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 = 760 mmHg
- $N_A = 6.02\times10^{23}$ 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!

$\boxed{\textit{10 pt}}$ Are you sitting in the seat assigned?

1.A◯ Yes, I am.

$\boxed{3\ pt}$ An apple, a brick and a hammer are all dropped from the second floor of a building at the same time. Which object(s) will hit the ground first?

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

All dense and compact objects fall together when they are released from rest from the same height at the same time.

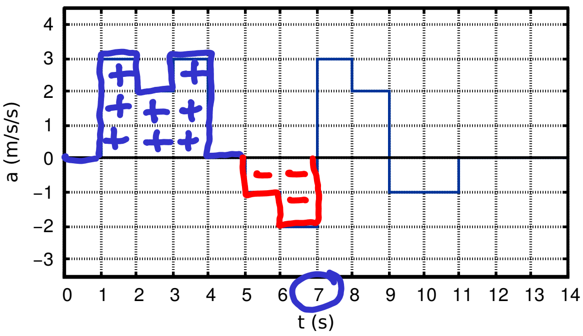
Galileo Galilei

Newton: $a = \frac{F_{net}}{m}$

$$a = \frac{mg}{m} = g = 9.81\ m/s^2$$

But this cancellation is one of the deepest questions in the Universe: the mass in the numerator is the gravitational mass, the mass in the denominator is the inertial mass. Why are they the same?

A car is initially at rest on a straight road. The graph shows the acceleration of the car along that road as a function of time.



$\boxed{4\ pt}$ What is the speed of the car at t=7 s?
(in m/s*)*

3. **A**◯ 1.0 **B**◯ 2.0 **C**◯ 3.0 **D**◯ 5.0 **E**◯ 6.0 **F**◯ 7.0 **G**◯ 8.0 **H**◯ 9.0

Definition of acceleration: $a = \frac{\Delta v}{\Delta t}$

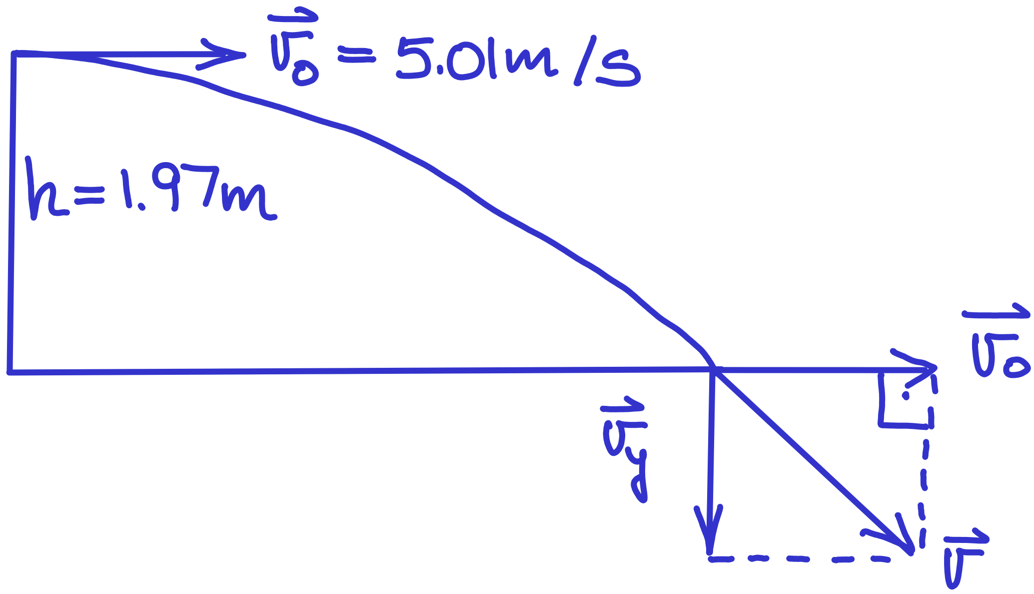
therefore : $\Delta v = a \cdot \Delta t$

very nicely $\Delta t = 1s$ and $v_0 = 0 \frac{m}{s}$.

$$v(t=7s) = v_0 + \Delta v = 0 + 8 - 3 = 5 \frac{m}{s}$$

$\boxed{3\ pt}$ A baseball is projected horizontally with an initial speed of 5.01 m/s from a height of 1.97 m. What is the speed of the baseball when it hits the ground? (Neglect air friction.)
(in m/s*)*

