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

nagytibo@msu

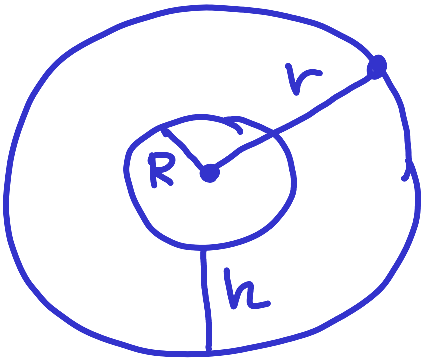
Please, sit in row C.

1 pt Are you sitting in the seat assigned?

1.A◯ Yes, I am.

4 pt A 215 kg satellite is orbiting on a circular orbit 5980 km above the Earth's surface. What is the gravitational acceleration at the location of the satellite? (The mass of the Earth is 5.97×10^{24} kg, and the radius of the Earth is 6370 km.)
(*in* `m/s^2`)

2. **A**◯ 1.24 **B**◯ 1.80 **C**◯ 2.61 **D**◯ 3.79
E◯ 5.49 **F**◯ 7.96 **G**◯ 11.54 **H**◯ 16.73



$r = R + h$

$r = 6370 + 5980 = 12{,}350\ \text{km}$

$r = 1.235 \cdot 10^{7}\ \text{m}$

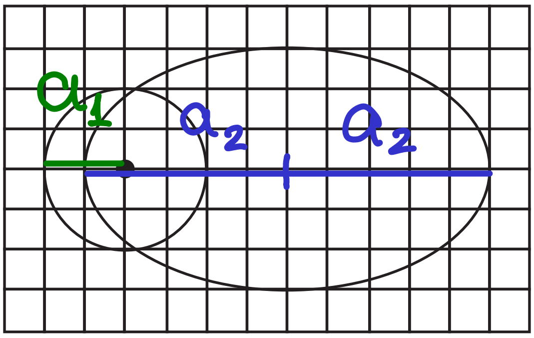
Gravitational force:

$$F_G = G\frac{Mm}{r^2} = \underbrace{\frac{GM}{r^2}}_{g_{local}} \cdot m$$

$$g_{local} = \frac{GM}{r^2} = \frac{6.67 \cdot 10^{-11} \cdot 5.97 \cdot 10^{24}}{(1.235 \cdot 10^{7})^2}$$

$$g_{local} = 2.61\ \text{m/s}^2$$

4 pt The paths of two small satellites, M1 = 8.00 kg and M2 = 9.00 kg, are shown below, drawn to scale, with M1 corresponding to the circular orbit. They orbit around a massive star, also shown below. The orbits are in the plane of the paper.



$M_1: a_1 = r_1 = 2$

$M_2: a_2 = 5$

The period of M1 is T1 = 22.0 years. Calculate the period of M2, in years.

3. **A**◯ 6.00×10^1 **B**◯ 8.70×10^1 **C**◯ 1.26×10^2 **D**◯ 1.83×10^2
E◯ 2.65×10^2 **F**◯ 3.84×10^2 **G**◯ 5.57×10^2 **H**◯ 8.08×10^2

Kepler's third law:

$$\frac{T_1^2}{T_2^2} = \frac{a_1^3}{a_2^3} \Rightarrow T_1^2 \cdot \frac{a_2^3}{a_1^3} = T_2^2 \Rightarrow$$

$$\Rightarrow T_2 = T_1 \left(\frac{a_2}{a_1}\right)^{3/2}$$

$$T_2 = 22 \cdot \left(\frac{5}{2}\right)^{3/2} \cong 87 \text{ years}$$

5 pt Glucose solution is administered to a patient in a hospital. The density of the solution is 1.288 kg/l. If the blood pressure in the vein is 39.7 mmHg, then what is the minimum necessary height of the IV bag above the position of the needle?
(in cm*)*

$1{,}288 \frac{kg}{l} = 1288 \frac{kg}{m^3}$

4. **A**◯ 26.8 **B**◯ 33.5 **C**◯ 41.9 **D**◯ 52.3
E◯ 65.4 **F**◯ 81.8 **G**◯ 102.2 **H**◯ 127.8

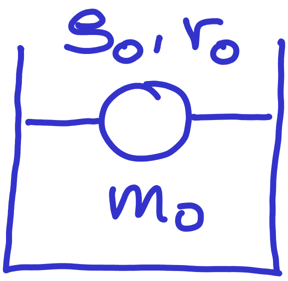
Hydrostatic pressure:

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

If 760 mmHg = 101,300 Pa,
then 1 mmHg = 133.3 Pa.

