Nagy,

Tibor

Keep this exam **CLOSED** until advised by the instructor.

120 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.

Four 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
- $G = 6.67 \times 10^{-11}$ Nm^2/kg^2
- $\rho_{water} = 1$ kg/l = 1000 kg/m^3
- 1 atm = 101.3 kPa = 101,300 Pa
- $N_A = 6.02\times10^{23}$ 1/mol
- $R = 8.31$ J/molK
- $k_B = 1.38\times10^{-23}$ J/K
- $c_{water} = 4.1868$ kJ/kg°C = 1 kcal/kg°C
- 1 cal = 4.1868 J
- $\sigma = 5.67\times10^{-8}$ W/m^{2}K^4
- $b = 2.90\times10^{-3}$ m K

Posssibly useful Moments of Inertia:

- Solid homogeneous cylinder: $I_{CM} = (1/2)MR^2$
- Solid homogeneous sphere: $I_{CM} = (2/5)MR^2$
- Thin spherical shell: $I_{CM} = (2/3)MR^2$
- Straight thin rod with axis through center: $I_{CM} = (1/12)ML^2$
- Straight thin rod with axis through end: $I = (1/3)ML^2$

nagytibo@msu

Please, sit in row:

Thank you!

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1 pt Are you sitting in the row assigned?

1.A ◯ Yes, I am.

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2 pt An apple, a brick and a hammer are all dropped from the second floor of a building. Which object(s) will hit the ground first?

2.A ◯ The apple will hit first.
B ◯ The brick will hit first.
C ◯ The hammer will hit first.
D ◯ The apple and the brick will hit the ground first in a tie.
E ◯ The brick and the hammer will hit the ground first in a tie.
F ◯ The hammer and the apple will hit the ground first in a tie.
G ◯ They all hit the ground at the same time.
H ◯ Without knowing the masses of the objects, we cannot tell which one hits the ground first.

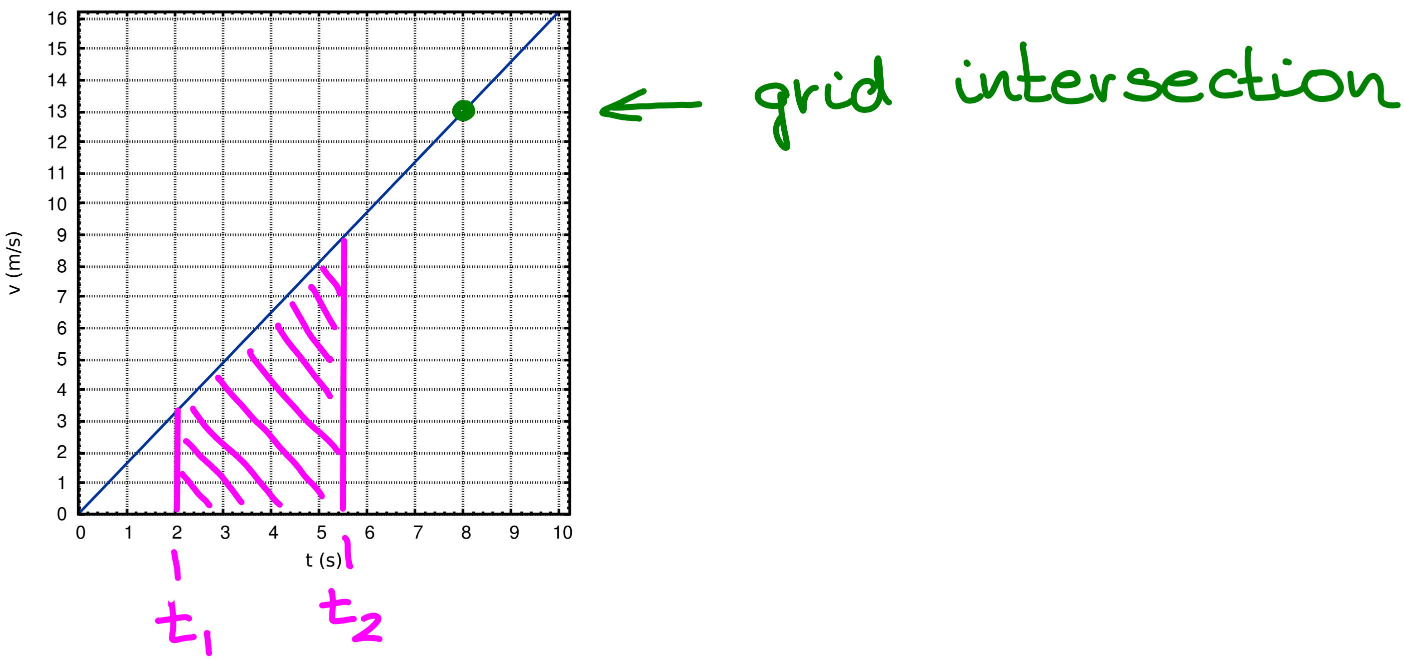
Galileo Galilei: All compact and dense objects (no feathers, no leafs) fall together.