4. **A**◯ 3.80 **B**◯ 5.51 **C**◯ 7.98 **D**◯ 1.16×10^{1}
E◯ 1.68×10^{1} **F**◯ 2.43×10^{1} **G**◯ 3.53×10^{1} **H**◯ 5.12×10^{1}



$\vec{v}_0$ doesn't change throughout the motion

$\vec{v}_y$: $v_y^2 = 2gh$

Pythagorean theorem:

$$v^2 = v_0^2 + v_y^2$$

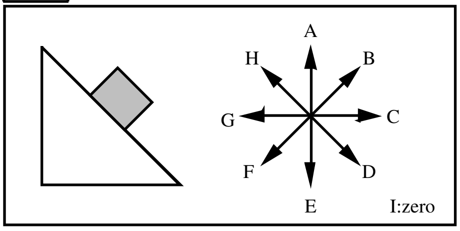
$$v^2 = v_0^2 + 2gh$$

$$v = \sqrt{v_0^2 + 2gh}$$

$$v = \sqrt{5.01^2 + 2 \cdot 9.81 \cdot 1.97}$$

$$v = 7.98 \ m/s$$

$\boxed{3\ pt}$ A block is at rest on a frictional incline. (See figure.)



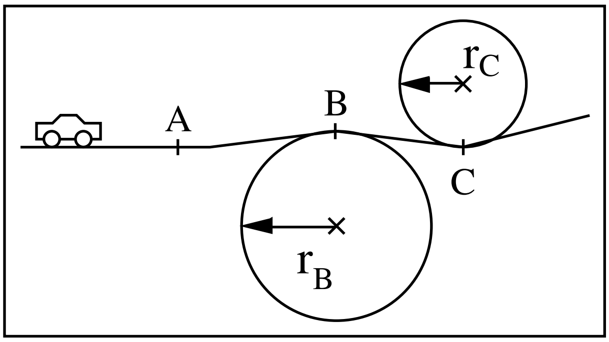
Which vector best represents the direction of the force exerted by the surface on the block?

5.**A**◯ A
B◯ B
C◯ C
D◯ D
E◯ E
F◯ F
G◯ G
H◯ H
I◯ I: the force is zero.

Since the object is at rest, the weight mg must be exactly balaced out to zero. The weight mg points vertically down, therefore we need a force which points vertically up.

Only a frictional incline with a sufficiently large coefficient of static friction can do this. A frictionless incline wouldn't be able to hold an object at rest at any non-zero angle.

2 pt A car with a mass of 1160 kg is traveling in a mountainous area with a constant speed of 66.9 km/h. The road is horizontal and flat at point **A**, horizontal and curved at points **B** and **C**.



centripetal acceleration:

$$a_{cp} = \frac{v^2}{r}$$

$(3.6\,km/h = 1\,m/s)$

The radii of curvatures at **B** and **C** are: $\mathbf{r}_B = 135$ m and $\mathbf{r}_C = 125$ m. Calculate the normal force exerted by the road on the car at point **A**.
(in N)

6. **A**◯ 1.14×10^4 **B**◯ 1.42×10^4 **C**◯ 1.78×10^4 **D**◯ 2.22×10^4
E◯ 2.78×10^4 **F**◯ 3.47×10^4 **G**◯ 4.34×10^4 **H**◯ 5.43×10^4

$F_A = mg$

$F_A = 1160 \cdot 9.81 = 1.14 \cdot 10^4$ N

2 pt Now calculate the normal force exerted by the road on the car at point **B**.
(in N)

7. **A**◯ 4.57×10^3 **B**◯ 5.16×10^3 **C**◯ 5.83×10^3 **D**◯ 6.59×10^3
E◯ 7.44×10^3 **F**◯ 8.41×10^3 **G**◯ 9.51×10^3 **H**◯ 1.07×10^4

F_B is less than mg.

2 pt And finally calculate the normal force exerted by the road on the car at point **C**.
(in N)

8. **A**◯ 1.98×10^3 **B**◯ 2.63×10^3 **C**◯ 3.50×10^3 **D**◯ 4.66×10^3
E◯ 6.20×10^3 **F**◯ 8.24×10^3 **G**◯ 1.10×10^4 **H**◯ 1.46×10^4

F_C is more than mg.

