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
- $\rho_{\text{water}} = 1000$ kg/m^3 = 1 kg/l = 1 g/cm^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
- $c_{\text{water}} = 4.1868$ 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 seat:

Thank you!

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1 pt Are you sitting in the seat assigned?

1.A ◯ Yes, I am.

3 pt A pen, a pineapple and an apple are all dropped from the second floor of a building at the same time. Which object(s) will hit the ground first? Important: the pen is not a goose feather pen, but a heavy ball pen with steel casing.

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

All compact, dense objects fall together when released from the same height at the same time.

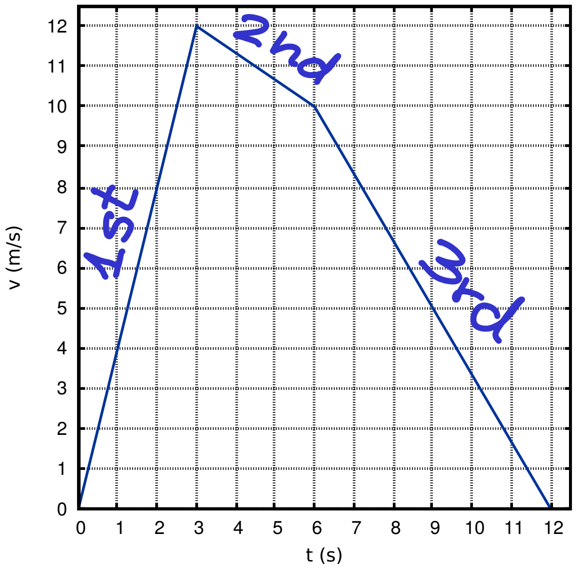
(Galileo Galilei)

Explanation by Newton:

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

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. The experiments show they are the same up to very high precision, but we don't understand why.

A car is waiting at an intersection. When the traffic light turns green, the car starts moving. After some time the car comes to rest at another traffic light. The figure below shows the velocity of the car as a function of time.



One can clearly identify three different stages of this motion.

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2 pt What is the acceleration of the car during the third stage of the motion?
(in `m/s^2`*)*

3. **A**◯ -1.83 **B**◯ -1.67 **C**◯ -1.50 **D**◯ -1.33 **E**◯ 1.33 **F**◯ 1.50 **G**◯ 1.67 **H**◯ 2.00

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2 pt What is the average speed of the car for the whole motion from start to stop?
(in `m/s`*)*

4. **A**◯ 3.24 **B**◯ 3.66 **C**◯ 4.14 **D**◯ 4.68 **E**◯ 5.29 **F**◯ 5.97 **G**◯ 6.75 **H**◯ 7.63

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acceleration: $a = \frac{\Delta v}{\Delta t} = \frac{-10 m/s}{6 s} = -1.67 \frac{m}{s^2}$

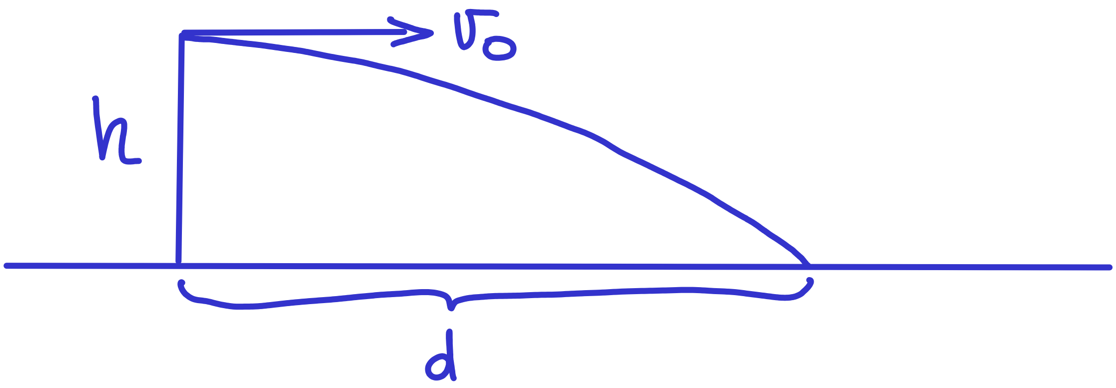
average speed: $\frac{\text{total distance}}{\text{total time}}$