Newton: $F_{net} = ma$

$$a = \frac{F_{net}}{m} = \frac{mg}{m} = g$$

(But this cancellation is the biggest puzzle in the Universe: the mass in the numerator is the gravitational mass, the mass in the denominator is the inertial mass. Experiments say they are the same or directly proportional to each-other, but we don't understand why.)

The graph shows the speed of a car as a function of time.



2 pt Initially the car is at rest. What is the acceleration of the car? Please, note that the graph goes through at least one grid intersection point.
(in m/s^2*)*

3. **A**◯ 0.7729 **B**◯ 1.121 **C**◯ 1.625 **D**◯ 2.356
E◯ 3.417 **F**◯ 4.954 **G**◯ 7.183 **H**◯ 10.42

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2 pt How much distance does the car cover between $t_1 = 2.15$ s and $t_2 = 5.55$ s?
(in m*)*

4. **A**◯ 4.461 **B**◯ 5.576 **C**◯ 6.970 **D**◯ 8.713
E◯ 10.89 **F**◯ 13.61 **G**◯ 17.02 **H**◯ 21.27

→ acceleration = $\dfrac{\text{change in velocity}}{\text{chang in time}}$

$$a = \frac{\Delta v}{\Delta t} = \frac{13\,m/s}{8\,s} = 1.625\,m/s^2$$

→ distance travelled is the area under the velocity versus time diagram.

$$d = \frac{v_1 + v_2}{2} \cdot \Delta t = \frac{at_1 + at_2}{2} \cdot (t_2 - t_1) =$$

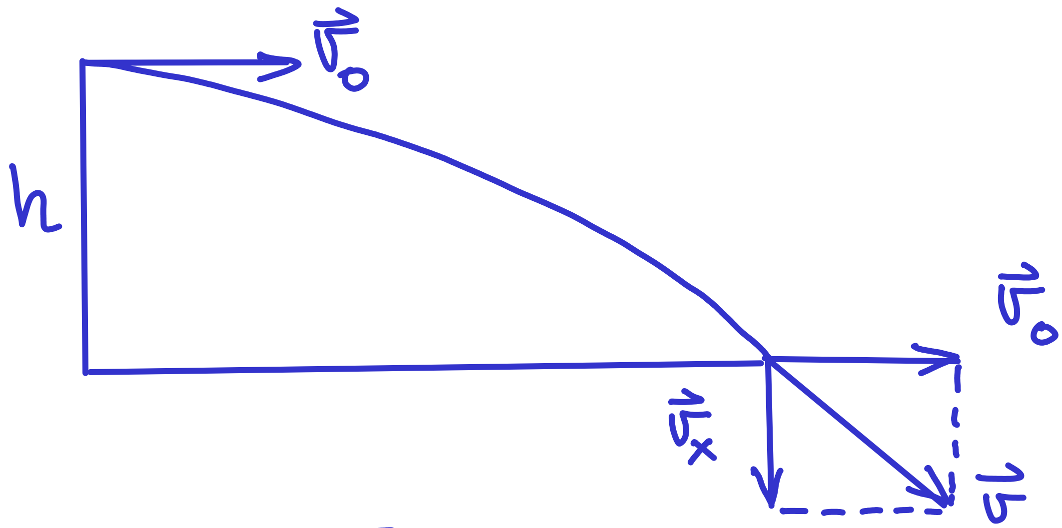
$$= \frac{1}{2} a (t_2 + t_1)(t_2 - t_1) = \frac{1}{2} a (t_2^2 - t_1^2) =$$

$$= d_2 - d_1$$

$$d = \frac{1}{2} \cdot 1.625 \cdot (5.55^2 - 2.15^2) = 21.27 m$$

$\boxed{4\ pt}$ A baseball is projected horizontally with an initial speed of 8.95 m/s from a height of 1.87 m. What is the speed of the baseball when it hits the ground? (Neglect air friction.)
(in m/s*)*

