Nagy,

Tibor

Keep this exam **CLOSED** until advised by the instructor.

50 minute long closed book exam.

Fill out the bubble sheet: last name, first initial, **student number (PID)**. Leave the section, code, form and signature areas empty.

Three two-sided handwritten 8.5 by 11 help sheets are allowed.

When done, hand in your **test** and your **bubble sheet**.

Thank you and good luck!

Posssibly useful constants:

- $g = 9.81$ m/s^2
- $G = 6.67\times10^{-11}$ Nm^2/kg^2
- $\rho_{water} = 1000$ kg/m^3 = 1 kg/l = 1 g/cm^3
- 1 atm = 101.3 kPa = 760 mmHg
- $N_A = 6.02\times10^{23}$ 1/mol
- R = 8.31 J/(molK)
- $k_B = 1.38\times10^{-23}$ J/K
- 0 °C = 273.15 K

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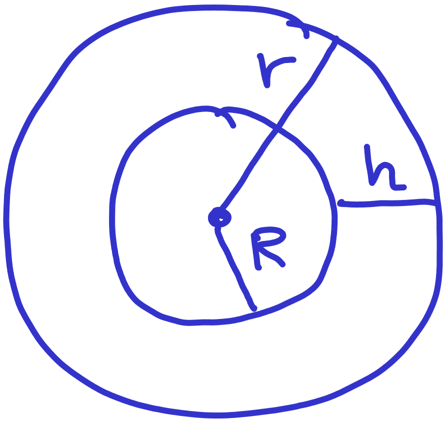
Please, sit in row G.

1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

4 pt A 210 kg satellite is orbiting on a circular orbit 5155 km above the Earth's surface. Determine the speed of the satellite. (The mass of the Earth is 5.97×10^{24} kg, and the radius of the Earth is 6370 km.)
(in km/s*)*

2. **A** ◯ 2.29 **B** ◯ 2.68 **C** ◯ 3.14 **D** ◯ 3.67 **E** ◯ 4.29 **F** ◯ 5.02 **G** ◯ 5.88 **H** ◯ 6.88



$R = 6370$ km

$h = 5155$ km

$r = R + h = 11{,}525$ km $=$
$= 11.525 \cdot 10^6$ m

Speed of a satellite:

$$v = \sqrt{\frac{GM}{r}}$$

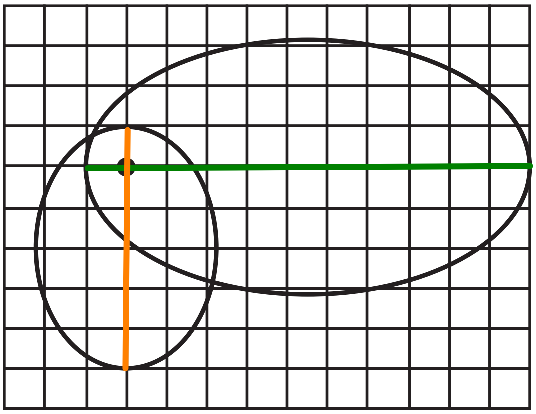
$G = 6.67 \cdot 10^{-11} \frac{Nm^2}{kg^2}$

$M = 5.97 \cdot 10^{24}$ kg

$$v = \sqrt{\frac{6.67 \cdot 10^{-11} \cdot 5.97 \cdot 10^{24}}{11.525 \cdot 10^6}} = 5878 \frac{m}{s}$$

$v \cong 5.88$ km/s

4 pt The paths of two small sattellites, M_L= 6.00 kg and M_R= 9.00 kg, are shown below, drawn to scale, with M_L corresponding to the orbit on the left hand side in the figure. They orbit in the same plane around a massive star, as shown below.



$2a_R = 11$

$2a_L = 6$

Kepler's 3rd law:

$$\frac{T_R^2}{T_L^2} = \frac{a_R^3}{a_L^3}$$

The period of M_L is 26.0 years. Calculate the period of M_R, in years.

