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
- $\rho_{\text{water}} = 1000$ kg/m^3 = 1 kg/l = 1 g/cm^3
- 1 atm = 101.3 kPa
- $N_A = 6.02\times10^{23}$ 1/mol
- $R = 8.31$ J/(molK)
- $k_B = 1.38\times10^{-23}$ J/K
- 0 °C = 273.15 K

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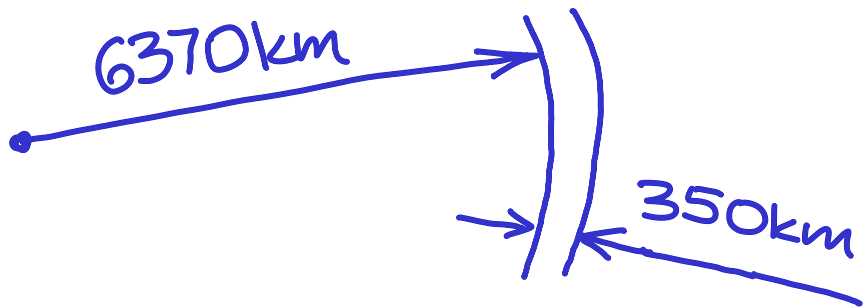
Please, sit in row I.

$\boxed{\textit{1 pt}}$ Are you sitting in the seat assigned?

1.A◯ Yes, I am.

$\boxed{3\ pt}$ The gravitational acceleration is 9.81 m/s^2 here on Earth at sea level. What is the gravitational acceleration at a height of 350 km above the surface of the Earth, where the International Space Station (ISS) flies? (The mass of the Earth is 5.97×10^{24} kg, and the radius of the Earth is 6370 km.)

2.A◯ It is 9.81 m/s^2, the same.
B◯ It is somewhat less than 9.81 m/s^2.
C◯ It is twice of 9.81 m/s^2.
D◯ It is zero, since the ISS is in the state of weightlessness.
E◯ It is somewhat greater than 9.81 m/s^2.
F◯ It is half of 9.81 m/s^2.



The height of the space station is small compared to the radius of Earth, it is about 5% of it: 350/6370 = 0.055. Therefore the gravitational acceleration is only somewhat less than g = 9.81 m/s^2.

But we can calculate it:

$$g = G\frac{M_E}{(R_E+h)^2} = 8.82\,\mathrm{m/s^2}$$

$\boxed{4\ pt}$ A 345 kg satellite is orbiting on a circular orbit 8290 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*)*

3. **A**◯ 5.21 **B**◯ 7.56 **C**◯ 1.10×10^1 **D**◯ 1.59×10^1
E◯ 2.30×10^1 **F**◯ 3.34×10^1 **G**◯ 4.84×10^1 **H**◯ 7.02×10^1

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

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

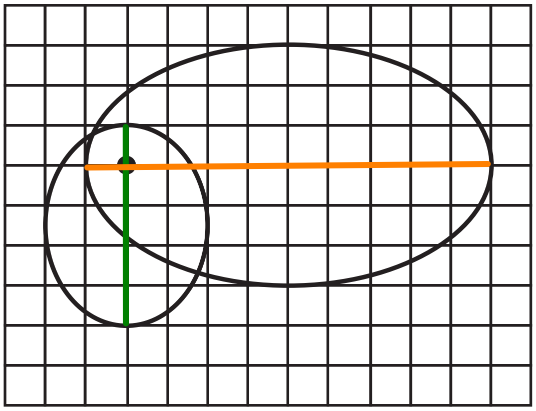
$$\left.\begin{aligned} R &= 6370\ km \\ h &= 8290\ km \end{aligned}\right\} r = R + h = 14{,}660\ km = 1.466 \times 10^7\ m$$

$m = 345\ kg$: the mass of the satellite is not needed for the speed.

