on the station's platform,

▷ the frequency of the second blast was ________________ the frequency of the first blast.

9. **A**◯ higher than **B**◯ lower than
C◯ equal to



4 pt

A massive piston traps a fixed amount of helium gas as shown. After being brought to point (a) the system equilibrates to room temperature. Weight is then added on top of the piston and the gas is ADIABATICALLY compressed to half of its original volume (b).

▷ The temperature T_b is ________________ T_a.

10. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ the pressure P_b is ________________ P_a.

11. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ The internal energy U_b is ________________ U_a.

12. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ The entropy of the gas at "b" is ________________ the entropy of the gas at "a".

13. **A**◯ greater than **B**◯ less than **C**◯ equal to

3 pt Answer the following questions about thermodynamics.

▷ An air conditioner uses an amount of electrical energy U to cool a home. The amount of heat moved from inside the home must be less than or equal to U.

14. **A**◯ True **B**◯ False

▷ If an engine does an amount of work W, and exhausts heat at a temperature of 50 degrees C, the chemical energy contained in the fuel must be greater than, and not equal to, W.

15. **A**◯ True **B**◯ False

▷ A heat pump uses an amount of electrical energy U to heat a home. The amount of heat added to a home must be less than or equal to U.

16. **A**◯ True **B**◯ False

1 pt A pipe is 3.4 m long and is open at one end and closed at the other end. What are the first three frequencies for standing waves generated in the pipe? DATA: The speed of sound is 340 m/s.

▷

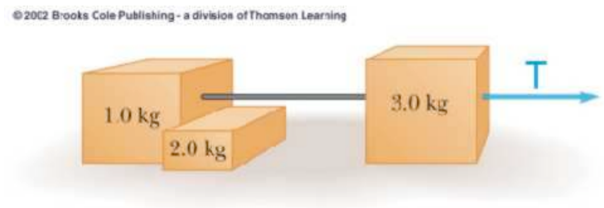
17. **A**◯ 100 Hz, 200 Hz, 300 Hz
B◯ 100 Hz, 200 Hz, 400 Hz
C◯ 100 Hz, 300 Hz, 500 Hz
D◯ 50 Hz, 100 Hz, 150 Hz
E◯ 50 Hz, 150 Hz, 250 Hz
F◯ 200 Hz, 400 Hz, 600 Hz
G◯ impossible to calculate
H◯ 25 Hz, 75 Hz, 125 Hz

1 pt Nolan Ryan throws a rock horizontally from the roof of a tall building with an initial speed of 41 m/s. The rock travels a horizontal distance of 56 m before it hits the ground. From what height (above the ground) was the ball released? *(in* m*)*

18. **A**◯ 6.68 **B**◯ 7.82 **C**◯ 9.15 **D**◯ 10.71
E◯ 12.53 **F**◯ 14.66 **G**◯ 17.15 **H**◯ 20.06

1 pt How much power does is required to pull up a load of bricks at a constant velocity. The mass of the load is 115 kg, the height raised is 300 m, and the time required is 101 seconds? The efficiency of the engine is 0.4.

19. **A**◯ 5231 **B**◯ 6120 **C**◯ 7160 **D**◯ 8377
E◯ 9802 **F**◯ 11468 **G**◯ 13417 **H**◯ 15698



1 pt
Assume that the three blocks in the figure move together on a frictionless surface and that a T=35 N force acts as shown on the 3.0-kg block. What is the acceleration of the blocks? *(in* `m/s^2`*)*

20. **A**◯ 1.91 **B**◯ 2.39 **C**◯ 2.99 **D**◯ 3.73
E◯ 4.67 **F**◯ 5.83 **G**◯ 7.29 **H**◯ 9.11

1 pt Beginning at rest at an extremely large separation, a ball is released and allowed to fall toward a star of mass 4.70E+30 kg and radius 8.50E+7 m. What is the speed of the ball when it reaches the surface? *(in* `m/s`*)*

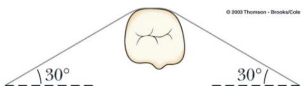
21. **A**◯ 6.53×10^5 **B**◯ 8.68×10^5 **C**◯ 1.15×10^6
D◯ 1.54×10^6 **E**◯ 2.04×10^6 **F**◯ 2.72×10^6
G◯ 3.61×10^6 **H**◯ 4.80×10^6

In an amusement park ride, a rotating cylinder of radius 3.05 m rotates as seen above. The floor then drops away, leaving the riders suspended against the wall in a vertical position. If the coefficient of friction between the rider's clothes and the wall is 0.32, what is the minimum rotational frequencey necessary to keep the rider pinned to the wall?
1 pt
(in `in Hz`*)*

22. **A**◯ 0.114 **B**◯ 0.166 **C**◯ 0.240 **D**◯ 0.348
E◯ 0.505 **F**◯ 0.732 **G**◯ 1.061 **H**◯ 1.538

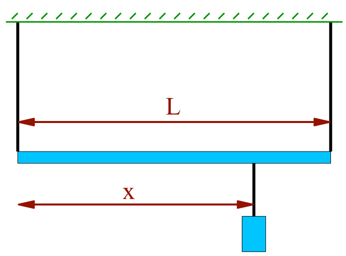
[*1 pt*] A solid cylinder ($I = MR^2/2$) rolls down a hill of height 25 m without slipping. What is the velocity of the cyclinder at the bottom of the hill? DATA: g=9.80 m/s^2 *(in* `m/s`*)*

