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 = 6.67×10^{-11} Nm^2/kg^2
- ρ_{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 C.

1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

$\boxed{4\ pt}$ Planet-X has a mass of 4.32×10^{24} kg and a radius of 5060 km. What is the Escape Speed *i.e.* the minimum speed required for a satellite in order to break free permanently from the planet?
(in `km/s`*)*

2. **A**◯ 4.87 **B**◯ 5.70 **C**◯ 6.66 **D**◯ 7.80
E◯ 9.12 **F**◯ 1.07×10^1 **G**◯ 1.25×10^1 **H**◯ 1.46×10^1

Escape Speed or Second Cosmic Speed :

$$v_{II} = \sqrt{\frac{2GM}{R}}$$

$G = 6.67 \cdot 10^{-11} \frac{Nm^2}{kg^2}$: Univ. Grav. Constant

$M = 4.32 \cdot 10^{24}$ kg : mass of the planet

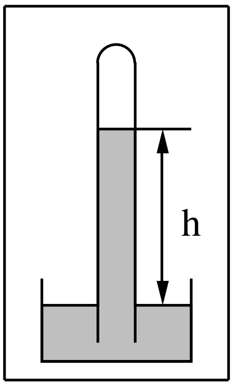
$R = 5060\,km = 5.06 \cdot 10^6$ m : radius of the planet

$$v_{II} = \sqrt{\frac{2 \cdot 6.67 \cdot 10^{-11} \cdot 4.32 \cdot 10^{24}}{5.06 \cdot 10^6}} = 10{,}672 \frac{m}{s} \cong$$

$$\cong 10.7 \frac{km}{s}$$

$$v_{II} = 1.07 \cdot 10^1 \frac{km}{s}$$

The height of the Mercury column in the Toricelli barometer is h = 760 mm here on Earth at sea level. See figure.



$\boxed{3\ pt}$ What would be the height of the Mercury column on the surface of the Moon? The Moon has no atmosphere, and the gravitational field is six times weaker on the Moon than here on Earth.

3.A◯ 0 mm.
B◯ 127 mm, six times shorter.
C◯ 760 mm, same as on Earth.
D◯ 4560 mm, six times higher.

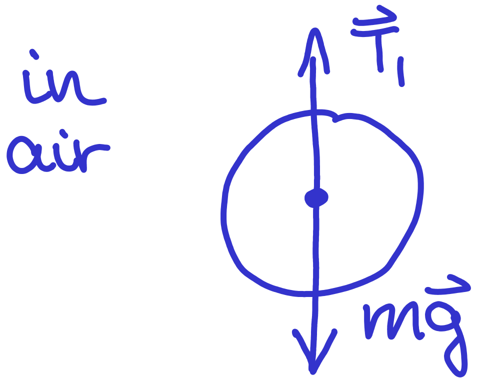
$\boxed{3\ pt}$ What would be the height of the Mercury column inside a Moon-base where an Earth-like air atmosphere is maintained for comfortable living? (The Toricelli barometer has sufficient amount of Mercury, and the glass tube can be extended, if necessary.)

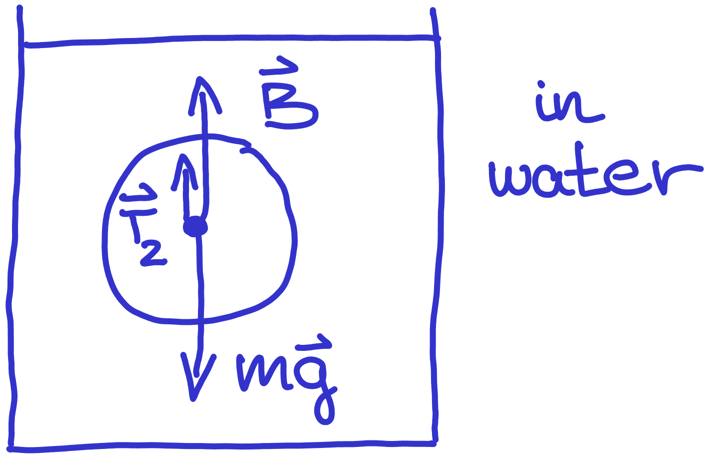
4.A◯ 0 mm.
B◯ 4560 mm, six times higher.
C◯ 127 mm, six times shorter.
D◯ 760 mm, same as on Earth.