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \cdot 5.97 \times 10^{24}}{1.466 \times 10^7}}$$

$v = 5212\ m/s \cong 5.21\ km/s$

4 pt The paths of two small sattellites, M_L= 8.00 kg and M_R= 3.00 kg, are shown below, drawn to scale, with M_R corresponding to the orbit on the right hand side in the figure. They orbit in the same plane around a massive star, as shown below.



$2a_L = 5 \Rightarrow a_L = 2.5$

$2a_R = 10 \Rightarrow a_R = 5$

$T_L = ?$

$T_R = 28$ yrs

The period of M_R is 28.0 years. Calculate the period of M_L, in years.

4. **A**◯ 9.90 **B**◯ 1.24×10^1 **C**◯ 1.55×10^1 **D**◯ 1.93×10^1
E◯ 2.42×10^1 **F**◯ 3.02×10^1 **G**◯ 3.78×10^1 **H**◯ 4.72×10^1

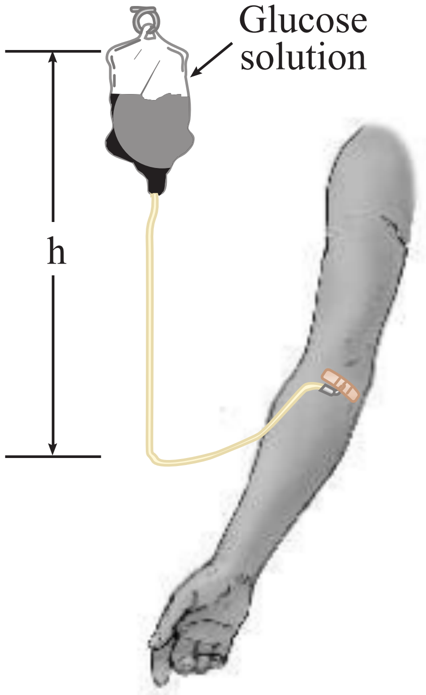
Kepler's third law:

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

$$T_L = 28 \cdot \sqrt{\frac{2.5^3}{5^3}} = \frac{28}{\sqrt{2^3}} = \frac{28}{2\sqrt{2}} = \frac{14}{\sqrt{2}}$$

$T_L = 9.9$ yrs

3 pt A collapsible plastic bag (see figure) contains a glucose solution.



If the average gauge pressure in the vein is 1.34×10^4 Pa, what must be the minimum height, h, of the bag in order to infuse glucose into the vein? Assume that the density of the solution is 1.02 kg/l.
(in m*)*

5. **A**◯ 3.03×10^{-1} **B**◯ 4.39×10^{-1} **C**◯ 6.37×10^{-1} **D**◯ 9.24×10^{-1}
E◯ 1.34 **F**◯ 1.94 **G**◯ 2.82 **H**◯ 4.08

$p = 1.34 \times 10^4 \text{ Pa} = 13.4 \text{ kPa}$

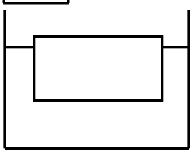
$\rho = 1.02 \text{ kg/l} = 1020 \text{ kg/m}^3$

Hydrostatic pressure:

$$p = \rho g h \Rightarrow h = \frac{p}{\rho g} = \frac{1.34 \times 10^4}{1020 \cdot 9.81}$$

$h = 1.34 \text{ m}$ ($\approx$ 4 feet)

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



When floating ice melts, the water level remain the same.

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

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

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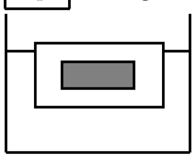
2 pt A large ice cube floats in a glass of water.



There is a block of wood frozen inside the block of ice. What happens to the water level when all the ice melts? All we know is that the density of the wood is less than the density of water. (No water is lost due to evaporation.)

7.A◯ The water level will not change.
B◯ Without knowing the density of the wood block compared to the density of the ice, we cannot answer this question.
C◯ The water level will fall.
D◯ The water level will rise.

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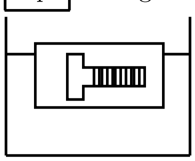
2 pt A large ice cube floats in a glass of water.