$$\bar{v} = \frac{1}{12}\left(\frac{0+12}{2}\cdot 3 + \frac{12+10}{2}\cdot 3 + \frac{10+0}{2}\cdot 6\right)$$

$$\bar{v} = \frac{1}{12}(18 + 33 + 30) = 6.75 \frac{m}{s}$$

$\boxed{4\ pt}$ A baseball is projected horizontally with an initial speed of 23.8 m/s from a height of 1.56 m. At what horizontal distance will the ball hit the ground? (Neglect air friction.)
(in m*)*

5. **A**◯ 1.34×10^1 **B**◯ 1.68×10^1 **C**◯ 2.10×10^1 **D**◯ 2.62×10^1
E◯ 3.28×10^1 **F**◯ 4.10×10^1 **G**◯ 5.12×10^1 **H**◯ 6.40×10^1



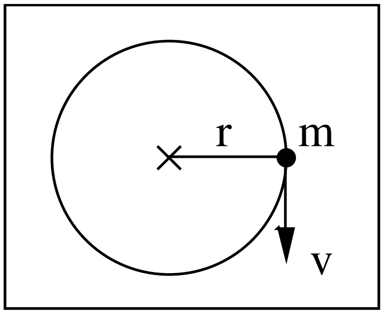
Time of fall: $h = \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2h}{g}}$

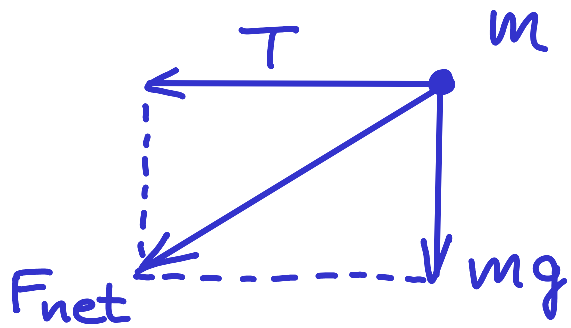
Horizontal distance:

$$d = v_0 \cdot t = v_0 \cdot \sqrt{\frac{2h}{g}}$$

$$d = 23.8 \cdot \sqrt{\frac{2 \cdot 1.56}{9.81}} = 13.4\,\text{m}$$

A small object with a mass of m = 718 g is whirled at the end of a rope in a vertical circle with a radius of r = 134 cm.





2 pt When it is at the location shown, (mid-height), its speed is v = 4.13 m/s. Determine the tension in the rope. *(in* N*)*

6. **A** ◯ 7.31 **B** ◯ 9.14 **C** ◯ 1.14×10^1 **D** ◯ 1.43×10^1
E ◯ 1.79×10^1 **F** ◯ 2.23×10^1 **G** ◯ 2.79×10^1 **H** ◯ 3.49×10^1

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2 pt Calculate the magnitude of the total force acting on the mass at that location. *(in* N*)*

7. **A** ◯ 3.84 **B** ◯ 4.50 **C** ◯ 5.26 **D** ◯ 6.16
E ◯ 7.20 **F** ◯ 8.43 **G** ◯ 9.86 **H** ◯ 1.15×10^1

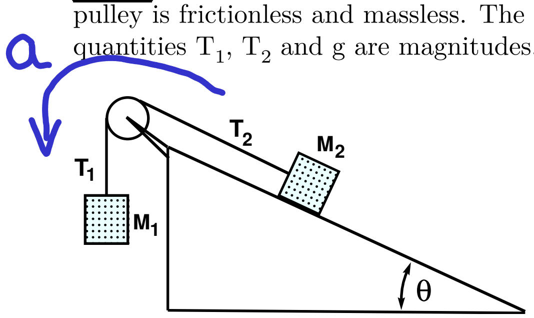
The tension in the rope provides the force needed to accelerate the object toward the center: $T = m a_{cp}$

$$T = m\frac{v^2}{r} = 0.718 \cdot \frac{4.13^2}{1.34} = 9.14\,N$$

Total force by Pythagoras' theorem:

$$F_{net} = \sqrt{T^2 + (mg)^2} = 11.5\,N$$

10 pt M_1 and M_2 have equal masses and are connected as shown. T_1 and T_2 are the tensions in the rope. The pulley is frictionless and massless. The incline is frictionless and is at an angle of $\theta = 30.0°$ from the horizontal. The quantities T_1, T_2 and g are magnitudes.