5. **A**◯ 4.21 **B**◯ 4.93 **C**◯ 5.77 **D**◯ 6.75
E◯ 7.89 **F**◯ 9.24 **G**◯ 1.08×10^{1} **H**◯ 1.26×10^{1}



$v_x = \sqrt{2gh}$ (from kinematics)

$v_x^2 = 2gh$ (energy: $\frac{1}{2}mv^2 = mgh$)

$v = \sqrt{v_x^2 + v_0^2}$ (Pythagorean theorem)

$v = \sqrt{2gh + v_0^2} = \sqrt{2 \cdot 9.81 \cdot 1.87 + 8.95^2}$

$v = 10.81 \text{m/s}$

$\boxed{4\ pt}$ Two forces $\mathbf{F_1}$ = -7.70**i** + 3.30**j** and $\mathbf{F_2}$ = 6.60**i** + 4.60**j** are acting on a mass of m = 6.00 kg. The forces are measured in newtons. What is the magnitude of the object's acceleration?
(in `m/s^2`*)*

6. **A**◯ 7.09×10^{-1} **B**◯ 8.30×10^{-1} **C**◯ 9.71×10^{-1} **D**◯ 1.14
E◯ 1.33 **F**◯ 1.56 **G**◯ 1.82 **H**◯ 2.13

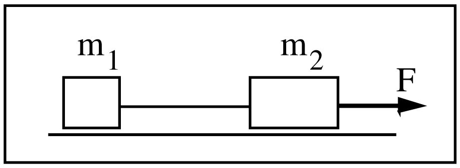
$$\left.\begin{aligned}\vec{F}_1 &= -7.70\,\hat{i} + 3.30\,\hat{j} \\ \vec{F}_2 &= 6.60\,\hat{i} + 4.60\,\hat{j}\end{aligned}\right\} \text{ in newtons}$$

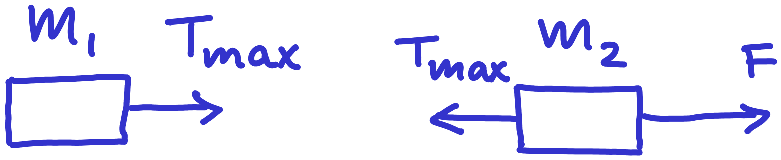
$$\vec{F}_{net} = -1.10\,\hat{i} + 7.90\,\hat{j}$$

$$F_{net} = |\vec{F}_{net}| = \sqrt{(-1.10)^2 + (7.90)^2} = 7.98\,N$$

$$a = \frac{F_{net}}{m} = 1.33\,m/s^2$$

Two masses, $m_1 = 2.45$ kg and $m_2 = 8.08$ kg are on a horizontal frictionless surface and they are connected together with a rope as shown in the figure.





$\boxed{3\ pt}$ The rope will snap if the tension in it exceeds 60.0 N. What is the maximum value of the force **F** which can be applied?
(in `N`*)*

7. **A**◯ 1.10×10^2 **B**◯ 1.46×10^2 **C**◯ 1.94×10^2 **D**◯ 2.58×10^2
E◯ 3.43×10^2 **F**◯ 4.56×10^2 **G**◯ 6.07×10^2 **H**◯ 8.07×10^2

$\boxed{3\ pt}$ What is the acceleration of the whole system, when this maximum force is applied?
(in `m/s^2`*)*

8. **A**◯ 1.69×10^1 **B**◯ 2.45×10^1 **C**◯ 3.55×10^1 **D**◯ 5.15×10^1
E◯ 7.47×10^1 **F**◯ 1.08×10^2 **G**◯ 1.57×10^2 **H**◯ 2.28×10^2

When the tension in the rope is maxed out, we have maximum acceleration: $a_{max} = \frac{T_{max}}{m_1} = \frac{60N}{2.45kg}$

