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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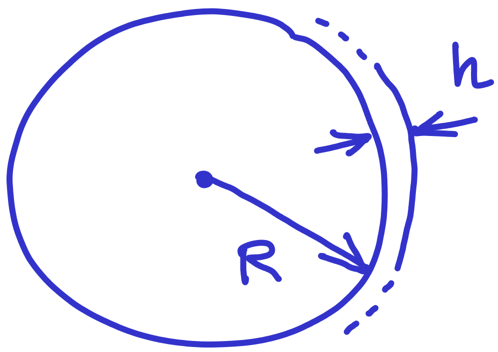
Please, sit in row J.

1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

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



$h = 350$ km
$R = 6370$ km

Since $h \ll R$ (h is about 5.5% of R), we can immediately tell that the local gravitational acceleration is somewhat less than 9.81 m/s^2.

But if we want to calculate it:

$$g = G \cdot \frac{M}{r^2} = G \cdot \frac{M}{(R+h)^2} = 8.82\ m/s^2$$

3 pt A 153 kg satellite is orbiting Earth on a circular orbit with a speed of 5.17 km/s. Determine the height of the satellite above Earth's surface. (The mass of the Earth is 5.97×10^{24} kg, and the radius of the Earth is 6370 km.) *(in* km*)*

3. **A**◯ 5.46×10^3 **B**◯ 6.82×10^3 **C**◯ 8.53×10^3 **D**◯ 1.07×10^4
E◯ 1.33×10^4 **F**◯ 1.67×10^4 **G**◯ 2.08×10^4 **H**◯ 2.60×10^4

From $G\frac{Mm}{r^2} = m\frac{v^2}{r} \Rightarrow \frac{GM}{v^2} = r \Rightarrow$

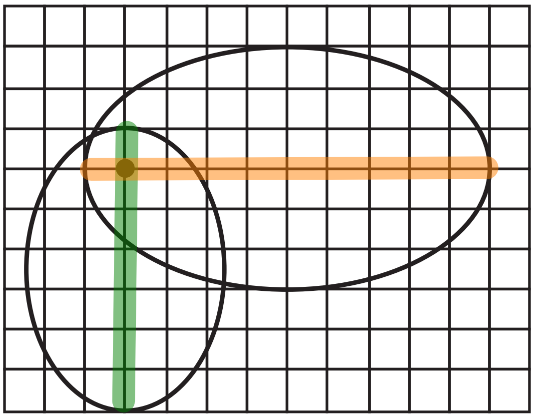
$$r = \frac{6.67\cdot 10^{-11} \cdot 5.97\cdot 10^{24}}{5170^2} = 1.49\cdot 10^7\,\text{m} =$$

$= 14{,}900$ km

From $R + h = r \Rightarrow h = r - R =$

$= 14{,}900 - 6370 = 8530$ km

3 pt The paths of two small sattellites, M_L= 2.00 kg and M_R= 3.00 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.



Kepler's third law:

$$\frac{T_1^2}{T_2^2} = \frac{a_1^3}{a_2^3} = \frac{(2a_1)^3}{(2a_2)^3}$$

$2a_1 = 7$ $2a_2 = 10$

The period of M_L is 36.0 years. Calculate the period of M_R, in years.

4. **A**◯ 2.02×10^1 **B**◯ 2.92×10^1 **C**◯ 4.24×10^1 **D**◯ 6.15×10^1
E◯ 8.91×10^1 **F**◯ 1.29×10^2 **G**◯ 1.87×10^2 **H**◯ 2.72×10^2

$$\frac{36^2}{T_2^2} = \frac{7^3}{10^3} \Rightarrow T_2 = 36 \cdot \sqrt{\frac{10^3}{7^3}}$$

$T_2 = 61.5$ years

3 pt Glucose solution is administered to a patient in a hospital. The density of the solution is 1.202 kg/l. If the blood pressure in the vein is 41.4 mmHg, then what is the minimum necessary height of the IV bag above the position of the needle?
(in cm*)*