$M_1 = M_2$ & no friction anywhere

▷ The magnitude of the acceleration of M_2 is .... that of M_1
8. **A**◯ greater than **B**◯ less than **C**◯ equal to

$a_1 = a_2$ b/c the rope doesn't stretch

▷ M_1g is .... T_1
9. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ T_1 is .... M_2g
10. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ M_2gsin(θ) is .... T_2
11. **A**◯ greater than **B**◯ less than **C**◯ equal to

▷ T_1 is .... T_2
12. **A**◯ greater than **B**◯ less than **C**◯ equal to

$T_1 = T_2$ b/c the pulley is ideal

$$M_1 g > T_1 = T_2 > M_2 g \cdot \sin(\theta)$$

2 pt There are 143 steps between the ground floor and the sixth floor in a building. Each step is 16.6 cm tall. It takes 5 minutes and 55 seconds for a person with a mass of 90.0 kg to walk all the way up. How much work did the person do?
(in J*)*

13. **A** ◯ 1.85×10^4 **B** ◯ 2.10×10^4 **C** ◯ 2.37×10^4 **D** ◯ 2.68×10^4
E ◯ 3.02×10^4 **F** ◯ 3.42×10^4 **G** ◯ 3.86×10^4 **H** ◯ 4.36×10^4

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2 pt What was the average power performed by the person during the walk?
(in W*)*

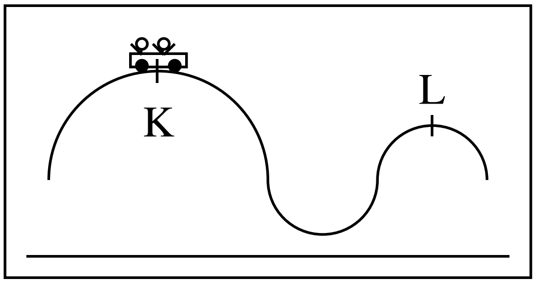
14. **A** ◯ 5.22×10^1 **B** ◯ 5.90×10^1 **C** ◯ 6.67×10^1 **D** ◯ 7.54×10^1
E ◯ 8.52×10^1 **F** ◯ 9.63×10^1 **G** ◯ 1.09×10^2 **H** ◯ 1.23×10^2

$$W = F \cdot d = mg \cdot h = 90 \cdot 9.81 \cdot 143 \cdot 0.166$$

$$W = 2.1 \cdot 10^4 J$$

$$P = \frac{W}{t} = \frac{2.1 \cdot 10^4 J}{5min\, 55s} = 59W$$

On a roller coaster ride the total mass of the cart - with passengers included - is 295 kg. Peak **K** is at 44.5 m above the ground, peak **L** is at 27.0 m. The speed of the cart at **K** is 17.3 m/s, at **L** it is 13.3 m/s. (The wheel mechanism on roller coaster carts always keeps the carts safely on the rail.)



4 pt How much energy is lost due to friction between the two peaks?
(in J)

15. **A** ◯ 2.81×10^4 **B** ◯ 3.52×10^4 **C** ◯ 4.40×10^4 **D** ◯ 5.50×10^4
E ◯ 6.87×10^4 **F** ◯ 8.59×10^4 **G** ◯ 1.07×10^5 **H** ◯ 1.34×10^5

Energy balance:

$$KE_K + PE_K = KE_L + PE_L + \Delta E_{th}$$

$$(KE_K + PE_K) - (KE_L + PE_L) = \Delta E_{th}$$

$$\Delta E_{th} = \left(\tfrac{1}{2} m v_K^2 + m g h_K\right) - \left(\tfrac{1}{2} m v_L^2 + m g h_L\right)$$