3. **A**◯ 4.45×10^1 **B**◯ 6.45×10^1 **C**◯ 9.36×10^1 **D**◯ 1.36×10^2
E◯ 1.97×10^2 **F**◯ 2.85×10^2 **G**◯ 4.14×10^2 **H**◯ 6.00×10^2

$$\frac{T_R^2}{T_L^2} = \frac{a_R^3}{a_L^3} = \frac{(2a_R)^3}{(2a_L)^3}$$

$$T_R = T_L \cdot \sqrt{\left(\frac{2a_R}{2a_L}\right)^3}$$

$$T_R = 26\,\text{yrs} \cdot \sqrt{\left(\frac{11}{6}\right)^3} = 64.5\,\text{yrs}$$

4 pt Glucose solution is administered to a patient in a hospital. The density of the solution is 1.336 kg/l. If the blood pressure in the vein is 39.2 mmHg, then what is the minimum necessary height of the IV bag above the position of the needle?
(in cm*)*

4. **A**◯ 16.9 **B**◯ 22.5 **C**◯ 30.0 **D**◯ 39.9
E◯ 53.0 **F**◯ 70.5 **G**◯ 93.8 **H**◯ 124.7

$$\rho = 1.336 \frac{kg}{l} = 1336 \frac{kg}{m^3}$$

$$p = 39.2 \text{ mmHg} = 5225 \text{ Pa}$$

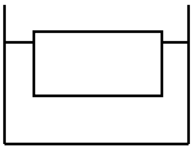
(If 760 mmHg = 101,300 Pa,
then 1 mmHg = 133.3 Pa)

Hydrostatic pressure:

$$p = \rho g h \Rightarrow h = \frac{p}{\rho g}$$

$$h = \frac{5225}{1336 \cdot 9.81} = 0.399 \text{ m} = 39.9 \text{ cm}$$

3 pt A large ice cube floats in a glass of water.



A melting ice cube doesn't change the water level.

What happens to the water level, when the ice cube melts? (No water is lost due to evaporation.)

5.A◯ The water level will fall.
B◯ The water level will rise.
C◯ It depends on how much water we have in the glass, and how big the ice cube is.
D◯ The water level will not change.

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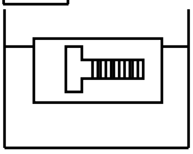
3 pt A large ice cube floats in a glass of water.

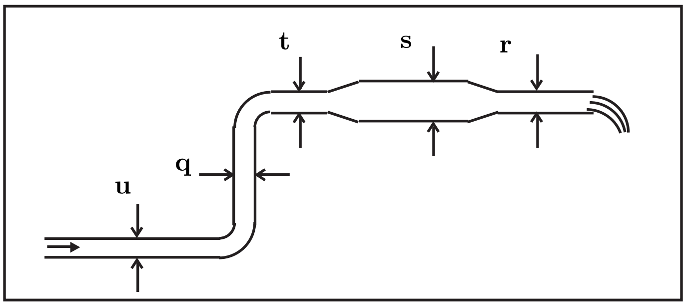


There is a steel bolt frozen inside the ice cube. What happens to the water level when all the ice melts? (No water is lost due to evaporation.)

6.A◯ The water level will fall.
B◯ The water level will rise.
C◯ Without knowing the mass of the bolt, we cannot answer this question.
D◯ The water level will not change.

Move the bolt to the top of the ice cube. Toss the bolt in to the water. The water level will fall. (See the boat on pond question.) Then let the ice cube melt. The melting ice cube doesn't change the water level.

8 pt The figure illustrates the flow of an ideal fluid through a pipe of circular cross section, with diameters of 1 cm and 2 cm and with different elevations. p_x is the pressure in the pipe, and v_x is the speed of the fluid at locations x = q, r, s, t, or u.



▷ p_r is .... p_s
7. A◯ Greater than B◯ Less than C◯ Equal to

▷ p_u is .... p_q
8. A◯ Greater than B◯ Less than C◯ Equal to

▷ v_q is .... $2v_s$
9. A◯ Greater than B◯ Less than C◯ Equal to

▷ v_u is .... v_r
10. A◯ Greater than B◯ Less than C◯ Equal to

#7: When the fluid speeds up, its pressure drops.

#8: When you climb in a fluid, the pressure drops. (When you dive deeper in a fluid, the pressure increases.