$1.202\,kg/l = 1202\,kg/m^3$

5. **A**◯ 32.4 **B**◯ 36.6 **C**◯ 41.4 **D**◯ 46.8 **E**◯ 52.9 **F**◯ 59.8 **G**◯ 67.5 **H**◯ 76.3

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

$$1\,atm = 760\,mmHg = 101{,}300\,Pa$$

$$1\,mmHg = 133.3\,Pa$$

$$h = \frac{41.4 \cdot 133.3}{1202 \cdot 9.81} = 0.468\,m = 46.8\,cm$$

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

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

Since they are both a kg they both weigh the same: weight = m · g

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

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

Since they both float on the surface, they both displace water equivalent to their mass.

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

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

Since the styrofoam floats on the surface, it displaces water equivalent to its mass: 1kg. Since the iron sinks, it displaces water equivalent to its volume. The volume of the iron is small, because the density of it is high: V = m/ϱ. Therefore the iron will displace less than 1kg water.

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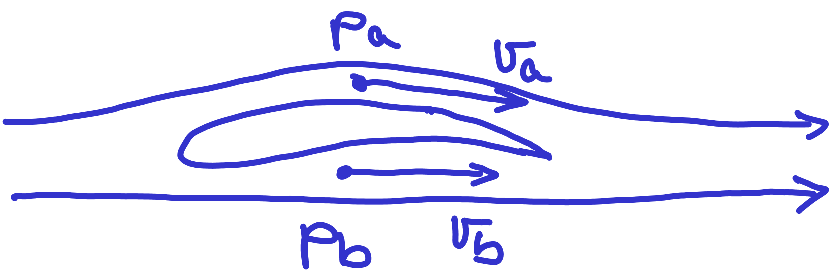
4 pt An Airbus A380-800 passanger airplane is cruising at constant altitude on a straight line with a constant speed. The total surface area of the two wings is 395 m^2. The average speed of the air just below the wings is 243 m/s, and it is 271 m/s just above the surface of the wings. What is the mass of the airplane? The average density of the air around the airplane is $\rho_{\text{air}} = 1.25$ kg/m^3.
(in kg*)*

9. **A**◯ 3.622×10^5 **B**◯ 4.527×10^5 **C**◯ 5.659×10^5 **D**◯ 7.074×10^5
E◯ 8.842×10^5 **F**◯ 1.105×10^6 **G**◯ 1.382×10^6 **H**◯ 1.727×10^6



Bernoulli principle:

$$\frac{1}{2}\rho v_a^2 + \cancel{\rho g h} + p_a = \frac{1}{2}\rho v_b^2 + \cancel{\rho g h} + p_b$$

$$\frac{1}{2}\rho v_a^2 - \frac{1}{2}\rho v_b^2 = p_b - p_a = \Delta p$$

This dynamic lift holds the weight:

$$\Delta p \cdot A = mg$$

$$m = \frac{\Delta p \cdot A}{g} = \frac{(p_b - p_a)\cdot A}{g} = \frac{\frac{1}{2}\rho(v_a^2 - v_b^2)\cdot A}{g} =$$

$$= \frac{\frac{1}{2}\cdot 1.25\cdot(271^2 - 243^2)\cdot 395}{9.81} = 3.62\cdot 10^5 \text{ kg} =$$

$$= 362 \text{ t}$$

3 pt Two sounds have intensities of 1.00×10^{-8} and 6.30×10^{-4} W/m^2 respectively. What is the magnitude of the sound level difference between them in dB units?