B: $mg - F_B = m a_{cp}$

$$mg - m\frac{v^2}{r_B} = F_B$$

$$F_B = m\left(g - \frac{v^2}{r_B}\right)$$

$$F_B = 1160\left(9.81 - \frac{18.58^2}{135}\right)$$

$$F_B \cong 8412\,N$$

C: $F_C - mg = m a_{cp}$

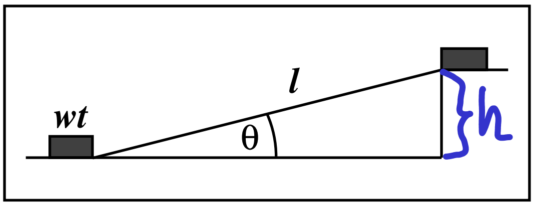
$$F_C = mg + m\frac{v^2}{r_C}$$

$$F_C = m\left(g + \frac{v^2}{r_C}\right)$$

$$F_C = 1160\left(9.81 + \frac{18.58^2}{125}\right)$$

$$F_C \cong 14{,}580\,N$$

A block with a weight of 600 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 $\theta = 20.0°$ and the length of the ramp is $l = 14.4$ m.



$h = l \cdot \sin\theta$

[*3 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)*

9. **A**◯ 9.68×10^2 **B**◯ 1.21×10^3 **C**◯ 1.51×10^3 **D**◯ 1.89×10^3
E◯ 2.36×10^3 **F**◯ 2.96×10^3 **G**◯ 3.69×10^3 **H**◯ 4.62×10^3

The work done by the external force is equal to the change in potential energy:

$$W_{ext} = \Delta PE = PE_f = mgh$$

from the energy balance:

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

$$W_{ext} = mgh = mg\, l \sin\theta$$

$$W_{ext} = 600 \cdot 14.4 \cdot \sin 20° \cong 2955 N$$

Or you can say that a force of $F_{\parallel} = mg \cdot \sin\theta$ pushes for a distance of l : $W_{ext} = mg \cdot \sin\theta \cdot l$

$\boxed{\textit{3 pt}}$ An athlete, swimming at a constant speed, covers a distance of 125 m in a time period of 1.85 minutes. The drag force exerted by the water on the swimmer is 52.0 N. Calculate the power the swimmer must provide in overcoming that force.
(in `W`*)*

10. **A**◯ 2.79×10^1 **B**◯ 4.04×10^1 **C**◯ 5.86×10^1 **D**◯ 8.49×10^1
E◯ 1.23×10^2 **F**◯ 1.79×10^2 **G**◯ 2.59×10^2 **H**◯ 3.75×10^2

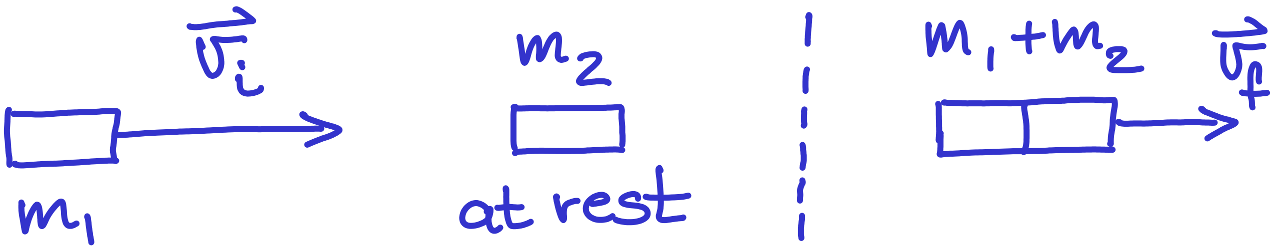
Power : $P = \vec{F} \cdot \vec{v} = F \cdot v$ b/c $\theta = 0°$

$$P = F \cdot \frac{d}{t} = 52\,N \cdot \frac{125\,m}{1.85 \cdot 60\,s}$$

$P = 58.6\ W$

$\boxed{3\ pt}$ A 629 kg automobile slides across an icy street at a speed of 63.5 km/h and collides with a parked car. The two cars lock up and they slide together with a speed of 26.1 km/h. What is the mass of the parked car?
(in kg*)*

11. **A**◯ 3.83×10^2 **B**◯ 5.10×10^2 **C**◯ 6.78×10^2 **D**◯ 9.01×10^2
E◯ 1.20×10^3 **F**◯ 1.59×10^3 **G**◯ 2.12×10^3 **H**◯ 2.82×10^3



Conservation of momentum:

