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
- $N_A = 6.02\times10^{23}$ 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 L.

1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

3 pt Planet-X has a mass of 4.70×10^{24} kg and a radius of 8160 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**◯ 5.61 **B**◯ 7.01 **C**◯ 8.77 **D**◯ 1.10×10^{1}
E◯ 1.37×10^{1} **F**◯ 1.71×10^{1} **G**◯ 2.14×10^{1} **H**◯ 2.68×10^{1}

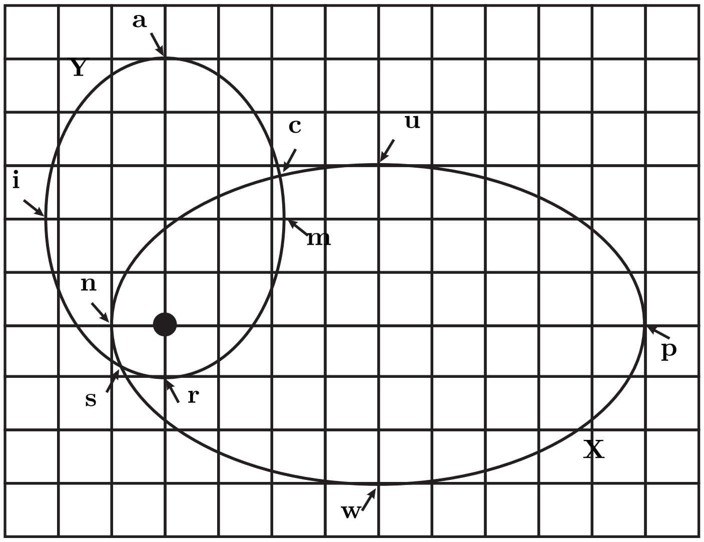
Escape Speed or Second Cosmic Speed:

$$v_{II} = \sqrt{\frac{2GM}{R_p}} \quad \text{from} \quad \underbrace{\underbrace{-G\frac{Mm}{R_p}}_{PE} + \underbrace{\frac{1}{2}mv^2}_{KE}}_{TE} = 0$$

$$v_{II} = \sqrt{\frac{2 \cdot 6.67\times10^{-11} \cdot 4.70\times10^{24}}{8.16\times10^{6}}}$$

$$v_{II} = 8766 \frac{m}{s} \approx 8.77 \frac{km}{s}$$

10 pt The paths of two small satellites, X and Y, of equal mass of 6.00 kg each, are shown below. They orbit around a massive star, as illustrated, with M = 7.20×10^{29} kg. The orbits are in the plane of the paper and are drawn to scale.



In the statements below KE is kinetic energy, PE is potential energy, and $|\mathbf{L}|$ is magnitude of the angular momentum.

▷ The PE of Y at a is .... the PE of X at p.
3. A◯ greater than B◯ less than C◯ equal to

▷ The $|\mathbf{L}|$ of Y at a is .... that at r.
4. A◯ greater than B◯ less than C◯ equal to

▷ The speed of X at p is .... that at u
5. A◯ greater than B◯ less than C◯ equal to

▷ At s, the PE of X is .... that of Y.
6. A◯ greater than B◯ less than C◯ equal to

▷ At s, the KE of X is .... that of Y.
7. A◯ greater than B◯ less than C◯ equal to

#3: $PE = -G\frac{Mm}{d}$: larger distance means larger potential energy. Lager, because it is less negative.

#4: L is constant, because $\tau = 0$. The torque is zero, because gravitational force is central, and central forces cannot apply torque.

#5: Kepler's second law: when you move in you speed up, when you move out you slow down.

#6: $PE = -G\frac{Mm}{d}$: at the same distance you have the same potential energy.

#7: $TE = -\frac{1}{2}G\frac{Mm}{a}$: the longer ellipse has more mechanical energy (less negative). Since PE is the same at the intersection point, the satellite with the larger total mechanical energy has larger kinetic energy.

2 pt Which one weighs more, one kilogram iron or one kilogram feather?

8.A ◯ They weigh the same.
B ◯ The feather weighs more.
C ◯ The iron weighs more.
D ◯ It depends on the type of the iron and the feather.

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2 pt Which one displaces more water, one kilogram wood or one kilogram styrofoam?