$a_{max} = 24.5 m/s^2$ (about 2.5g)

Newton's second law for the composite system at maximum acceleration:

$$F_{max} = (m_1 + m_2) \cdot a_{max} = (2.45 + 8.08) \cdot 24.5$$

$$F_{max} = 258 N$$

$\boxed{4\ pt}$ An athlete, swimming at a constant speed, covers a distance of 135 m in a time period of 2.05 minutes. The drag force exerted by the water on the swimmer is 56.0 N. Calculate the power the swimmer must provide in overcoming that force.
(in W*)*

9. **A**◯ 4.62×10^1 **B**◯ 6.15×10^1 **C**◯ 8.17×10^1 **D**◯ 1.09×10^2
E◯ 1.45×10^2 **F**◯ 1.92×10^2 **G**◯ 2.56×10^2 **H**◯ 3.40×10^2

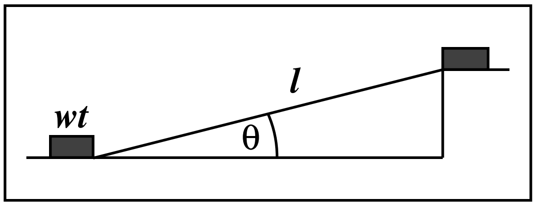
Work : $W = \vec{F} \cdot \vec{d}$

Power : $P = \vec{F} \cdot \vec{v}$

$$P = F \cdot v = F \cdot \frac{d}{t} = 56N \cdot \frac{135m}{2.05 min \cdot 60 \frac{s}{min}}$$

$P = 61.5W$

A block with a weight of 694 N is pulled up at a constant speed on a very smooth ramp by a constant force. The angle of the ramp with respect to the horizontal is $\theta = 27.0°$ and the length of the ramp is $l = 13.7$ m.



$\boxed{4\ pt}$ Calculate the work done by the force in pulling the block all the way to the top of the ramp. (Neglect friction.)
(in J*)*

10. **A**◯ 3.38×10^3 **B**◯ 3.82×10^3 **C**◯ 4.32×10^3 **D**◯ 4.88×10^3
E◯ 5.51×10^3 **F**◯ 6.23×10^3 **G**◯ 7.04×10^3 **H**◯ 7.95×10^3

weight = mg = 694N

parallel component of the weight on an incline: $F_{\parallel} = mg \cdot \sin\theta$

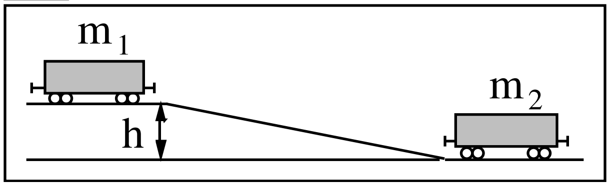
work = force times displacement

$$W = F_{\parallel} \cdot l = mg \cdot \underbrace{\sin\theta \cdot l}_{h\,:\,\text{height}}$$

$$W = 694N \cdot \sin 27° \cdot 13.7m$$

$$W = 4316N$$

$\boxed{\textit{4 pt}}$ A railroad cart with a mass of m_1 = 12.6 t is at rest at the top of an h = 13.8 m high hump yard hill.



After it is pushed very slowly over the edge, it starts to roll down. At the bottom it hits another cart originally at rest with a mass of m_2 = 24.3 t. The bumper mechanism locks the two carts together. What is the final common speed of the two carts? (Neglect losses due to rolling friction of the carts. The letter t stands for metric ton in the SI system.) *(in* m/s*)*

11. **A**◯ 3.89 **B**◯ 4.40 **C**◯ 4.97 **D**◯ 5.62 **E**◯ 6.35 **F**◯ 7.17 **G**◯ 8.11 **H**◯ 9.16

m_1 rolling down : conservation of energy : $m_1 g h = \frac{1}{2} m v_1^2 \Rightarrow v_1 = \sqrt{2gh}$

collision between m_1 and m_2 : conservation of momentum :