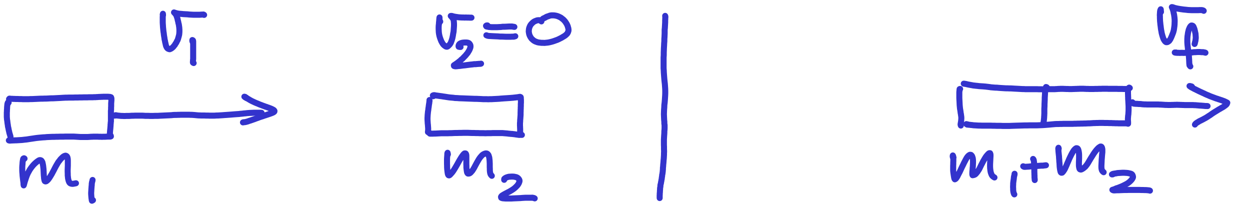
$$\Delta E_{th} = m\left(\tfrac{1}{2}(v_K^2 - v_L^2) + g(h_K - h_L)\right)$$

$$\Delta E_{th} = 295\left(\tfrac{1}{2}(17.3^2 - 13.3^2) + 9.81(44.5 - 27.0)\right)$$

$$\Delta E_{th} = 68.7 \text{ kJ}$$

3 pt A 646 kg automobile slides across an icy street at a speed of 45.7 km/h and collides with a parked car which has a mass of 848 kg. The two cars lock up and slide together. What is the speed of the two cars just after they collide? *(in* `km/h`*)*

16. **A**◯ 1.44×10^1 **B**◯ 1.69×10^1 **C**◯ 1.98×10^1 **D**◯ 2.31×10^1
E◯ 2.71×10^1 **F**◯ 3.16×10^1 **G**◯ 3.70×10^1 **H**◯ 4.33×10^1



Conservation of momentum:

$$m_1 v_1 + \underbrace{m_2 v_2}_{=0} = (m_1 + m_2) v_f$$

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

$$v_f = \frac{646}{646 + 848} \cdot 45.7 = 19.8\,\text{km/h}$$

$\boxed{\textit{2 pt}}$ An object is performing simple harmonic oscillation whose amplitude is 20.4 cm, and period is 2.50 s. Determine the maximum speed of the object.
(in `m/s`*)*

17. **A**◯ 1.68×10^{-1} **B**◯ 2.10×10^{-1} **C**◯ 2.63×10^{-1} **D**◯ 3.28×10^{-1}
E◯ 4.10×10^{-1} **F**◯ 5.13×10^{-1} **G**◯ 6.41×10^{-1} **H**◯ 8.01×10^{-1}

$\boxed{\textit{2 pt}}$ Determine the maximum acceleration of the object.
(in `m/s^2`*)*

18. **A**◯ 8.05×10^{-1} **B**◯ 9.41×10^{-1} **C**◯ 1.10 **D**◯ 1.29
E◯ 1.51 **F**◯ 1.76 **G**◯ 2.06 **H**◯ 2.41

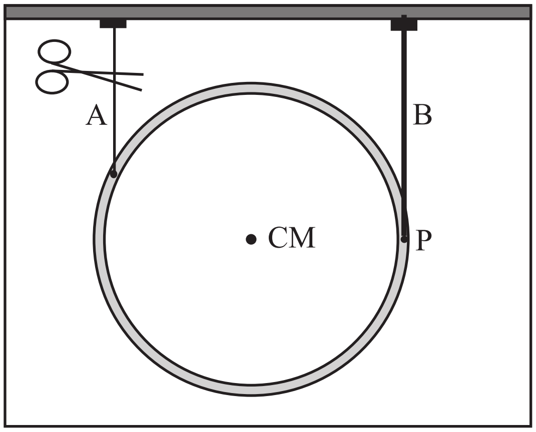
$A = 20.4\,cm = 0.204\,m$

$T = 2.5\,s \Rightarrow \omega = \frac{2\pi}{T} = 2.51\,\frac{rad}{s}$

$v_{max} = A\omega = 0.513\,m/s$

$a_{max} = A\omega^2 = v_{max} \cdot \omega = 1.29\,m/s^2$

$\boxed{4\ pt}$ A thin circular hoop with radius r and mass m is suspended vertically by two thin strings, A and B as shown in the figure. The center of the mass of the hoop is at the same height as the point P where string B is attached.