Since the Moon doesn't have any kind of atmosphere, the barometer will show zero pressure.
Inside a Moon-base with $p = 1\,atm$:
$p = \rho g h$ (ρ: density: constant!)
Since g is six times less, therefore we need a Mercury column six times taller to balance out the one atm pressure.

$\boxed{4\ pt}$ An object weighs 87.9 N in air. When it is suspended from a force scale and completely immersed in water the scale reads 18.4 N. Determine the density of the object.
(in `kg/m^3`*)*

5. **A**◯ 6.48×10^2 **B**◯ 8.09×10^2 **C**◯ 1.01×10^3 **D**◯ 1.26×10^3
E◯ 1.58×10^3 **F**◯ 1.98×10^3 **G**◯ 2.47×10^3 **H**◯ 3.09×10^3





$$\left.\begin{array}{l} T_1 = mg \\ T_2 + B = mg \end{array}\right\} \Rightarrow T_1 = T_2 + B \Rightarrow$$

Archimedes said: $B = m_{displ.} \cdot g$

$$\Rightarrow T_1 = T_2 + m_{displ.} \cdot g = T_2 + \rho_{water} \cdot V_{obj} \cdot g =$$

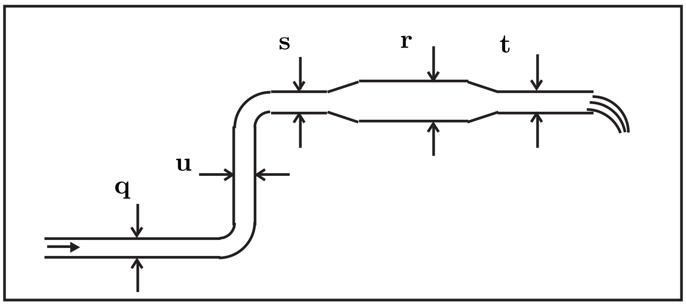
$$= T_2 + \rho_{water} \cdot \frac{m}{\rho_{obj}} \cdot g = T_2 + \frac{\rho_{water}}{\rho_{obj}} \cdot T_1$$

$$T_1 = T_2 + \frac{\rho_{water}}{\rho_{obj}} \cdot T_1 \Rightarrow \frac{T_1 - T_2}{T_1} = \frac{\rho_{water}}{\rho_{obj}} \Rightarrow$$

$$\Rightarrow \rho_{obj} = \rho_{water} \cdot \frac{T_1}{T_1 - T_2} = 1000 \cdot \frac{87.9}{87.9 - 18.4}$$

$$\rho_{obj} = 1265\ kg/m^3$$

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.



→ when you dive, the pressure increases; when you climb, the pressure decreases:

$p_q > p_u$

▷ v_q is .... $2v_r$

6. **A**◯ Greater than **B**◯ Less than **C**◯ Equal to

▷ p_q is .... p_u

7. **A**◯ Greater than **B**◯ Less than **C**◯ Equal to

▷ p_t is .... p_r

8. **A**◯ Greater than **B**◯ Less than **C**◯ Equal to

▷ v_q is .... v_s

9. **A**◯ Greater than **B**◯ Less than **C**◯ Equal to

→ when you speed up, the pressure decreases; when you slow down, the pressure increases:

$p_t < p_r$

Continuity: $v_1 \cdot A_1 = v_2 \cdot A_2$: v_1 and v_2 : speeds
A_1 and A_2 : cross sectional areas
Warning! $A = \pi r^2 = \frac{\pi d^2}{4}$: cross sectional areas are quadratic in radius or diameter.

$v_q = v_s$ because $A_q = A_s$

$v_q > 2v_r$ because $v_q = 4v_r$

since $A_q = \frac{1}{4} A_r$

3 pt What is the sound level of a sound with an intensity of I = 1.00×10^{-6} W/m^2? Give your answer in dB units.

10. **A**◯ 37.46 **B**◯ 43.83 **C**◯ 51.28 **D**◯ 60.00
E◯ 70.20 **F**◯ 82.13 **G**◯ 96.10 **H**◯ 112.43

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3 pt Now the intensity of this sound is increased to a value of 34.0 times of its original intensity. What is the new increased sound level? Give your answer in dB units.