$$m_1 \cdot v_1 + m_2 \cdot 0 = (m_1 + m_2) \cdot v_f$$

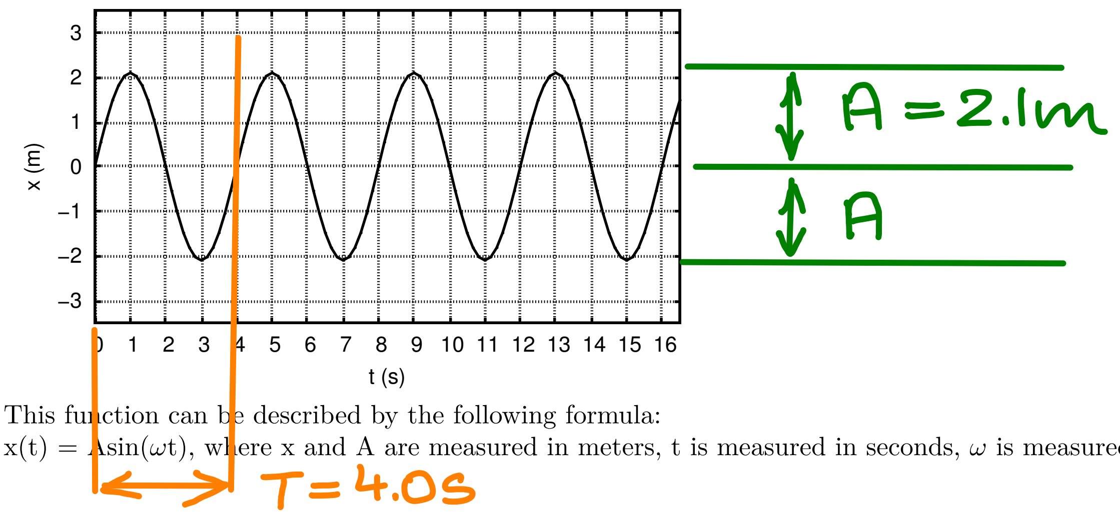
$$\frac{m_1}{m_1 + m_2} \cdot v_1 = v_f$$

$$v_f = \frac{12.6t}{12.6t + 24.3t} \cdot \sqrt{2 \cdot 9.81 \cdot 13.8}$$

$$v_f = 5.62 m/s$$

(1t = 1000 kg , but we didn't need it.)

The graph shows the x-displacement as a function of time for a particular object undergoing simple harmonic motion.



This function can be described by the following formula:
x(t) = Asin(ωt), where x and A are measured in meters, t is measured in seconds, ω is measured in rad/s.

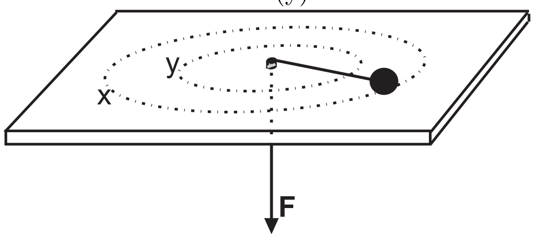
$\boxed{\textit{2 pt}}$ Using the graph determine the amplitude A of the oscillation.
(in m*)*

12. **A**◯ 1.80 **B**◯ 2.10 **C**◯ 2.40 **D**◯ 3.90 **E**◯ 4.50 **F**◯ 4.80 **G**◯ 5.10 **H**◯ 5.40

$\boxed{\textit{2 pt}}$ Determine the period T of the oscillation.
(in s*)*

13. **A**◯ 2.80 **B**◯ 3.20 **C**◯ 4.00 **D**◯ 4.40 **E**◯ 5.20 **F**◯ 6.80 **G**◯ 7.60 **H**◯ 8.00

$\boxed{10\ pt}$ A small mass M attached to a string slides in a circle (x) on a frictionless horizontal table, with the force **F** providing the necessary tension (see figure). The force is then increased slowly and then maintained constant when M travels around in circle (y). The radius of circle (x) is twice the radius of circle (y).



▷ M's kinetic energy at y is four times that at x.
14. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

▷ M's angular velocity at x is half that at y.
15. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

▷ M's angular momentum at x is .... that at y.
16. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

▷ While going from x to y, there is a torque on M.
17. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

▷ As M moves from x to y, the work done by **F** is .... 0.
18. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

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→ Torque: $\tau = 0$ because the tension in a rope is central. Central forces cannot apply torque.

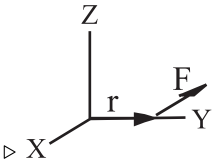
→ Angular momentum L is constant, b/c the torque is zero.