Hoop: $I_{CM} = mr^2$

Parallel axis theorem:

$I_P = I_{CM} + mr^2$

$I_P = 2mr^2$

Which of the equations below represents the initial angular acceleration α of the hoop when the string A is cut? (Hint: Use the parallel axis theorem.)

19.A◯ mgr
B◯ $g/(2r)$
C◯ mg/r
D◯ $(2g)/r$
E◯ g/r
F◯ mgr^2
G◯ $mg/(2r)$

Newton's second law for rotation:

$$\tau = I \cdot \alpha \Rightarrow \alpha = \frac{\tau}{I} = \frac{mgr}{2mr^2} = \frac{g}{2r}$$

4 pt The work done in accelerating a flywheel from rest to an angular speed of 19.7 revolutions per second is 14.8 kJ. What is the moment of inertia of the flywheel?
(in `kg*m^2`*)*

20. **A**◯ 1.18 **B**◯ 1.34 **C**◯ 1.51 **D**◯ 1.71 **E**◯ 1.93 **F**◯ 2.18 **G**◯ 2.47 **H**◯ 2.79

Energy balance:

$$W_{ext} = KE_{f,r}$$

$$KE_{f,r} = \frac{1}{2} I \omega^2$$

$$W_{ext} = \frac{1}{2} I \omega^2 \Rightarrow \frac{2W_{ext}}{\omega^2} = I$$

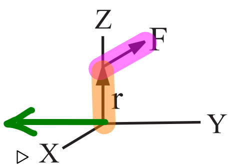
1 revolution per second = 2π rad/s

$$I = \frac{2 \cdot 14{,}800\,J}{(19.7 \cdot 2\pi)^2} = 1.93 \ kgm^2$$

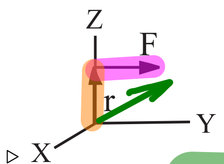
$\boxed{\textit{6 pt}}$ A body (not shown) has its center of mass (CM) at the origin. In each case below give the direction for the torque τ with respect to the CM on the body due to force **F** acting on the body at a location indicated by the vector **r**.

Torque:

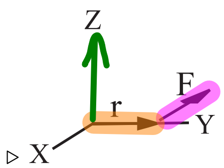
$$\vec{\tau} = \vec{r} \times \vec{F}$$



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



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



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

$\boxed{\textit{4 pt}}$ Planet-X has a mass of 3.73×10^{24} kg and a radius of 5890 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`*)*

24. **A**◯ 1.66 **B**◯ 2.21 **C**◯ 2.94 **D**◯ 3.91
E◯ 5.20 **F**◯ 6.91 **G**◯ 9.19 **H**◯ 1.22×10^1

Escape Speed or Second Cosmic Speed: $v_{II} = \sqrt{\frac{2GM}{R}}$

$$v_{II} = \sqrt{\frac{2 \cdot 6.67 \cdot 10^{-11} \cdot 3.73 \cdot 10^{24}}{5.89 \cdot 10^{6}}}$$

$$v_{II} = 9191\ m/s \cong 9.19\ km/s$$

3 pt An object weighs 93.9 N in air. When it is suspended from a force scale and completely immersed in water the scale reads 19.5 N. Determine the density of the object.
(*in* kg/m^3)

25. **A** ◯ 8.75×10^2 **B** ◯ 9.88×10^2 **C** ◯ 1.12×10^3 **D** ◯ 1.26×10^3
E ◯ 1.43×10^3 **F** ◯ 1.61×10^3 **G** ◯ 1.82×10^3 **H** ◯ 2.06×10^3

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3 pt When the object is immersed in oil, the force scale reads 37.4 N. Calculate the density of the oil.
(*in* kg/m^3)