11. **A**◯ 24.70 **B**◯ 35.82 **C**◯ 51.94 **D**◯ 75.31
E◯ 109.21 **F**◯ 158.35 **G**◯ 229.61 **H**◯ 332.93

Intensity: $I = 1 \cdot 10^{-6}$ W/m^2

Sound level: $10 \cdot \log\left(\frac{I}{I_0}\right) = 10 \log\left(\frac{10^{-6}}{10^{-12}}\right) =$

$= 10 \cdot \log(10^{-6} \cdot 10^{12}) = 10 \log 10^{6} = 10 \cdot 6 = 60\,\text{dB}$

When the intensity is increased by a factor of 34.0, the sound level changes to: $10 \log\left(34.0 \cdot \frac{I}{I_0}\right) = 10 \log 34 + 10 \log\left(\frac{I}{I_0}\right) =$

$= 15.31 + 60 = 75.31\,\text{dB}$

$\boxed{4\ pt}$ A truck horn emits a sound with a frequency of 200 Hz. The truck is moving on a straight road with a constant speed. If a person standing on the side of the road hears the horn at a frequency of 225 Hz, then what is the speed of the truck? Use 340 m/s for the speed of the sound.
(*in* m/s)

12. **A**◯ 3.78×10^1 **B**◯ 4.27×10^1 **C**◯ 4.82×10^1 **D**◯ 5.45×10^1
E◯ 6.16×10^1 **F**◯ 6.96×10^1 **G**◯ 7.87×10^1 **H**◯ 8.89×10^1

Doppler-effect:

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

$c = 340$ m/s : speed of sound
$f_s = 200$ Hz : source frequency
$f_o = 225$ Hz : observed frequency
$v_o = 0$ m/s : speed of the observer
$v_s = ?$: speed of the source

Since the shift is UP:

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

$$f_o c - f_o v_s = f_s c$$

$$f_o c - f_s c = f_o v_s$$

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

$$v_s = 340 \cdot \frac{225 - 200}{225} = 340 \cdot \frac{25}{225} = \frac{340}{9}$$

$$v_s = 37.8 \frac{m}{s} = 136 \frac{km}{h} = 84.5 \frac{mi}{h} \Big\} \text{ too fast!}$$

$\boxed{3\ pt}$ An organ pipe is 1.70 m long and it is open at one end and closed at the other end. 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.

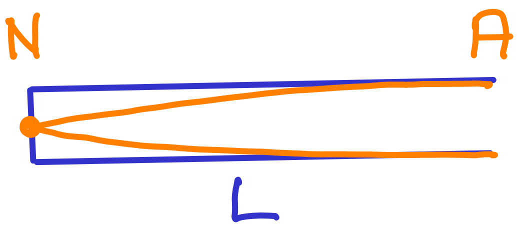
13.A◯ 200 Hz, 300 Hz, 400 Hz
B◯ 50 Hz, 100 Hz, 150 Hz
C◯ 100 Hz, 300 Hz, 500 Hz
D◯ 50 Hz, 100 Hz, 200 Hz
E◯ 100 Hz, 200 Hz, 300 Hz
F◯ 200 Hz, 600 Hz, 1000 Hz
G◯ 50 Hz, 150 Hz, 250 Hz
H◯ 200 Hz, 400 Hz, 600 Hz

$c = 340\,\mathrm{m/s}$

$c = \lambda f$

An open-closed pipe can hold

$\frac{1}{4}, \frac{3}{4}, \frac{5}{4}, \frac{7}{4}, \frac{9}{4} \ldots$ wavelengths.



lowest mode:

$L = \frac{1}{4}\lambda$

$4L = \lambda$

$$c = \lambda f \Rightarrow f = \frac{c}{\lambda} = \frac{c}{4L} = \frac{340}{4 \cdot 1.7} = 50\,\mathrm{Hz}$$

$f_1 = 50\,\mathrm{Hz}$: fundamental frequency

The possible frequencies are:

f_1 ; $3f_1$; $5f_1$; $7f_1$; $9f_1$; ...