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

$$m_1 v_i = m_1 v_f + m_2 v_f$$

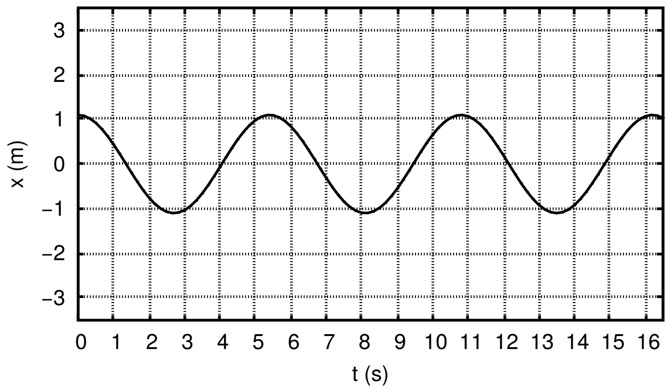
$$m_1 v_i - m_1 v_f = m_2 v_f$$

$$m_1 \frac{v_i - v_f}{v_f} = m_2$$

$$m_2 = 629 \cdot \frac{63.5 - 26.1}{26.1} = 901 \text{ kg}$$

There is no need to convert to m/s, because the km/h cancels out in the division.

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) = Acos(ωt), where x and A are measured in meters, t is measured in seconds, ω is measured in rad/s.

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

from the figure:
A = 1.1 m

12. **A**◯ 8.00×10^{-1} **B**◯ 1.10 **C**◯ 1.40 **D**◯ 1.70
E◯ 2.00 **F**◯ 2.30 **G**◯ 2.90 **H**◯ 4.40

---

from the figure:
T = 5.4 s

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

13. **A**◯ 3.80 **B**◯ 5.40 **C**◯ 6.20 **D**◯ 7.00 **E**◯ 7.40 **F**◯ 7.80 **G**◯ 8.60 **H**◯ 9.00

$$\omega = \frac{2\pi}{T} = \frac{2 \cdot 3.14}{5.4} = 1.16 \frac{rad}{s}$$

$\boxed{2\ pt}$ Determine the angular frequency ω.
(in rad/s*)*

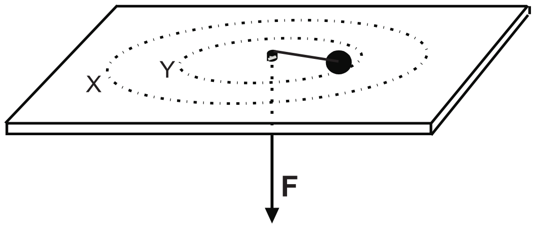
14. **A**◯ 3.82×10^{-1} **B**◯ 5.53×10^{-1} **C**◯ 8.02×10^{-1} **D**◯ 1.16
E◯ 1.69 **F**◯ 2.45 **G**◯ 3.55 **H**◯ 5.14

$$f = \frac{1}{T} = \frac{1}{5.4} = 0.185 \text{ Hz}$$

$\boxed{2\ pt}$ Determine the linear frequency f.
(in Hz*)*

15. **A**◯ 3.88×10^{-2} **B**◯ 4.85×10^{-2} **C**◯ 6.07×10^{-2} **D**◯ 7.59×10^{-2}
E◯ 9.48×10^{-2} **F**◯ 1.19×10^{-1} **G**◯ 1.48×10^{-1} **H**◯ 1.85×10^{-1}

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



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

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

▷ M's kinetic energy at X is one quarter that at Y.
18. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

▷ While going from Y to X, there is no torque on M.
19. **A**◯ true **B**◯ false **C**◯ greater than **D**◯ less than **E**◯ equal to

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

→ $W<0$ b/c the force and the displacement points in opposite directions. (We are losing in the tug-of-war.)

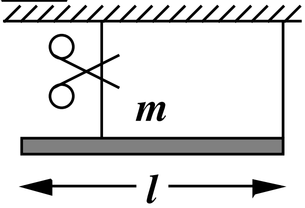
→ $KE_X = \frac{1}{4} KE_Y$ b/c $KE = \frac{L^2}{2I}$ and $I = mr^2$

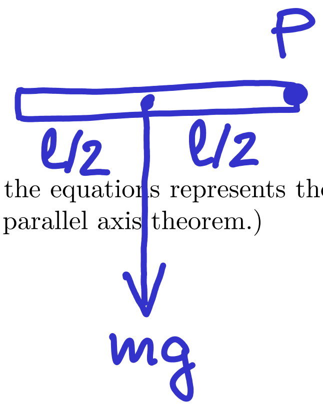
→ $\tau = 0$ b/c the force in the rope is central