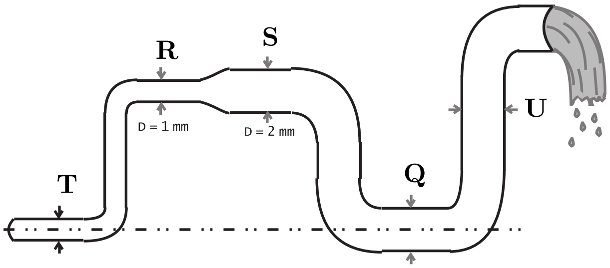
26. **A** ◯ 5.95×10^2 **B** ◯ 6.72×10^2 **C** ◯ 7.59×10^2 **D** ◯ 8.58×10^2
E ◯ 9.70×10^2 **F** ◯ 1.10×10^3 **G** ◯ 1.24×10^3 **H** ◯ 1.40×10^3

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

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

$$T_2 = T_1 - m_{fluid} \cdot g$$
$$m_{fluid} \cdot g = T_1 - T_2$$
$$\rho_{fluid} \cdot V_{obj} \cdot g = T_1 - T_2$$
$$\rho_{fluid} \cdot \frac{m_{obj}}{\rho_{obj}} \cdot g = T_1 - T_2$$
$$\frac{\rho_{fluid}}{\rho_{obj}} \cdot T_1 = T_1 - T_2$$
$$\rho_{fluid} \cdot \frac{T_1}{T_1 - T_2} = \rho_{obj}$$
$$\rho_{obj} = 1000 \frac{kg}{m^3} \cdot \frac{93.9\,N}{93.9N - 19.5N} = 1262 \frac{kg}{m^3}$$
$$\rho_{fluid} = \frac{T_1 - T_2}{T_1} \cdot \rho_{obj} = \frac{93.9N - 37.4N}{93.9N} \cdot 1262 \frac{kg}{m^3}$$
$$\rho_{fluid} = 759.4 \frac{kg}{m^3}$$

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.



Continuity:

$$A_1 \cdot v_1 = A_2 \cdot v_2$$

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

Bernoulli Principle:

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

Select the correct answers.

▷ v_T is ... $2v_S$.
27. A◯ Greater than B◯ Less than C◯ Equal to

▷ p_R is ... p_T.
28. A◯ Greater than B◯ Less than C◯ Equal to

▷ p_Q is ... p_T.
29. A◯ Greater than B◯ Less than C◯ Equal to

$p_R < p_T$: when you climb up, the pressure drops

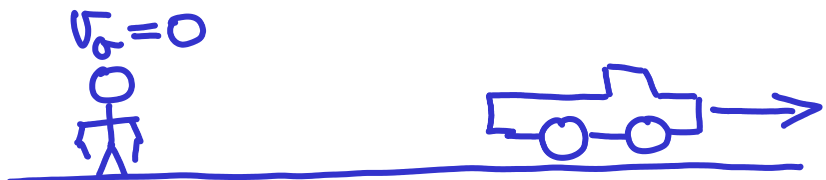
$p_Q > p_T$: when you slow down, the pressure increases

$v_T > 2v_S$ because $v_T = 4v_S$
$(4A_T = A_S)$

$\boxed{4\ pt}$ 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 222 Hz, then what is the speed of the truck? Use 340 m/s for the speed of the sound.
(in m/s*)*

30. **A**◯ 2.76×10^1 **B**◯ 3.68×10^1 **C**◯ 4.89×10^1 **D**◯ 6.50×10^1
E◯ 8.65×10^1 **F**◯ 1.15×10^2 **G**◯ 1.53×10^2 **H**◯ 2.03×10^2

$v_o = 0$ $c = 340\,\frac{m}{s}$



$v_s = ?$

$f_o = 222\,Hz$ $f_s = 246\,Hz$

Doppler effect:

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

since $v_o = 0$, therefore: $f_o = f_s \cdot \frac{c}{c \pm v_s}$

since the shift is down $f_o < f_s$:

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

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

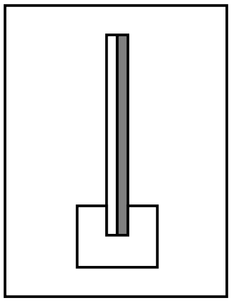
$$v_s f_o = c f_s - c f_o$$

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

$$v_s = 340 \cdot \frac{246 - 222}{222} = 340 \cdot \frac{24}{222}$$

$$v_s = 36.8\ m/s$$

3 pt A bimetallic strip is held fixed at the bottom end as shown in the figure.