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.)

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

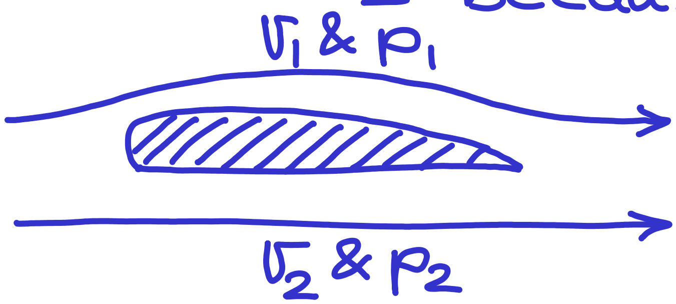
Move the wood block and the bolt to the top of the ice cubes, without changing the amount of the ice. Then toss them to the water. We are back to the boat on pond question.

4 pt An Airbus A380-800 passanger airplane is cruising at constant altitude on a straight line with a constant speed. The total surface area of the two wings is 395 m^2. The average speed of the air just below the wings is 253 m/s, and it is 283 m/s just above the surface of the wings. What is the mass of the airplane? The average density of the air around the airplane is $\rho_{\text{air}} = 1.19$ kg/m^3.
(in kg*)*

9. **A**◯ 1.637×10^5 **B**◯ 2.178×10^5 **C**◯ 2.897×10^5 **D**◯ 3.852×10^5
E◯ 5.124×10^5 **F**◯ 6.815×10^5 **G**◯ 9.063×10^5 **H**◯ 1.205×10^6

Bernoulli principle:

$$\frac{1}{2}\rho v_1^2 + \underbrace{\rho g h_1 + p_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2}_{= \text{ because } h_1 \cong h_2} + p_2$$



$$\Delta p = p_2 - p_1 = \frac{1}{2}\rho(v_1^2 - v_2^2)$$

$$F_{\text{lift}} = \Delta p \cdot A = \frac{1}{2}\rho(v_1^2 - v_2^2)A$$

$$mg = F_{\text{lift}} \Rightarrow m = \frac{F_{\text{lift}}}{g} = \frac{1}{2} \cdot \frac{\rho(v_1^2 - v_2^2)A}{g}$$

$$m = \frac{1}{2} \cdot \frac{1.19 \cdot (283^2 - 253^2) \cdot 395}{9.81} = 3.85 \times 10^5 \text{ kg} = \underbrace{= 385 \text{t}}$$

The Airbus A380 is twice as big as the Boeing 747 Jumbo Jet.

4 pt Two sounds have intensities of 1.50×10^{-8} and 9.30×10^{-4} W/m^2 respectively. What is the magnitude of the sound level difference between them in dB units?

10. **A**◯ 8.66 **B**◯ 11.52 **C**◯ 15.32 **D**◯ 20.37
E◯ 27.09 **F**◯ 36.03 **G**◯ 47.92 **H**◯ 63.74

$$I_A = 1.50 \times 10^{-8} \text{ W/m}^2$$
$$I_B = 9.30 \times 10^{-4} \text{ W/m}^2$$
$$I_o = 1.00 \times 10^{-12} \text{ W/m}^2$$

$$\beta_A = 10 \cdot \log(I_A / I_o) = 10 \cdot \log(1.5 \times 10^{-8} / 10^{-12})$$
$$\beta_A = 10 \cdot \log(1.5 \times 10^{4}) = 41.76 \text{ dB}$$
$$\beta_B = 10 \cdot \log(I_B / I_o) = 10 \cdot \log(9.3 \times 10^{-4} / 10^{-12})$$
$$\beta_B = 10 \cdot \log(9.3 \times 10^{8}) = 89.68 \text{ dB}$$

$$\beta_B - \beta_A = 47.92$$

Quick and short way:

$$\Delta\beta = \beta_B - \beta_A = 10(\log(I_B/I_o) - \log(I_A/I_o))$$
$$\Delta\beta = 10 \cdot \log \frac{I_B/I_o}{I_A/I_o} = 10 \cdot \log(I_B / I_A)$$
$$\Delta\beta = 10 \cdot \log(9.3 \times 10^{-4} / 1.5 \times 10^{-8})$$
$$\Delta\beta = 10 \cdot \log(6.2 \times 10^{4}) = 47.92$$