23.A◯ 5.8 **B**◯ 7.7 **C**◯ 10.2 **D**◯ 13.6
E◯ 18.1 **F**◯ 24.0 **G**◯ 32.0 **H**◯ 42.5



[*1 pt*]
A stainless steel orthodontic wire is applied to a tooth, as shown in the figure above. The wire has an unstretched length of 25 mm and a cross sectional area of 3 mm^2. The wire is stretched 0.1 mm. Young's modulus for stainless steel is 1.8×10^{11} Pa. What is the tension in the wire? *(in* `N`*)*

24.A◯ 1497 **B**◯ 1692 **C**◯ 1912 **D**◯ 2160
E◯ 2441 **F**◯ 2758 **G**◯ 3117 **H**◯ 3522



[*1 pt*]
Two wires support a beam of length L=12 as shown in the figure above. A box of weight 350 N hangs from a wire which is connected a distance of 9 m from the left edge of the beam. The mass of the beam is unknown. If the tension in the left support wire is 700 N, what is the tension in the right support wire?
DATA: g=9.81 m/s^2 *(in* `N`*)*

25.A◯ 875 **B**◯ 1164 **C**◯ 1548 **D**◯ 2059
E◯ 2738 **F**◯ 3641 **G**◯ 4843 **H**◯ 6441

[*1 pt*] Working for the Portugese Navy, Elsia Ovideo is designing a sonar device. Elsia does not know the speed of sound through the water due to the unknown salinity, but observes that sound of a frequency 7300 Hz has a wavelength of 28.08 cm. How much time would be required for a sound pulse to travel to the floor of the ocean and return if the depth of the ocean is 5520 m? *(in* `s`*)*

26.A◯ 3.73 **B**◯ 4.22 **C**◯ 4.77 **D**◯ 5.39
E◯ 6.09 **F**◯ 6.88 **G**◯ 7.77 **H**◯ 8.78

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1 pt To take the place of shock absorbers, a go-cart has a spring on each wheel with k = 650 N/m. Including the passenger, the mass of the vehicle is 155 kg. What would be the period of oscillation of the car (in sec) if it were to hit a rock or pot hole?

27.A◯ 0.11 **B**◯ 0.17 **C**◯ 0.24 **D**◯ 0.35
E◯ 0.50 **F**◯ 0.73 **G**◯ 1.06 **H**◯ 1.53

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1 pt Two point sound sources, source A and source B, have powers 4 and 75 W respectively. If you are 5.5 meters from source A, how far should you be from source B to make the two have equal sound intensity level?

28.A◯ 7.94 **B**◯ 9.28 **C**◯ 10.86 **D**◯ 12.71
E◯ 14.87 **F**◯ 17.40 **G**◯ 20.36 **H**◯ 23.82

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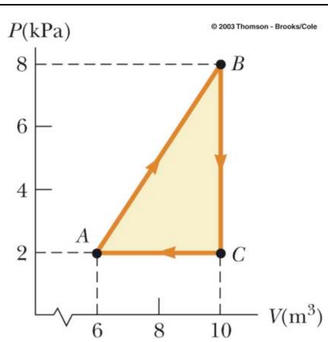
1 pt Two sounds have intensities $6 \cdot 10^{-3}$ and $4.5 \cdot 10^{-7}$ W/m^2. What is the magnitude of the difference in intensity levels between the two sounds in dB?

29.A◯ 26.40 **B**◯ 33.00 **C**◯ 41.25
D◯ 51.56 **E**◯ 64.45 **F**◯ 80.57
G◯ 100.71 **H**◯ 125.88



1 pt
A gas is taken through the cyclic process described by the figure above. How much work was done by the gas during the cycle ABCA? *(in J)*

30.A◯ 10619 **B**◯ 12000 **C**◯ 13560 **D**◯ 15323
E◯ 17315 **F**◯ 19566 **G**◯ 22109 **H**◯ 24983

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1 pt The motion of an object is described by the equation:
x = (1.5 m) cos(πt/2.3),
where t is assumed to be measured in seconds. What is the frequency (in Hz) of the motion?

31.A◯ 0.163 **B**◯ 0.217 **C**◯ 0.289 **D**◯ 0.385
E◯ 0.511 **F**◯ 0.680 **G**◯ 0.905 **H**◯ 1.203

A steel wire in a piano has a length of 90 cm and a mass of 4.3 g. To what tension must this wire be stretched in order that the fundamental vibration correspond to middle C (fC = 261.6 Hz on the chromatic musical scale)?

1 pt *(in* `N`*)*

32.A◯ 1059.4 **B**◯ 1536.1 **C**◯ 2227.3
D◯ 3229.6 **E**◯ 4682.9 **F**◯ 6790.3
G◯ 9845.9 **H**◯ 14276.5

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1 pt At high noon, the Sun delivers 1.11 kW to each square meter of a blacktop road. If the hot asphalt loses energy only by radiation, what is its equilibrium temperature (in degrees Celsius) of the road surface?

33.A◯ 69.6 **B**◯ 100.9 **C**◯ 146.3 **D**◯ 212.2
E◯ 307.6 **F**◯ 446.1 **G**◯ 646.8 **H**◯ 937.9