$h = \frac{39{,}7 \cdot 133{,}3}{1288 \cdot 9{,}81} = 0{,}419\ m = 41{,}9\ cm$

6 pt A solid, homogeneous sphere with a mass of m_0, a radius of r_0 and a density of ρ_0 is placed in a container of water. Initially the sphere floats and the water level is marked on the side of the container. What happens to the water level, when the original sphere is replaced with a new sphere which has different physical parameters? Notation: r means the water level rises in the container, f means falls, s means stays the same.



$\rho = \frac{m}{V}$

▷ The new sphere has a density of $\rho = \rho_0$ and a radius of $r < r_0$.
5. **A**◯ r **B**◯ f **C**◯ s

▷ The new sphere has a density of $\rho < \rho_0$ and a mass of $m = m_0$.
6. **A**◯ r **B**◯ f **C**◯ s

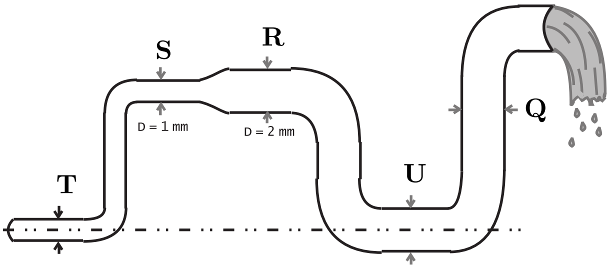
▷ The new sphere has a density of $\rho = \rho_0$ and a mass of $m < m_0$.
7. **A**◯ r **B**◯ f **C**◯ s

→ falls because if $r < r_0$ then $m < m_0$

→ same because $m = m_0$ and the object stays afloat

→ falls because $m < m_0$

6 pt The figure illustrates flow through a pipe with diameters of 1 mm and 2 mm and with different elevations. p_x is the pressure in the pipe, and v_x is the speed of a non-viscous incompressible fluid at locations x = Q,R,S,T, or U.



Circle area:

$A = \pi r^2 = \frac{\pi d^2}{4}$

$A \propto d^2$

Continuity:

$A_1 v_1 = A_2 v_2$

Select the correct answers.

▷ v_R is ... $0.5v_T$.

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

▷ p_U is ... p_R.

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

▷ p_U is ... p_T.

10. A◯ Greater than B◯ Less than C◯ Equal to

→ $v_R = 0.25 v_T$ b/c $A_R = 4A_T$ therefore $v_R < 0.5 v_T$

→ $p_u > p_R$ b/c the pressure increases when you dive deeper ($p = \rho g h$)

→ $p_u > p_T$ b/c the pressure increases when you slow down. Bernoulli:

$\frac{1}{2}\rho v^2 + \rho g h + p = \text{constant}$

4 pt You are listening to music in your room. Both of the speakers (left and right) of your stereo are set to 70 decibels. What is the sound level in your room?

11.A◯ 140 decibels.
B◯ 120 decibels, because our ears cannot hear beyond the pain threshold.
C◯ 73 decibels.
D◯ 70 decibels.
E◯ 63 decibels.
F◯ 60 decibels.
G◯ Zero decibels. The soundwaves from the two speakers cancel each-other out due to destructive interference.

$\beta_{left} = \beta_{right} = \beta_1 = 70\ dB$

Both speakers on: $\beta_2 = ?$

Intensity from one speaker: I_1

Intensity from two speakers:

$I_2 = I_1 + I_1 = 2I_1$ } energy conservation

Sound level from two speakers:

$$\beta_2 = 10 \cdot \log\left(\frac{I_2}{I_0}\right) = 10 \cdot \log\left(\frac{2I_1}{I_0}\right) =$$

$$= 10 \cdot \left[\log 2 + \log \frac{I_1}{I_0}\right] =$$

$$= \underbrace{10 \log 2}_{3.01} + \underbrace{10 \log \frac{I_1}{I_0}}_{\beta_1} = 3.01 + 70 \cong 73\ dB$$

4 pt A truck horn emits a sound with a frequency of 246 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 224 Hz, then what is the speed of the truck? Use 340 m/s for the speed of the sound.
(*in* m/s)

$v_o = 0$ m/s

12. **A** ◯ 1.89×10^1 **B** ◯ 2.51×10^1 **C** ◯ 3.34×10^1 **D** ◯ 4.44×10^1
E ◯ 5.91×10^1 **F** ◯ 7.86×10^1 **G** ◯ 1.04×10^2 **H** ◯ 1.39×10^2

Source frequency: $f_s = 246$ Hz
Observed freq. : $f_o = 224$ Hz
The shift is down, therefore the truck is moving away from the person.