→ $L_X = L_Y$ b/c $\tau = 0$ (Newton's 2nd: $\tau = \frac{\Delta L}{\Delta t}$)

→ $\omega_X = \frac{1}{4}\omega_Y$ b/c $L_X = L_Y$ means $I_X \omega_X = I_Y \omega_Y$ and $I_X = 4 I_Y$ (due to $I = mr^2$) therefore $\omega_X = \frac{1}{4}\omega_Y$

$\boxed{3\ pt}$ A uniform rod with length l and mass m is suspended by two thin strings as shown in the figure.





The rod is in horizontal position. Which of the equations represents the initial angular acceleration of the rod when the string on the left is cut? (Hint: Use the parallel axis theorem.)

21.A◯ g/l
B◯ $(3mg)/(2l)$
C◯ $(3g)/l$
D◯ $l/(2g)$
E◯ $(3l)/(2g)$
F◯ $(3ml)/(2g)$
G◯ $(12l)/mg$
H◯ $(3g)/(2l)$

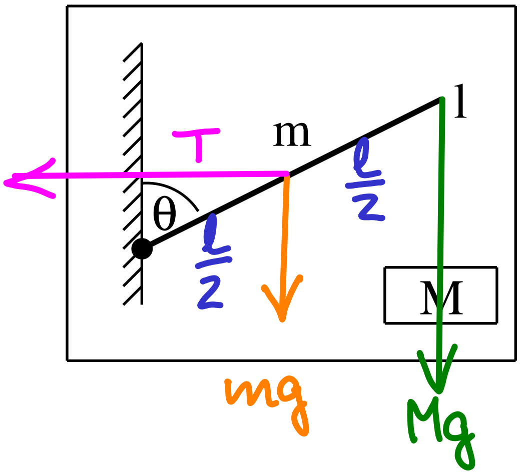
Newton's 2nd law for rotation:

$$\tau = I_P \cdot \alpha \longleftarrow \underbrace{I_P = \frac{1}{3} m l^2}_{\text{moment of inertia with respect to the end point P.}}$$

$$mg \frac{l}{2} = \frac{1}{3} m l^2 \cdot \alpha$$

$$\frac{3g}{2l} = \alpha$$

A crate with a mass of M = 74.5 kg is suspended by a rope from the endpoint of a uniform boom. The boom has a mass of m = 141 kg and a length of l = 6.61 m. The midpoint of the boom is supported by another rope which is horizontal and is attached to the wall as shown in the figure.



The vertical rope simply holds the weight of M:

$Mg = 74.5 \cdot 9.81 = 731\,N$

[2 pt] The boom makes an angle of $\theta = 51.4°$ with the vertical wall. Calculate the tension in the vertical rope. *(in N)*

22. **A** ◯ 6.47×10^2 **B** ◯ 7.31×10^2 **C** ◯ 8.26×10^2 **D** ◯ 9.33×10^2
E ◯ 1.05×10^3 **F** ◯ 1.19×10^3 **G** ◯ 1.35×10^3 **H** ◯ 1.52×10^3

[3 pt] What is the tension in the horizontal rope? *(in N)*

23. **A** ◯ 3.15×10^3 **B** ◯ 3.56×10^3 **C** ◯ 4.03×10^3 **D** ◯ 4.55×10^3
E ◯ 5.14×10^3 **F** ◯ 5.81×10^3 **G** ◯ 6.57×10^3 **H** ◯ 7.42×10^3

The balance of torques:

$$T \cdot \frac{l}{2}\cos\theta = mg\frac{l}{2}\sin\theta + Mgl\sin\theta$$

$$T = (m+2M)\,g\tan\theta$$

$$T = (141 + 2 \cdot 74.5) \cdot 9.81 \cdot \tan 51.4°$$

$$T \cong 3564\,N$$

3 pt A 334 kg satellite is orbiting Earth on a circular orbit with a speed of 4.19 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`*)*

24. **A**◯ 8.85×10^3 **B**◯ 1.00×10^4 **C**◯ 1.13×10^4 **D**◯ 1.28×10^4
E◯ 1.44×10^4 **F**◯ 1.63×10^4 **G**◯ 1.84×10^4 **H**◯ 2.08×10^4