4 pt A stationary horn emits a sound with a frequency of 202 Hz. A car is moving toward the horn on a straight road with constant speed. If the driver of the car hears the horn at a frequency of 226 Hz, then what is the speed of the car? Use 340 m/s for the speed of the sound.
(in m/s*)*

11. **A** ◯ 9.14 **B** ◯ 1.33×10^1 **C** ◯ 1.92×10^1 **D** ◯ 2.79×10^1
E ◯ 4.04×10^1 **F** ◯ 5.86×10^1 **G** ◯ 8.49×10^1 **H** ◯ 1.23×10^2

Doppler effect:

$$f_o = f_s \cdot \frac{c \pm v_o}{c \pm v_s}$$

$c = 340$ m/s
$v_s = 0$ m/s
$v_o = ?$

$$\left.\begin{array}{l} f_s = 202\text{ Hz} \\ f_o = 226\text{ Hz} \end{array}\right\} \text{up-shift}$$

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

$$f_o \cdot c = f_s \cdot c + f_s \cdot v_o$$

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

$$v_o = 340 \cdot \frac{226 - 202}{202} = 40.4\text{ m/s}$$

$= 145$ km/h

$\underbrace{= 91 \text{ mph}}_{\text{a little too fast}}$

Church organs have a set of pipes with different lengths. With those different pipes organs can produce sounds over a wide range of frequencies.

$\boxed{2\ pt}$ If the lowest frequency produced by an organ is 29.6 Hz, and the highest frequency is 1.35 kHz, then what is the shortest possible wavelength of sound the organ can produce? Assume that the speed of sound is 341 m/s.
(in cm*)*

12. **A**◯ 25.3 **B**◯ 36.6 **C**◯ 53.1 **D**◯ 77.0 **E**◯ 112 **F**◯ 162 **G**◯ 235 **H**◯ 340.

$\boxed{2\ pt}$ What is the longest possible sound wavelength the organ can produce?
(in m*)*

13. **A**◯ 4.72 **B**◯ 5.90 **C**◯ 7.37 **D**◯ 9.22 **E**◯ 11.5 **F**◯ 14.4 **G**◯ 18.0 **H**◯ 22.5

Speed - wavelength - frequency:

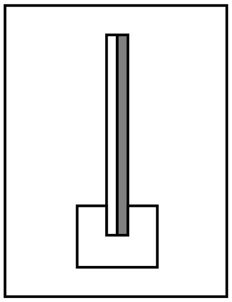
$$c = \lambda \cdot f \qquad (c = 341\,m/s)$$

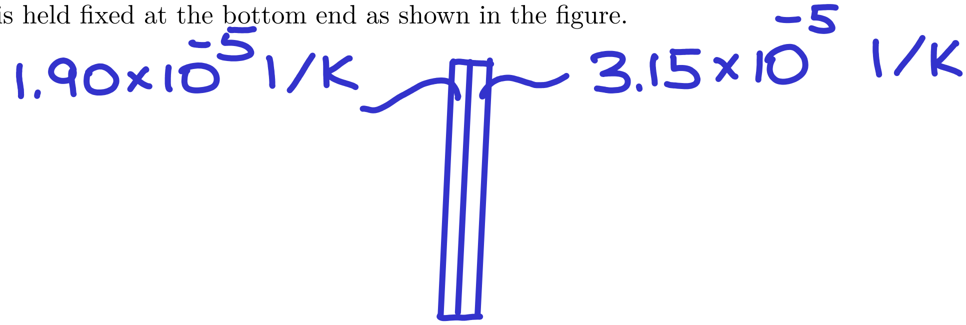
$$\lambda = \frac{c}{f}$$

$$\lambda_{shortest} = \frac{c}{f_{highest}} = \frac{341}{1350} = 0.253\,m = 25.3\,cm$$

$$\lambda_{longest} = \frac{c}{f_{lowest}} = \frac{341}{29.6} = 11.5\,m$$

$\boxed{\textit{3 pt}}$ A bimetallic strip is held fixed at the bottom end as shown in the figure.