Doppler formula:

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

$$c f_o + v_s f_o = c f_s$$

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

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

$$v_s = 340 \cdot \frac{246 - 224}{224} = 33.4 \frac{m}{s}$$

4 pt A transverse mechanical wave is traveling on a horizontal steel cable. The vertical position of the cable elements as a function of space and time is described by the following wave equation:
$y(x,t) = 0.19\sin(2.43x - 82.3t)$,
where x and y are measured in meters, and t in seconds. What is the speed of the wave?
(in m/s*)*

13. **A**◯ 18.1 **B**◯ 21.1 **C**◯ 24.7 **D**◯ 28.9 **E**◯ 33.9 **F**◯ 39.6 **G**◯ 46.4 **H**◯ 54.2

Wave equation:

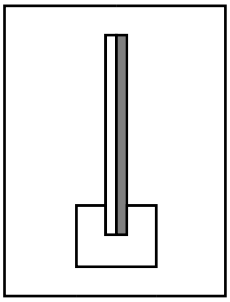
$$y(x,t) = A \cdot \sin(kx - \omega t)$$

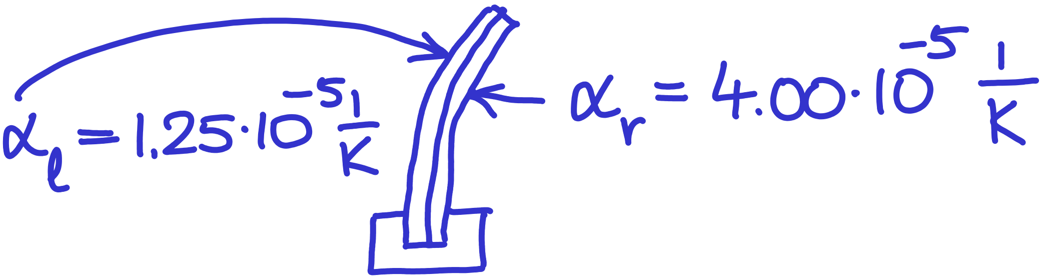
$$c = \frac{\omega}{k}$$ ← ω: angular frequency; k: wave number

↑ c: speed of the wave

$$c = \frac{82.3 \text{ rad/s}}{2.43 \text{ rad/m}} = 33.9 \text{ m/s}$$

4 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 $\alpha_{\text{left}} = 1.25 \times 10^{-5}$ 1/K, the metal on the right has $\alpha_{\text{right}} = 4.00 \times 10^{-5}$ 1/K. When the strip is cooled, it will ... (complete the sentence)

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

When the strip is cooled, the metal with the larger coefficient of heat expansion contract more.

4 pt What is the temperature of 1.07 moles of Nitrogen gas inside a 5.66 liter container, if the pressure of the gas is 10.4 atm?
(in K)

15. **A**◯ 504.2 **B**◯ 670.6 **C**◯ 891.9 **D**◯ 1186.3
E◯ 1577.7 **F**◯ 2098.4 **G**◯ 2790.8 **H**◯ 3711.8

Ideal Gas Law: $pV = nRT$

$n = 1.07 \text{ mol}$

$V = 5.66 \ell = 5.66 \cdot 10^{-3} \text{ m}^3$

$p = 10.4 \text{ atm} = 1.05 \cdot 10^6 \text{ Pa}$

$R = 8.31 \text{ J/(mol} \cdot \text{K)}$

$T = \frac{pV}{nR} = 670.6 \text{ K} \quad (= 397.5 ^\circ\text{C})$

4 pt A gas cylinder contains 7.99×10^{23} Oxygen molecules at a temperature of 313 K. What is the thermal energy of the gas?
(in J)

16. **A** ◯ 8.63×10^{3} **B** ◯ 9.75×10^{3} **C** ◯ 1.10×10^{4} **D** ◯ 1.25×10^{4}
E ◯ 1.41×10^{4} **F** ◯ 1.59×10^{4} **G** ◯ 1.80×10^{4} **H** ◯ 2.03×10^{4}

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

$$N = 7.99 \cdot 10^{23}$$

$$T = 313\,K$$

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

Oxygen : O_2 :  $f = 5$

$$E_{th} = \frac{5}{2} \cdot 7.99 \cdot 10^{23} \cdot 1.38 \cdot 10^{-23} \cdot 313$$

$$E_{th} = 8628\,J$$