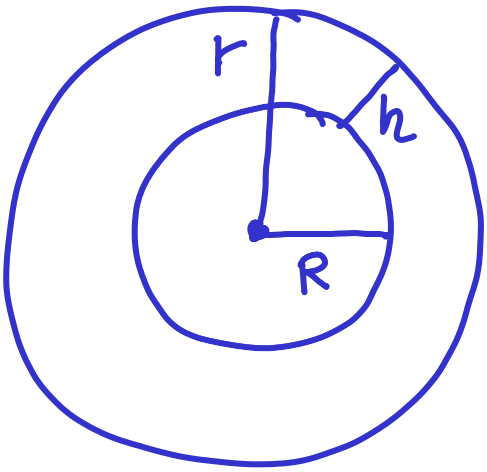
Speed of a satellite on an orbit with radius r: $v = \sqrt{\frac{GM}{r}} \Rightarrow$

$$r = \frac{GM}{v^2} = \frac{6.67 \cdot 10^{-11} \cdot 5.97 \cdot 10^{24}}{4190^2}$$

$$\left.\begin{array}{l} r = 22.68 \cdot 10^6 \text{ m} \\ R = 6.37 \cdot 10^6 \text{ m} \end{array}\right\} \quad h = r - R = 16.31 \cdot 10^6 \text{ m} =$$

$$= 16{,}310 \text{ km} =$$

$$= 1.63 \cdot 10^4 \text{ km}$$



$R + h = r$

3 pt Glucose solution is administered to a patient in a hospital. The density of the solution is 1.114 kg/l. If the blood pressure in the vein is 44.3 mmHg, then what is the minimum necessary height of the IV bag above the position of the needle?
(in cm*)*

25. **A**◯ 46.2 **B**◯ 54.0 **C**◯ 63.2 **D**◯ 74.0
E◯ 86.5 **F**◯ 101.2 **G**◯ 118.5 **H**◯ 138.6

Hydrostatic pressure: $p = \rho \cdot g \cdot h$

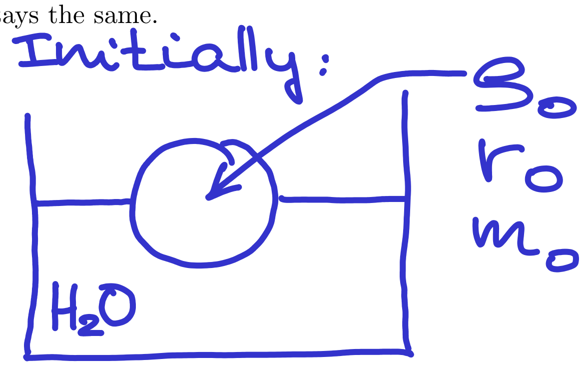
$g = 9.81\, m/s^2$

$\rho = 1.114\, kg/l = 1{,}114\, kg/m^3$

$p = 44.3\, mmHg = 5905\, Pa$

$$h = \frac{p}{\rho g} = \frac{5905}{1114 \cdot 9.81} = 0.54 m = 54 cm$$

$\boxed{6\ pt}$ 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.



▷ The new sphere has a radius of $r > r_0$ and a mass of $m = m_0$.
26. **A**◯ r **B**◯ f **C**◯ s

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

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

$$\rho = \frac{m}{V} \quad \text{and} \quad V = \frac{4\pi}{3} r^3$$

	ρ	m	V	H_2O level
26	↓	=	↑	same
27	=	↓	↓	falls
28	=	↓	↓	falls

Initially the sphere was floating. In all these three questions the sphere remained afloat. Objects floating on the surface displace water equivalent to their mass. If the mass stays the same, the water level will also stay the same. If the mass decreases, then the water level will fall.

$\boxed{3\ pt}$ 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?

29.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.

Intensity from one speaker: I_1

Its sound level in dB: $10\log\left(\frac{I_1}{I_0}\right) = 70\,dB$

Intensity from two speakers: I_2

$I_2 = I_1 + I_1 = 2I_1$: conservation of energy.