→ The work is positive, when the rope pulls the object in.

→ $\omega_y = 4\omega_x$ because $L_y = L_x$ and $L = I\omega$ and $I = mr^2$: $m r_y^2 \omega_y = m r_x^2 \omega_x$

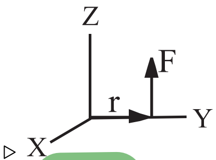
→ $KE_y = 4KE_x$ because $KE = \frac{1}{2} I\omega^2$ and $I = mr^2$ or $KE = \frac{L^2}{2I}$

$\boxed{6\ pt}$ A body (not shown) has its center of mass (CM) at the origin. In each case below give the direction for the torque τ with respect to the CM on the body due to force **F** acting on the body at a location indicated by the vector **r**.

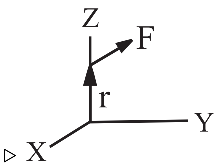


19. **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z

$$\boxed{\vec{\tau} = \vec{r} \times \vec{F}}$$



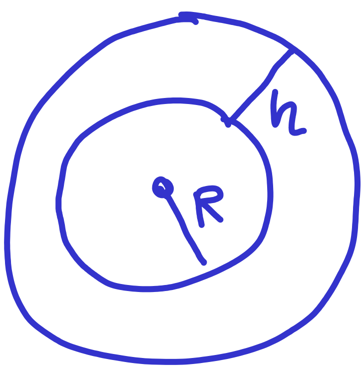
20. **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z



21. **A**◯ X **B**◯ -X **C**◯ Y **D**◯ -Y **E**◯ Z **F**◯ -Z

$\boxed{4\ pt}$ A 275 kg satellite is orbiting on a circular orbit 5240 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*)*

22. **A**◯ 5.86 **B**◯ 6.62 **C**◯ 7.48 **D**◯ 8.45
E◯ 9.55 **F**◯ 1.08×10^1 **G**◯ 1.22×10^1 **H**◯ 1.38×10^1



Radius of the orbit:

$$r = R + h$$

$$v = \sqrt{\frac{GM}{r}}$$

$$v = \sqrt{\frac{6.67 \times 10^{-11} \cdot 5.97 \times 10^{24}}{(6370 + 5240) \cdot 1000}}$$

$$v = 5856\,\frac{m}{s} \cong 5.86\,\frac{km}{s}$$

4 pt An object weighs 64.7 N in air. When it is suspended from a force scale and completely immersed in water the scale reads 23.4 N. Determine the density of the object.
(in `kg/m^3`*)*

23. **A**◯ 1.08×10^3 **B**◯ 1.57×10^3 **C**◯ 2.27×10^3 **D**◯ 3.29×10^3
E◯ 4.78×10^3 **F**◯ 6.93×10^3 **G**◯ 1.00×10^4 **H**◯ 1.46×10^4

$$T_1 = mg$$
$$T_2 = mg - B$$

Archimedes: $B = m_{fluid} \cdot g$

$$T_2 = T_1 - m_{fluid} \cdot g$$

$$m_{fluid} \cdot g = T_1 - T_2$$

$$\rho_{fluid} \cdot V_{obj} \cdot g = T_1 - T_2$$

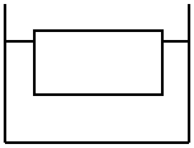
$$\rho_{fluid} \cdot \frac{m_{obj}}{\rho_{obj}} \cdot g = T_1 - T_2$$

$$\frac{\rho_{fluid}}{\rho_{obj}} \cdot T_1 = T_1 - T_2$$

$$\rho_{fluid} \cdot \frac{T_1}{T_1 - T_2} = \rho_{obj}$$

$$\rho_{obj} = 1000 \frac{kg}{m^3} \cdot \frac{64.7}{64.7 - 23.4} = 1566 \frac{kg}{m^3}$$

$\boxed{2\ pt}$ A large ice cube floats in a glass of water. (See figure.)