9.A ◯ It depends on the type of the wood and the styrofoam.
B ◯ They displace the same amount of water.
C ◯ The styrofoam displaces more water.
D ◯ The wood displaces more water.

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2 pt Which one displaces more water, one kilogram iron or one kilogram styrofoam?

10.A ◯ It depends on the type of the iron and the styrofoam.
B ◯ The styrofoam displaces more water.
C ◯ They displace the same amount of water.
D ◯ The iron displaces more water.

#8: weight $= mg$: same mass means same weight. (Their volumes and therefore their densities are very different.)

#9: Since they both float on the surface, they both displace 1kg of water.

#10: Since the iron sinks, it will displace water equivalent to its volume, which is small : $V = \frac{m}{\rho}$ because the density of the iron is greater than the density of water. The styrofoam still displaces 1 kg water.

4 pt An object weighs 73.8 N in air. When it is suspended from a force scale and completely immersed in water the scale reads 22.9 N. Determine the density of the object.
(*in* `kg/m^3`)

11. **A**◯ 1.45×10^3 **B**◯ 1.81×10^3 **C**◯ 2.27×10^3 **D**◯ 2.83×10^3
E◯ 3.54×10^3 **F**◯ 4.42×10^3 **G**◯ 5.53×10^3 **H**◯ 6.91×10^3

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in air: $F_1 = mg$
in water: $F_2 + B = mg$
$\Big\} \; F_1 = F_2 + B$

$$F_1 - F_2 = m_{water} \cdot g \quad \leftarrow B = m_{water} \cdot g$$

$$F_1 - F_2 = \rho_{water} \cdot V_{obj} \cdot g$$

$$F_1 - F_2 = \rho_{water} \cdot \frac{m_{obj}}{\rho_{obj}} \cdot g$$

$$F_1 - F_2 = \frac{\rho_{water}}{\rho_{obj}} \cdot F_1 \quad \leftarrow \quad F_1 = m_{obj} \cdot g$$

$$\rho_{obj} = \rho_{water} \cdot \frac{F_1}{F_1 - F_2}$$

$$\rho_{obj} = 1000 \cdot \frac{73.8}{73.8 - 22.9} = 1450 \frac{kg}{m^3}$$

3 pt What is the sound level of a sound with an intensity of $I = 1.00 \times 10^{-6}$ W/m²? Give your answer in dB units.

12. **A** ◯ 13.57 **B** ◯ 19.68 **C** ◯ 28.54 **D** ◯ 41.38
E ◯ 60.00 **F** ◯ 87.00 **G** ◯ 126.15 **H** ◯ 182.92

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3 pt Now the intensity of this sound is increased to a value of 44.0 times of its original intensity. What is the new increased sound level? Give your answer in dB units.

13. **A** ◯ 32.49 **B** ◯ 43.21 **C** ◯ 57.47 **D** ◯ 76.43
E ◯ 101.66 **F** ◯ 135.21 **G** ◯ 179.82 **H** ◯ 239.16

$$\beta(dB) = 10 \log(I/I_0) = 10 \log\left(\frac{10^{-6}}{10^{-12}}\right) =$$
$$= 10 \log(10^6) = 10 \cdot 6 = 60\,dB$$
$$\beta_{new}(dB) = 10 \log\left(\frac{44 I}{I_0}\right) = 10 \log(44) +$$
$$+ 10 \log\left(\frac{I}{I_0}\right) = 10 \cdot 1.643 + 10 \cdot 6 =$$
$$= 16.43 + 60 = 76.43\,dB$$

4 pt A truck horn emits a sound with a frequency of 235 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 255 Hz, then what is the speed of the truck? Use 340 m/s for the speed of the sound.
(in m/s*)*

14. **A**◯ 1.51×10^1 **B**◯ 2.01×10^1 **C**◯ 2.67×10^1 **D**◯ 3.55×10^1
E◯ 4.72×10^1 **F**◯ 6.27×10^1 **G**◯ 8.34×10^1 **H**◯ 1.11×10^2

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

$c = 340\ m/s$

$f_s = 235\ Hz$ } up-shift
$f_o = 255\ Hz$

$v_o = 0\ m/s$: person standing

$v_s = ?$ truck speed

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

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

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

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

$$v_s = 340 \cdot \frac{255 - 235}{255} = 26.7\ \frac{m}{s} = 96\ \frac{km}{h}$$

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.