10. **A** ◯ 20.40 **B** ◯ 23.05 **C** ◯ 26.05 **D** ◯ 29.44
E ◯ 33.26 **F** ◯ 37.59 **G** ◯ 42.47 **H** ◯ 47.99

$$I_1 = 1.00 \cdot 10^{-8} \text{ W/m}^2 \rightarrow \beta_1 = 10 \cdot \log(I_1/I_0)$$

$$I_2 = 6.30 \cdot 10^{-4} \text{ W/m}^2 \rightarrow \beta_2 = 10 \cdot \log(I_2/I_0)$$

$$\Delta\beta = \beta_2 - \beta_1 = 10 \log(I_2/I_0) - 10 \log(I_1/I_0) =$$

$$= 10 \cdot [\log(I_2/I_0) - \log(I_1/I_0)] =$$

$$= 10 \cdot \log \frac{I_2/I_0}{I_1/I_0} = 10 \cdot \log \frac{I_2}{I_1} =$$

$$= 10 \cdot \log \frac{6.3 \cdot 10^{-4}}{1.0 \cdot 10^{-8}} = 10 \cdot \log(63{,}000) =$$

$$= 47.99 \text{ dB}$$

3 pt A stationary horn emits a sound with a frequency of 248 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 269 Hz, then what is the speed of the car? Use 340 m/s for the speed of the sound.
(*in* m/s)

11. **A**◯ 2.88×10^1 **B**◯ 3.83×10^1 **C**◯ 5.09×10^1 **D**◯ 6.77×10^1
E◯ 9.01×10^1 **F**◯ 1.20×10^2 **G**◯ 1.59×10^2 **H**◯ 2.12×10^2

Doppler effect:

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

$c = 340\ m/s$
$v_s = 0\ m/s$
$v_o = ?$
$f_s = 248\ Hz$
$f_o = 269\ Hz$

The frequency is shifted up:

$$f_o = f_s \cdot \frac{c + v_o}{c}$$ ← greater than one

$$c f_o = c f_s + v_o f_s$$

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

$$c (f_o - f_s) = v_o f_s$$

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

$$v_o = 340 \cdot \frac{269 - 248}{248} = 28.8\ m/s$$

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

3 pt If the lowest frequency produced by an organ is 28.2 Hz, and the highest frequency is 1.43 kHz, then what is the shortest possible wavelength of sound the organ can produce? Assume that the speed of sound is 333 m/s.
(in cm*)*

12. **A**◯ 5.27 **B**◯ 7.64 **C**◯ 11.1 **D**◯ 16.1 **E**◯ 23.3 **F**◯ 33.8 **G**◯ 49.0 **H**◯ 71.0

3 pt What is the longest possible sound wavelength the organ can produce?
(in m*)*

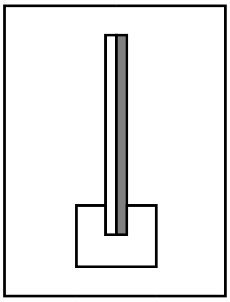
13. **A**◯ 5.02 **B**◯ 5.67 **C**◯ 6.41 **D**◯ 7.24 **E**◯ 8.18 **F**◯ 9.25 **G**◯ 10.5 **H**◯ 11.8

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

$$\lambda_{shortest} = \frac{c}{f_{highest}} = \frac{333}{1430} = 0.233\,m = 23.3\,cm$$