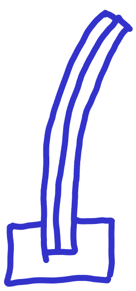


The metal on the left has a coefficient of linear heat expansion of $\alpha_{\text{left}} = 1.00 \times 10^{-5}$ 1/K, the metal on the right has $\alpha_{\text{right}} = 3.25 \times 10^{-5}$ 1/K. When the strip is cooled, it will ... (complete the sentence)

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

The metal with the larger coefficient of heat expansion contracts more:

$\alpha_{\text{left}} = 1 \cdot 10^{-5} \frac{1}{K}$



$\alpha_{\text{right}} = 3.25 \cdot 10^{-5} \frac{1}{K}$

cooled: bends right

$\boxed{\textit{4 pt}}$ A 26.3 l gas bottle contains 9.04×10^{23} Neon molecules at a temperature of 359 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*)*

32. **A**◯ 5.05×10^3 **B**◯ 6.72×10^3 **C**◯ 8.94×10^3 **D**◯ 1.19×10^4
E◯ 1.58×10^4 **F**◯ 2.10×10^4 **G**◯ 2.80×10^4 **H**◯ 3.72×10^4

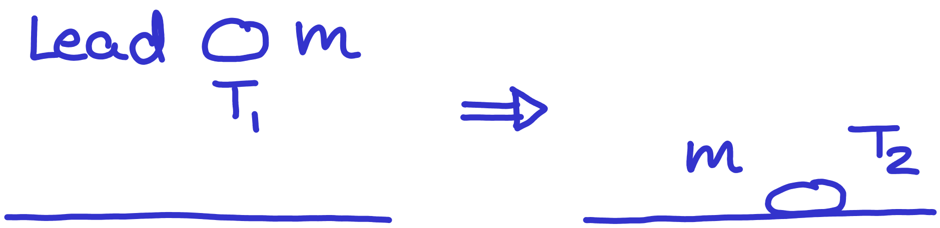
Neon is a noble gas : $f = 3$

$$U = \frac{f}{2} N k_B T = \frac{3}{2} \cdot 9.04 \cdot 10^{23} \cdot 1.38 \cdot 10^{-23} \cdot 359$$

$$U = 6718\,\text{J}$$

$\boxed{4\ pt}$ A bag filled with lead shots is dropped from a height of h = 23.0 m. The total mass of the bag is m = 635 g. What is the increase in the temperature of the lead shots, after the bag hits the ground? (The specific heat of lead is c = 130 J/kgK.)
(in K*)*

33. **A**◯ 5.69×10^{-1} **B**◯ 8.26×10^{-1} **C**◯ 1.20 **D**◯ 1.74
E◯ 2.52 **F**◯ 3.65 **G**◯ 5.29 **H**◯ 7.67



Energy balance :

$$PE_i + \underbrace{KE_i}_{=0} = \underbrace{PE_f}_{=0} + \underbrace{KE_f}_{=0} + \Delta E_{th}$$

$$PE_i = \Delta E_{th}$$

$$mgh = mc\Delta T$$

$$\frac{gh}{c} = \Delta T$$

$$\Delta T = \frac{9.81 \cdot 23}{130} = 1.74\,K$$

$\boxed{10\ pt}$ Constant amount of ideal gas is kept inside a cylinder by a piston. The piston is locked in to position, it is not allowed to move. The gas is then heated up. Compare the initial (i) and the final (f) physical quantities of the gas to each other.