Sound level of I_2: $10\log\left(\frac{I_2}{I_0}\right) =$

$$= 10\log\left(\frac{2I_1}{I_0}\right) = \underbrace{10\log 2}_{=3dB} + \underbrace{10\log\left(\frac{I_1}{I_0}\right)}_{=70dB} = 73dB$$

3 pt A stationary horn emits a sound with a frequency of 208 Hz. A car is moving away from the horn on a straight road with constant speed. If the driver of the car hears the horn at a frequency of 183 Hz, then what is the speed of the car? Use 340 m/s for the speed of the sound.
(*in* m/s)

30. **A**◯ 1.86×10^1 **B**◯ 2.18×10^1 **C**◯ 2.55×10^1 **D**◯ 2.99×10^1
E◯ 3.49×10^1 **F**◯ 4.09×10^1 **G**◯ 4.78×10^1 **H**◯ 5.59×10^1

Doppler effect: $f_o = f_s \dfrac{c \pm v_o}{c \mp v_s}$

$c = 340\,m/s$: speed of sound

$f_s = 208\,Hz$: source freq.

$f_o = 183\,Hz$: observed freq.

$v_s = 0\,m/s$: the horn is at rest

$v_o = ?$: observer speed

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

since the frequency shift is DOWN, we need a fraction less than one.

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

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

$$v_o = c\,\frac{f_s - f_o}{f_s} = 340 \cdot \frac{208 - 183}{208} = 40.9\,\frac{m}{s}$$

$\boxed{3\ pt}$ An aluminium object with a mass of 5.44 kg and at a temperature of 25.0 °C comes to thermal contact with a 8.52 kg copper object which is initially at a temperature of 84.1 °C. What is going to be the equilibrum temperature of the two objects? Neglect heat transfer between the objects and the environment. The specific heats are: $c_{Al} = 900$ J/kg°C and $c_{Cu} = 387$ J/kg°C.
(in `degC`*)*

31. **A**◯ 1.90×10^1 **B**◯ 2.23×10^1 **C**◯ 2.60×10^1 **D**◯ 3.05×10^1
E◯ 3.56×10^1 **F**◯ 4.17×10^1 **G**◯ 4.88×10^1 **H**◯ 5.71×10^1

Al	Cu
$m_{Al} = 5.44\,\text{kg}$	$m_{Cu} = 8.52\,\text{kg}$
$c_{Al} = 900\,\text{J}/(\text{kg}^\circ\text{C})$	$c_{Cu} = 387\,\text{J}/(\text{kg}^\circ\text{C})$
$T_{Al} = 25.0^\circ\text{C}$	$T_{Cu} = 84.1^\circ\text{C}$

Conservation of energy:

$$\underbrace{\Delta U_{Al}}_{\text{gain}} + \underbrace{\Delta U_{Cu}}_{\text{loss}} = 0$$

$$c_{Al} \cdot m_{Al} \cdot (T_f - T_{Al}) + c_{Cu} \cdot m_{Cu} \cdot (T_f - T_{Cu}) = 0$$

$$c_{Al} \cdot m_{Al} \cdot T_f - c_{Al} \cdot m_{Al} \cdot T_{Al} +$$
$$+ c_{Cu} \cdot m_{Cu} \cdot T_f - c_{Cu} \cdot m_{Cu} \cdot T_{Cu} = 0$$

$$(c_{Al} \cdot m_{Al} + c_{Cu} \cdot m_{Cu}) \cdot T_f = c_{Al} \cdot m_{Al} \cdot T_{Al} + c_{Cu} \cdot m_{Cu} \cdot T_{Cu}$$

$$T_f = \frac{c_{Al} \cdot m_{Al} \cdot T_{Al} + c_{Cu} \cdot m_{Cu} \cdot T_{Cu}}{c_{Al} \cdot m_{Al} + c_{Cu} \cdot m_{Cu}}$$

$$T_f = 48.8^\circ\text{C}$$

(Stay in celsius, don't convert to kelvin.)

$\boxed{3\ pt}$ What is the volume of 2.19 moles of Nitrogen gas, if the temperature of the gas is 13.7 °C and the pressure is 2.95 atm?
(in L*)*

32. **A**◯ 7.97 **B**◯ 9.32 **C**◯ 10.91 **D**◯ 12.76
E◯ 14.93 **F**◯ 17.47 **G**◯ 20.44 **H**◯ 23.91

Ideal gas law: $pV = nRT$

$n = 2.19$ mol

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

$T = 13.7\ °C = 286.7\ K$

$p = 2.95\ atm = 2.99 \cdot 10^5\ Pa$

$$V = \frac{nRT}{p} = \frac{2.19 \cdot 8.31 \cdot 286.7}{2.99 \cdot 10^5} = 17.45\ \ell$$