#9: $v_q > 2v_s$ b/c $v_q = 4v_s$

$A_q = \frac{1}{4} A_s$ and $v_q A_q = v_s A_s$

#10: $v_u = v_r$ b/c $A_u = A_r$

4 pt A rock band uses a wall built out of 37 identical speakers. If one single speaker can produce a sound level of 95.5 dB in the front row area, then what is the sound level produced by the whole wall?
(in dB*)*

11. **A**◯ 59.3 **B**◯ 69.4 **C**◯ 81.2 **D**◯ 95.0
E◯ 111.2 **F**◯ 130.1 **G**◯ 152.2 **H**◯ 178.1

Intensity from one speaker: I_1

Intensity from 37 speakers: I_{37}

Conservation of energy: $I_{37} = 37 \cdot I_1$

Sound level of one speaker: β_1

$$\beta_1 = 10 \cdot \log\left(\frac{I_1}{I_0}\right) = 95.5 \text{ dB}$$

Sound level of 37 speakers: β_{37}

$$\beta_{37} = 10 \cdot \log\left(\frac{I_{37}}{I_0}\right) = 10 \cdot \log\left(\frac{37 \cdot I_1}{I_0}\right) =$$

$$= 10 \cdot \left[\log(37) + \log\left(\frac{I_1}{I_0}\right)\right] =$$

$$= 10 \log(37) + 10 \cdot \log\left(\frac{I_1}{I_0}\right) =$$

$$= 15.7 + 95.5 = 111.2 \text{ dB}$$

4 pt A stationary horn emits a sound with a frequency of 205 Hz. A car is moving away from the horn on a straight road with constant speed. If the driver of the car hears the horn at a frequency of 185 Hz, then what is the speed of the car? Use 340 m/s for the speed of the sound.
(in m/s*)*

12. **A**◯ 2.30×10^1 **B**◯ 2.60×10^1 **C**◯ 2.94×10^1 **D**◯ 3.32×10^1
E◯ 3.75×10^1 **F**◯ 4.24×10^1 **G**◯ 4.79×10^1 **H**◯ 5.41×10^1

Doppler effect:

$$f_o = f_s \cdot \frac{c \pm v_o}{c \pm v_s} \qquad c = 340\ \frac{m}{s}$$

Stationary horn: $v_s = 0\ \frac{m}{s}$

source frequency: $f_s = 205\ Hz$

Observed frequency: $f_o = 185\ Hz$

The shift is down, we need a fraction less than one:

$$f_o = f_s \cdot \frac{c - v_o}{c}$$

$$c f_o = c f_s - v_o f_s$$

$$v_o f_s = c f_s - c f_o$$

$$v_o = c\ \frac{f_s - f_o}{f_s}$$

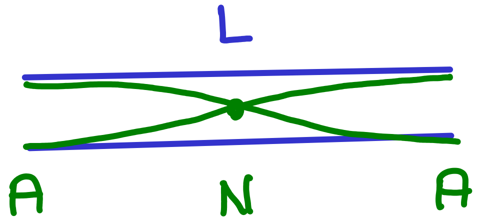
$$v_o = 340 \cdot \frac{205 - 185}{205}$$

$$v_o = 33.2\ \frac{m}{s}$$

4 pt A pipe is 1.70 m long and it is open at both ends. What are the frequencies of the lowest three harmonics produced by this pipe? The speed of sound is 340 m/s. Only one answer is correct.

13.A◯ 100 Hz, 200 Hz, 300 Hz
B◯ 100 Hz, 300 Hz, 500 Hz
C◯ 50 Hz, 100 Hz, 150 Hz
D◯ 50 Hz, 100 Hz, 200 Hz
E◯ 50 Hz, 150 Hz, 250 Hz
F◯ 200 Hz, 400 Hz, 600 Hz
G◯ 200 Hz, 600 Hz, 1000 Hz
H◯ 200 Hz, 300 Hz, 400 Hz

An open-open pipe holds a half wave as the lowest mode:



$$L = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2L$$
$$\lambda_1 = 3.4\,m$$

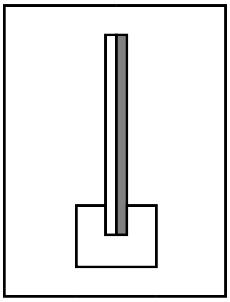
$$c = \lambda_1 \cdot f_1 \Rightarrow f_1 = \frac{c}{\lambda_1} = \frac{340\,m/s}{3.4\,m}$$
$$f_1 = 100\text{ Hz}$$

The frequencies of the standing waves in an open-open pipe go as : $f_n = n \cdot f_1$ where $n = 1, 2, 3, 4, 5 \ldots$

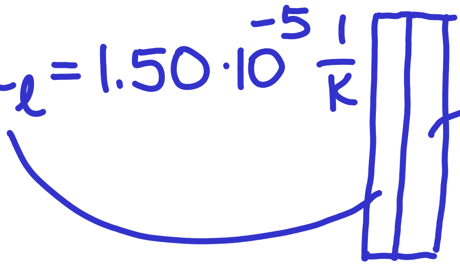
Therefore the frequencies are:

100 Hz, 200 Hz, 300 Hz, 400 Hz, 500 Hz

3 pt A bimetallic strip is held fixed at the bottom end as shown in the figure.