The metal on the left has a coefficient of linear heat expansion of $\alpha_{\text{left}} = 1.90 \times 10^{-5}$ 1/K, the metal on the right has $\alpha_{\text{right}} = 3.15 \times 10^{-5}$ 1/K. When the strip is heated, it will ... (complete the sentence)

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

The metal on the right expands more than the metal on the left when the bimetallic strip is heated, because it has a larger coefficent of heat expansion than the metal on the left. Therefore the strip will bend left.

$\boxed{4\ pt}$ What is the temperature of 1.67 moles of Nitrogen gas inside a 7.81 liter container, if the pressure of the gas is 10.7 atm?
(in K*)*

15. **A**◯ 610.0 **B**◯ 762.5 **C**◯ 953.1 **D**◯ 1191.4
E◯ 1489.2 **F**◯ 1861.6 **G**◯ 2326.9 **H**◯ 2908.7

Ideal gas-law:

$$pV = nRT \Rightarrow T = \frac{pV}{nR}$$

$$R = 8.31 \frac{J}{molK}$$

$$p = 10.7 atm = 1.084 \times 10^{6} Pa$$

(because $1 atm = 101{,}300 Pa$)

$$n = 1.67 mol$$

$$V = 7.81 \ell = 7.81 \times 10^{-3} m^3$$

(because $1\ell = 10^{-3} m^3$ or $1 m^3 = 1000 \ell$)

$$T = \frac{pV}{nR} = \frac{1.084 \times 10^{6} \cdot 7.81 \times 10^{-3}}{1.67 \cdot 8.31} = 610 K$$

2 pt A gas bottle contains 6.15×10^{23} Ammonia molecules at a temperature of 308 K. What is the thermal energy of the gas? (You might need to know Boltzmann's constant: $k_B = 1.38 \times 10^{-23}$ J/K.)
(in J)

16. **A** ◯ 7.85×10^{3} **B** ◯ 8.87×10^{3} **C** ◯ 1.00×10^{4} **D** ◯ 1.13×10^{4}
E ◯ 1.28×10^{4} **F** ◯ 1.45×10^{4} **G** ◯ 1.63×10^{4} **H** ◯ 1.85×10^{4}

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2 pt What is the average energy of a single molecule?
(in J)

17. **A** ◯ 1.37×10^{-21} **B** ◯ 1.99×10^{-21} **C** ◯ 2.89×10^{-21} **D** ◯ 4.18×10^{-21}
E ◯ 6.07×10^{-21} **F** ◯ 8.80×10^{-21} **G** ◯ 1.28×10^{-20} **H** ◯ 1.85×10^{-20}

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

18. **A** ◯ 5.57×10^{-22} **B** ◯ 6.97×10^{-22} **C** ◯ 8.71×10^{-22} **D** ◯ 1.09×10^{-21}
E ◯ 1.36×10^{-21} **F** ◯ 1.70×10^{-21} **G** ◯ 2.13×10^{-21} **H** ◯ 2.66×10^{-21}

Ammonia : $NH_3 \Rightarrow f = 6$: degrees of frdm.

$N = 6.15 \times 10^{23}$: number of molecules

$T = 308\,K$: temperature

$k_B = 1.38 \times 10^{-23}$ J/K

$E_1 = \frac{1}{2} k_B T = \frac{1}{2} \cdot 1.38 \times 10^{-23} \cdot 308 = 2.13 \times 10^{-21}$ J

$E = f \cdot E_1 = 1.28 \times 10^{-20}$ J

$U = N \cdot E = 7.84 \times 10^{3}$ J