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

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

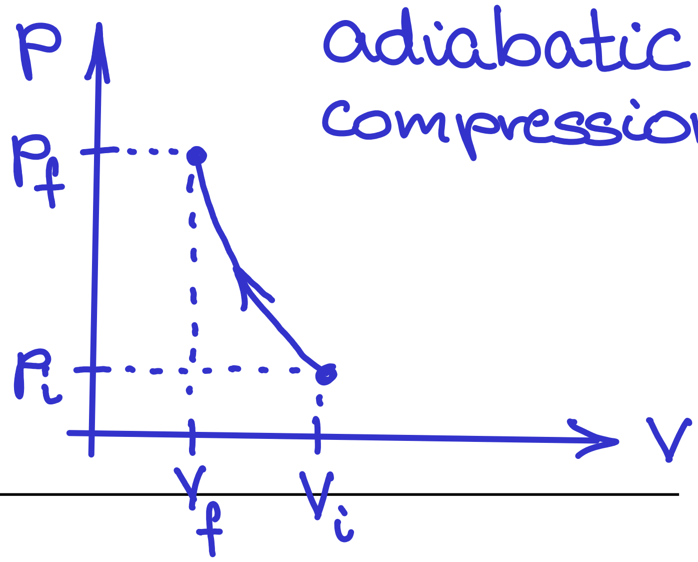
▷ The pressure p_f is ... p_i.
34. **A**◯ equal to **B**◯ less than **C**◯ greater than

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

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

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

adiabatic compression:



→ $V_f < V_i$ b/c it is a compression

→ $P_f > P_i$ b/c $P_f \cdot V_f^{\gamma} = P_i \cdot V_i^{\gamma}$

→ $U_f > U_i$ b/c $W > 0$ & $Q = 0$ in $\Delta U = Q + W$ or we are crossing isotherms moving to higher and higher temperatures.

→ $T_f > T_i$ b/c $U = \frac{f}{2} N k_B T$: the internal energy and the temperature are directly proportional to each-other, they always change together.

→ $S_f = S_i$ b/c $Q = 0$ in an adiabatic process. Another word for adiabatic process : iso-entropic, meaning it keeps the entropy constant.

1 pt A Stirling-engine is used in the heat-pump mode to heat a house. The engine maintains a temperature of 22.1 °C inside the house. The temperature of the Earth loop is 11.1 °C. (The Earth loop buried deep under the ground is the cold reservoir of this heat pump.) What is the coefficient of performance of this heat pump?

38. **A**◯ 2.68×10^1 **B**◯ 3.03×10^1 **C**◯ 3.43×10^1 **D**◯ 3.87×10^1
E◯ 4.38×10^1 **F**◯ 4.95×10^1 **G**◯ 5.59×10^1 **H**◯ 6.31×10^1

---

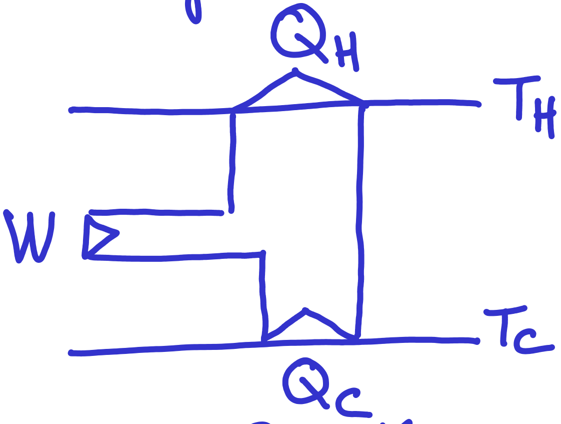
1 pt If the power of the electric motor driving the heat pump is 199 W, then what is the rate at which heat is delivered to the house?
(in `W`*)*

39. **A**◯ 1.40×10^3 **B**◯ 1.75×10^3 **C**◯ 2.19×10^3 **D**◯ 2.73×10^3
E◯ 3.42×10^3 **F**◯ 4.27×10^3 **G**◯ 5.34×10^3 **H**◯ 6.68×10^3

Hot reservoir: $T_H = 22.1°C = 295.1\,K$

Cold reservoir: $T_C = 11.1°C = 284.1\,K$

The goal is to heat the house with Q_H.



Coefficient of performance by Carnot:

$$K = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} = \frac{T_H}{T_H - T_C}$$

$$K = \frac{295.1\,K}{11.0\,K} = 26.8$$

$Q_H = K \cdot W$ or with powers: $P_H = K \cdot P$:

$$P_H = 26.8 \cdot 199 = 5333\,W$$