$\alpha_\ell = 1.50 \cdot 10^{-5} \frac{1}{K}$

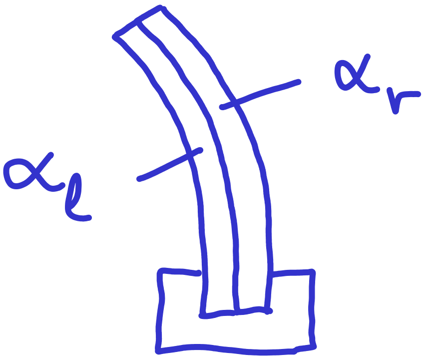


$\alpha_r = 3.85 \cdot 10^{-5} \frac{1}{K}$

The metal on the left has a coefficient of linear heat expansion of $\alpha_{\text{left}} = 1.50 \times 10^{-5}$ 1/K, the metal on the right has $\alpha_{\text{right}} = 3.85 \times 10^{-5}$ 1/K. When the strip is heated, it will ... (complete the sentence)

14.A◯ ... bend right.
B◯ ... remain straight.
C◯ ... bend left.

When the strip is heated:



because $\alpha_r > \alpha_\ell$: the right side expands more than the left side.

4 pt 5.20 liters of Nitrogen gas at 70.0°C temperature and 2.90 atm pressure contains how many moles?

15. **A**◯ 0.257 **B**◯ 0.291 **C**◯ 0.329 **D**◯ 0.371
E◯ 0.420 **F**◯ 0.474 **G**◯ 0.536 **H**◯ 0.605

$V = 5.20\,\ell = 0.0052\,m^3$

$T = 70^\circ C = 343\,K$

$p = 2.90\,atm = 2.94 \cdot 10^5\,Pa$

Ideal gas law: $pV = nRT$

$$\Rightarrow n = \frac{pV}{RT} = \frac{2.94 \cdot 10^5 \cdot 5.2 \cdot 10^{-3}}{8.31 \cdot 343}$$

$n = 0.536\,mol$

2 pt A gas bottle contains 8.44×10^{23} Methane molecules at a temperature of 349 K. What is the thermal energy of the gas?
(*in* J)

16. **A**◯ 1.22×10^{4} **B**◯ 1.38×10^{4} **C**◯ 1.56×10^{4} **D**◯ 1.76×10^{4}
E◯ 1.99×10^{4} **F**◯ 2.25×10^{4} **G**◯ 2.54×10^{4} **H**◯ 2.87×10^{4}

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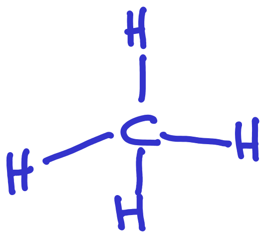
2 pt On average how much energy is stored by ONE degree of freedom for ONE single molecule?
(*in* J)

17. **A**◯ 2.41×10^{-21} **B**◯ 3.01×10^{-21} **C**◯ 3.76×10^{-21} **D**◯ 4.71×10^{-21}
E◯ 5.88×10^{-21} **F**◯ 7.35×10^{-21} **G**◯ 9.19×10^{-21} **H**◯ 1.15×10^{-20}

$T = 349\,K$

$E = \frac{1}{2} k_B T = \frac{1}{2} \cdot 1.38 \cdot 10^{-23} \frac{J}{K} \cdot 349\,K$

$E = 2.41 \cdot 10^{-21}\,J$

Methane : CH_4 :  : $f = 6$

$E_{th} = \frac{f}{2} N k_B T = f N E$

$E_{th} = 6 \cdot 8.44 \cdot 10^{23} \cdot 2.41 \cdot 10^{-21}$

$E_{th} = 1.22 \cdot 10^{4}\,J$