▷ The internal energy U_f is ... U_i.
34. **A**◯ equal to **B**◯ less than **C**◯ greater than

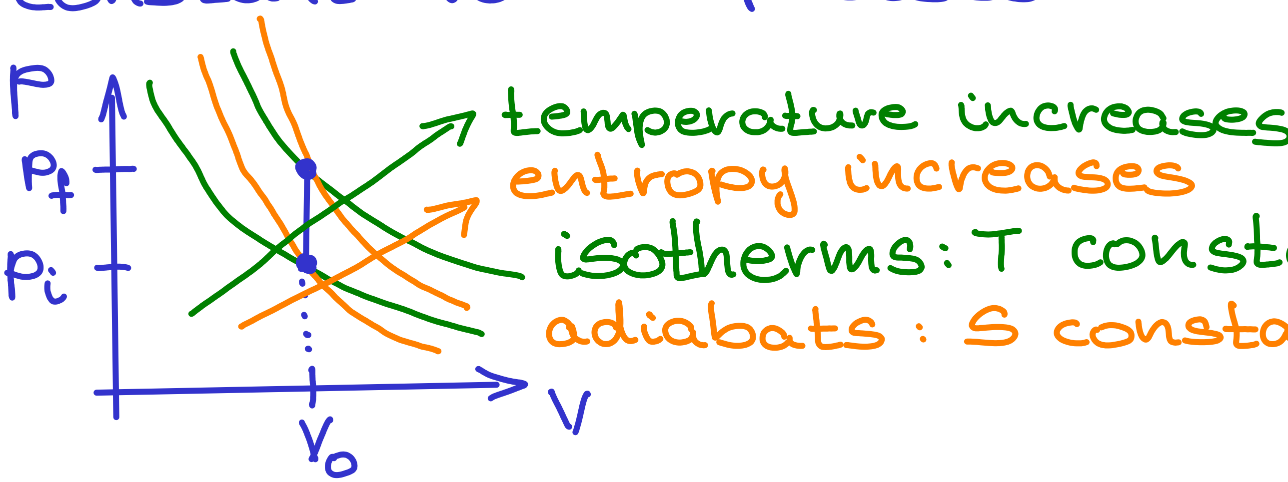
▷ The volume V_f is ... V_i.
35. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The pressure p_f is ... p_i.
36. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The temperature T_f is ... T_i.
37. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The entropy S_f is ... S_i.
38. **A**◯ equal to **B**◯ less than **C**◯ greater than

Constant volume process:



isotherms: T constant
adiabats: S constant

$V_f = V_i$: constant volume process

$p_f > p_i$

$T_f > T_i \Rightarrow U_f > U_i$

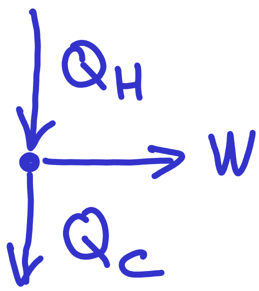
$S_f > S_i$

[*2 pt*] An ideal heat engine absorbs 80.3 kJ of heat and exhausts 61.8 kJ of heat in each cycle. What is the efficiency of the engine?

39. **A**◯ 1.41×10^{-1} **B**◯ 1.60×10^{-1} **C**◯ 1.80×10^{-1} **D**◯ 2.04×10^{-1}
E◯ 2.30×10^{-1} **F**◯ 2.60×10^{-1} **G**◯ 2.94×10^{-1} **H**◯ 3.32×10^{-1}

[*2 pt*] How much work is done in a cycle?
(in kJ*)*

40. **A**◯ 1.39×10^{1} **B**◯ 1.85×10^{1} **C**◯ 2.46×10^{1} **D**◯ 3.27×10^{1}
E◯ 4.35×10^{1} **F**◯ 5.79×10^{1} **G**◯ 7.70×10^{1} **H**◯ 1.02×10^{2}



conservation of energy:

$$Q_H = Q_c + W$$

$$\Rightarrow W = Q_H - Q_c$$

$$W = 80.3\,\text{kJ} - 61.8\,\text{kJ} = 18.5\,\text{kJ}$$

Definition of efficiency:

$$\eta = \frac{\text{useful work}}{\text{total heat absorbed}}$$

$$\eta = \frac{W}{Q_H} = \frac{18.5\,\text{kJ}}{80.3\,\text{kJ}} = 0.23$$