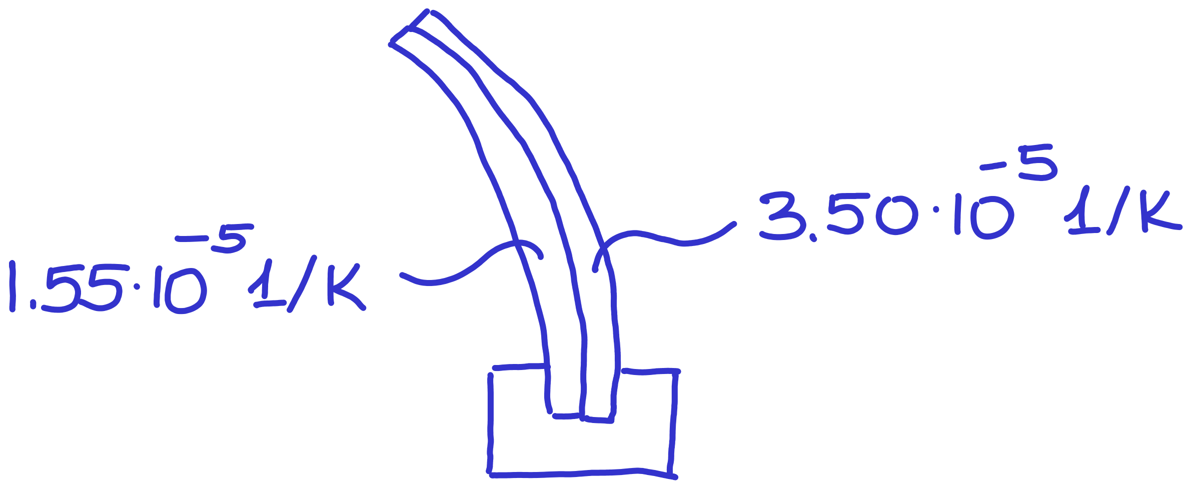
$$\lambda_{longest} = \frac{c}{f_{lowest}} = \frac{333}{28.2} = 11.8\,m$$

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 $\alpha_{\text{left}} = 1.55 \times 10^{-5}$ 1/K, the metal on the right has $\alpha_{\text{right}} = 3.50 \times 10^{-5}$ 1/K. When the strip is heated, it will ... (complete the sentence)

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



The side with the larger coefficient of heat expansion will expand more when the strip is heated.

3 pt What is the volume of 1.87 moles of Nitrogen gas, if the temperature of the gas is 10.7 °C and the pressure is 2.67 atm?
(in L)

15. **A** ◯ 10.18 **B** ◯ 11.91 **C** ◯ 13.94 **D** ◯ 16.31
E ◯ 19.08 **F** ◯ 22.32 **G** ◯ 26.12 **H** ◯ 30.56

$n = 1.87$ mol $\quad R = 8.31 \frac{J}{mol K}$

$T = 10.7°C = 283.7$ K

$p = 2.67$ atm $= 2.70 \cdot 10^5$ Pa

Ideal gas law:

$$pV = nRT$$

$$V = \frac{nRT}{p} = \frac{1.87 \cdot 8.31 \cdot 283.7}{2.70 \cdot 10^5} =$$

$= 0.0163$ m^3 $= 16.3$ liters

3 pt A gas bottle contains 5.21×10^{23} Ammonia molecules at a temperature of 342 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**◯ 1.55×10^3 **B**◯ 1.93×10^3 **C**◯ 2.42×10^3 **D**◯ 3.02×10^3
E◯ 3.78×10^3 **F**◯ 4.72×10^3 **G**◯ 5.90×10^3 **H**◯ 7.38×10^3

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

17. **A**◯ 1.42×10^{-20} **B**◯ 1.77×10^{-20} **C**◯ 2.21×10^{-20} **D**◯ 2.77×10^{-20}
E◯ 3.46×10^{-20} **F**◯ 4.32×10^{-20} **G**◯ 5.40×10^{-20} **H**◯ 6.75×10^{-20}

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

18. **A**◯ 1.33×10^{-21} **B**◯ 1.78×10^{-21} **C**◯ 2.36×10^{-21} **D**◯ 3.14×10^{-21}
E◯ 4.18×10^{-21} **F**◯ 5.55×10^{-21} **G**◯ 7.39×10^{-21} **H**◯ 9.82×10^{-21}

Ammonia: $f = 6$.

One degree of freedom will carry:

$$\frac{1}{2} k_B T = \frac{1}{2} \cdot 1.38 \cdot 10^{-23} \cdot 342 = 2.36 \cdot 10^{-21} \text{ J}$$

One molecule will carry:

$$\frac{f}{2} k_B T = f \cdot \left(\frac{1}{2} k_B T\right) = 1.42 \cdot 10^{-20} \text{ J}$$

N molecules will carry:

$$N \cdot \left(\frac{f}{2} k_B T\right) = 7380 \text{ J}$$