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

Open-closed: it holds a quarter wavelength and the harmonic number goes as: $n = 1, 3, 5, 7, \ldots$

$$L = \frac{1}{4}\lambda_1 \Rightarrow \lambda_1 = 4L \Rightarrow f_1 = \frac{c}{\lambda_1} = \frac{c}{4L}$$

$$f_1 = \frac{340}{4 \cdot 1.7} = \frac{340}{6.8} = 50\,\text{Hz}$$

Therefore the frequencies are:

50 Hz, 150 Hz, 250 Hz, 350 Hz, ...

3 pt The height of the Eiffel tower is 321 m during the Summer when the temperature is 28.2 °C. What is the magnitude of the change in the height of the tower, when the temperature cools down to -19.5 °C during the Winter? The coefficient of linear expansion of the tower's material is 1.10×10^{-5} 1/C°.
(in cm*)*

16. **A**◯ 6.90 **B**◯ 8.62 **C**◯ 1.08×10^1 **D**◯ 1.35×10^1
E◯ 1.68×10^1 **F**◯ 2.11×10^1 **G**◯ 2.63×10^1 **H**◯ 3.29×10^1

$L_0 = 321\,m$

$T_1 = 28.2\,°C$, $T_2 = -19.5\,°C$ $\Big\}$ $|\Delta T| = |T_2 - T_1| = 47.7\,°C$

$\alpha = 1.10 \times 10^{-5}\ 1/°C$

$\Delta L = \alpha L_0 \Delta T = 1.10 \times 10^{-5} \cdot 321 \cdot 47.7$

$\Delta L = 0.168\,m = 16.8\,cm$

[*4 pt*] What is the pressure of 1.66 moles of Nitrogen gas in a 6.13 liter container, if the temperature of the gas is 31.6 °C?
(in `atm`*)*

17. **A**◯ 4.23 **B**◯ 4.95 **C**◯ 5.79 **D**◯ 6.77
E◯ 7.92 **F**◯ 9.27 **G**◯ 10.84 **H**◯ 12.69

Ideal Gas Law: $pV = nRT$

$$p = \frac{nRT}{V} = \frac{1.66 \cdot 8.31 \cdot (31.6 + 273)}{0.00613}$$

$p = 6.85 \times 10^5\ Pa = 6.77\ atm$

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

2 pt A gas bottle contains 5.12×10^{23} Hydrogen molecules at a temperature of 315 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)

18. **A** ◯ 4.19×10^{3} **B** ◯ 5.57×10^{3} **C** ◯ 7.40×10^{3} **D** ◯ 9.85×10^{3}
E ◯ 1.31×10^{4} **F** ◯ 1.74×10^{4} **G** ◯ 2.32×10^{4} **H** ◯ 3.08×10^{4}

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

19. **A** ◯ 1.17×10^{-21} **B** ◯ 1.70×10^{-21} **C** ◯ 2.46×10^{-21} **D** ◯ 3.57×10^{-21}
E ◯ 5.17×10^{-21} **F** ◯ 7.50×10^{-21} **G** ◯ 1.09×10^{-20} **H** ◯ 1.58×10^{-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)

20. **A** ◯ 1.86×10^{-21} **B** ◯ 2.17×10^{-21} **C** ◯ 2.54×10^{-21} **D** ◯ 2.98×10^{-21}
E ◯ 3.48×10^{-21} **F** ◯ 4.07×10^{-21} **G** ◯ 4.77×10^{-21} **H** ◯ 5.58×10^{-21}

#20: $\epsilon_1 = \frac{1}{2} k_B T = \frac{1}{2} \cdot 1.38 \times 10^{-23} \cdot 315 = 2.17 \times 10^{-21}$ J

#19: $\bar{\epsilon} = f \cdot \epsilon_1 = \frac{f}{2} k_B T$ and $f = 5$ for H_2

$\bar{\epsilon} = \frac{5}{2} k_B T = 5 \cdot \epsilon_1 = 1.09 \times 10^{-20}$ J

#18: $E_{th} = N \bar{\epsilon} = \frac{f}{2} N k_B T$ where $N = 5.12 \times 10^{23}$

$E_{th} = N \bar{\epsilon} = 5.12 \times 10^{23} \cdot 1.09 \times 10^{-20} \cong 5570$ J