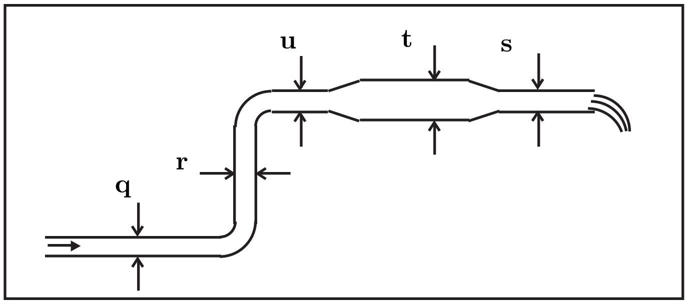


What happens to the water level, when the ice cube melts? (No water is lost due to evaporation.)

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

A 1kg ice block displaces 1kg water. When the 1kg ice block melts, it gives you 1kg water which displaces 1kg of water.

$\boxed{8\ pt}$ 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.



Bernoulli principle:

$$\frac{1}{2}\rho v^2 + \rho g y + p = \text{const.}$$

Continuity:

$$A_1 v_1 = A_2 v_2$$

Cross sectional area:

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

▷ p_r is .... p_q

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

▷ v_q is .... v_s

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

▷ v_t is .... $0.5v_q$

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

▷ p_t is .... p_s

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

When you climb up, the pressure drops:
$\rho g y$ increases, therefore p drops.
When you dive, the pressure increases:
$\rho g y$ decreases, therefore p increases.
When you speed up, the pressure drops:
$\frac{1}{2}\rho v^2$ increases, therefore p decreases.
When you slow down, the pressure increases:
$\frac{1}{2}\rho v^2$ decreases, therefore p increases.

$\boxed{3\ pt}$ A truck horn emits a sound with a frequency of 229 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 254 Hz, then what is the speed of the truck? Use 340 m/s for the speed of the sound.
(in m/s*)*

29. **A** ◯ 2.31×10^1 **B** ◯ 3.35×10^1 **C** ◯ 4.85×10^1 **D** ◯ 7.04×10^1
E ◯ 1.02×10^2 **F** ◯ 1.48×10^2 **G** ◯ 2.14×10^2 **H** ◯ 3.11×10^2

$$\left.\begin{aligned} f_s &= 229 \text{ Hz} \\ f_o &= 254 \text{ Hz} \end{aligned}\right\}$$ It is an up-shift.

Doppler-effect:

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

$c = 340$ m/s

$v_o = 0$ m/s b/c the person is standing at rest.

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

$$cf_o - v_s f_o = cf_s$$

$$cf_o - cf_s = v_s f_o$$

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

$$v_s = 340 \cdot \frac{254 - 229}{254} = 33.5 \text{ m/s}$$

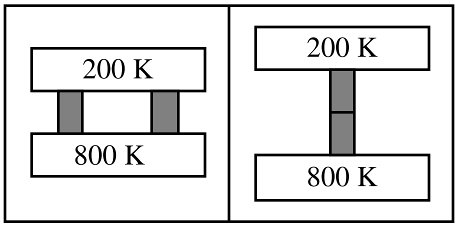
4 pt Two sounds have intensities of 4.20×10^{-8} and 6.40×10^{-4} W/m^2 respectively. What is the magnitude of the sound level difference between them in dB units?

30. **A**◯ 26.12 **B**◯ 30.56 **C**◯ 35.75 **D**◯ 41.83
E◯ 48.94 **F**◯ 57.26 **G**◯ 66.99 **H**◯ 78.38

$$\Delta\beta(dB) = 10 \log\left(\frac{I_2}{I_1}\right) = 10 \log\left(\frac{6.40 \times 10^{-4}}{4.20 \times 10^{-8}}\right) =$$

$$= 10 \cdot 4.183 = 41.83 \text{ dB}$$

2 pt A hot (800 K) and a cold (200 K) heat reservoirs are connected to each other by two identical aluminum bars in two different ways as shown in the figure.



$P = k \cdot \frac{A}{L} \cdot \Delta T$

Compared to the left configuration, the rate of heat transfer in the right configuration is ..... as high. (Complete the sentence.)

because A halves and L doubles

31.**A**◯ one third
B◯ three times
C◯ four times
D◯ one fourth
E◯ one half
F◯ twice

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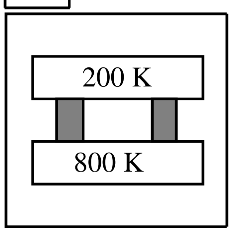
2 pt Consider the configuration shown in the figure.