50Hz ; 150Hz ; 250Hz ; 350Hz ; 450Hz

$\boxed{\textit{4 pt}}$ The height of the Eiffel tower is 321 m during the Summer when the temperature is 25.3 °C. What is the magnitude of the change in the height of the tower, when the temperature cools down to -12.0 °C during the Winter? The coefficient of linear expansion of the tower's material is 1.18×10^{-5} 1/C°.
(in cm*)*

14. **A**◯ 1.06×10^1 **B**◯ 1.41×10^1 **C**◯ 1.88×10^1 **D**◯ 2.50×10^1
E◯ 3.32×10^1 **F**◯ 4.42×10^1 **G**◯ 5.88×10^1 **H**◯ 7.82×10^1

Heat expansion/contraction:

$$\Delta l = \alpha \cdot l_0 \cdot \Delta T =$$
$$= 1.18 \cdot 10^{-5} \cdot 321 \cdot (25.3 - (-12.0)) =$$
$$= 0.141\,m = 14.1\,cm$$

$\boxed{3\ pt}$ What is the pressure of 1.07 moles of Nitrogen gas in a 4.71 liter container, if the temperature of the gas is 40.2 °C?
(in `atm`*)*

15. **A**◯ 1.32 **B**◯ 1.92 **C**◯ 2.78 **D**◯ 4.03
E◯ 5.84 **F**◯ 8.47 **G**◯ 12.28 **H**◯ 17.80

Ideal gas law:

$$pV = nRT$$

$$p = \frac{nRT}{V}$$

$$R = 8.31 \frac{J}{mol \cdot K} \text{ : Regnault constant}$$

$$T = 40.2\,°C \cong 313.2\,K$$

$$V = 4.71\,\ell = 0.00471\,m^3$$

$$n = 1.07\,mol$$

$$p = \frac{1.07 \cdot 8.31 \cdot 313.2}{0.00471} = 5.91 \cdot 10^5\,Pa \cong$$

$$\cong 5.84\,atm$$

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

$\boxed{4\ pt}$ A 24.5 l gas bottle contains 9.87×10^{23} Radon molecules at a temperature of 312 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**◯ 6.38×10^{3} **B**◯ 9.25×10^{3} **C**◯ 1.34×10^{4} **D**◯ 1.94×10^{4}
E◯ 2.82×10^{4} **F**◯ 4.09×10^{4} **G**◯ 5.93×10^{4} **H**◯ 8.59×10^{4}

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

Rn : Radon : noble gas : single atom molecules : $f=3$: three translations only.

$$E_{th} = \frac{3}{2} \cdot 9.87 \cdot 10^{23} \cdot 1.38 \cdot 10^{-23} \cdot 312$$

$$E_{th} = 1.5 \cdot 9.87 \cdot 1.38 \cdot 312$$

$$E_{th} = 6374\,J$$

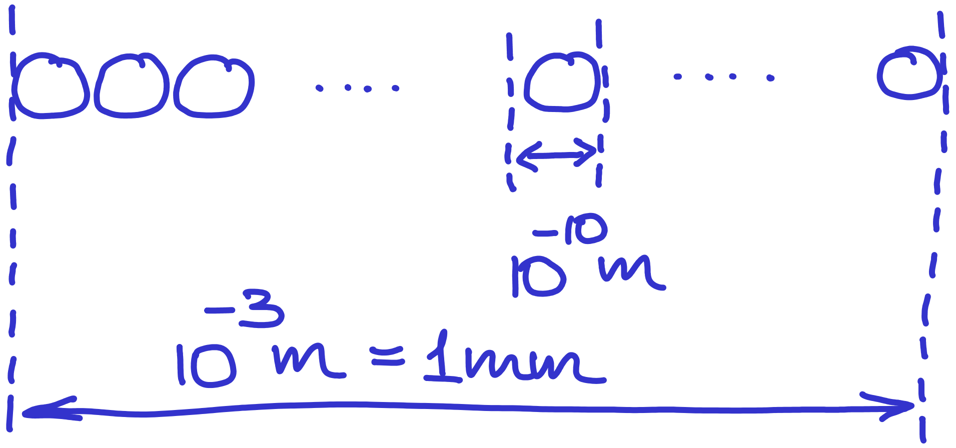
The volume of the gas was not needed!

3 pt The diameter of the Hydrogen atom is almost exactly one angstrom which is 10^{-10} meter. How many Hydrogen atoms do we need to place next to each-other side by side to form a one millimeter long chain?

17.A◯ one hundred
B◯ one thousand
C◯ one million
D◯ ten million
E◯ hundred million
F◯ one billion
G◯ one trillion
H◯ 6×10^{23}

$1\,\text{Å} = 10^{-10}\,\text{m}$: diameter of the H-atom

$1\,\text{mm} = 10^{-3}\,\text{m}$: length of the chain



$$N = \frac{10^{-3}}{10^{-10}} = 10^{-3}\cdot 10^{10} = 10^{7} = \text{ten million}$$