Lowering the temperature of the hot reservoir from 800 K to 400 K will reduce the rate of the heat transfer by a factor of ..... (Complete the sentence.)

because ΔT goes from 600K to 200K

32.**A**◯ three
B◯ four
C◯ two

---

4 pt What is the pressure of 1.46 moles of Nitrogen gas in a 7.71 liter container, if the temperature of the gas is 41.0 °C?
(in atm*)*

33. **A**◯ 3.37 **B**◯ 4.88 **C**◯ 7.08 **D**◯ 10.26
E◯ 14.88 **F**◯ 21.57 **G**◯ 31.28 **H**◯ 45.36

Ideal Gas Law:

$$pV = nRT$$

$$p = \frac{nRT}{V} = \frac{1.46 \cdot 8.31 \cdot (41 + 273)}{0.00771}$$

$$p = 4.94 \times 10^5 \text{ Pa} = 4.88 \text{ atm}$$

$\boxed{10\ pt}$ Constant amount of ideal gas is kept inside a cylinder by a piston. Then the gas expands **adiabatically**. Compare the initial (i) and the final (f) physical quantities of the gas to each other.

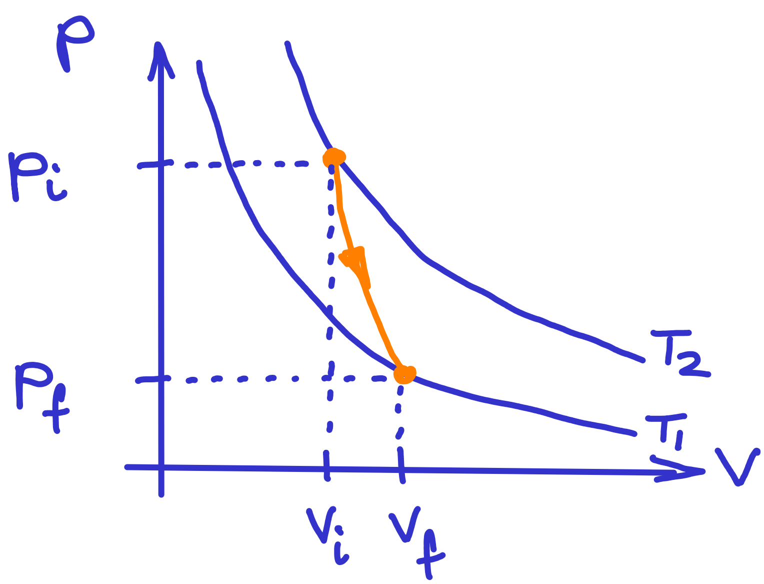
▷ The temperature T_f is ... T_i.
34. **A**◯ equal to **B**◯ less than **C**◯ greater than
b/c we are crossing isotherms

▷ The internal energy U_f is ... U_i.
35. **A**◯ equal to **B**◯ less than **C**◯ greater than
b/c $U = \frac{f}{2} nRT$

▷ The volume V_f is ... V_i.
36. **A**◯ equal to **B**◯ less than **C**◯ greater than
b/c it is expansion

▷ The pressure p_f is ... p_i.
37. **A**◯ equal to **B**◯ less than **C**◯ greater than
b/c $p_f \cdot V_f^{\gamma} = p_i \cdot V_i^{\gamma}$

▷ The entropy S_f is ... S_i.
38. **A**◯ equal to **B**◯ less than **C**◯ greater than
b/c no heat is transferred



4 pt An ideal heat engine has an efficiency of 15.1 percent. It operates between two heat reservoirs differing in temperature by 72.8 C°. What is the temperature of the hot reservoir?
(in K*)*

39. **A** ◯ 1.58×10^2 **B** ◯ 2.29×10^2 **C** ◯ 3.32×10^2 **D** ◯ 4.82×10^2
E ◯ 6.99×10^2 **F** ◯ 1.01×10^3 **G** ◯ 1.47×10^3 **H** ◯ 2.13×10^3

Heat engine efficiency à la Carnot:

$$\eta = \frac{T_H - T_C}{T_H}$$

$$\eta = \frac{\Delta T}{T_H} \Rightarrow T_H = \frac{\Delta T}{\eta} = \frac{72.8}{0.151} = 482\,K$$