University of São Paulo
São Carlos Institute of Physics
Graduate Program

Admission Test

Biomolecular Physics

First Semester 2024

Answer Key

Candidate's Code:

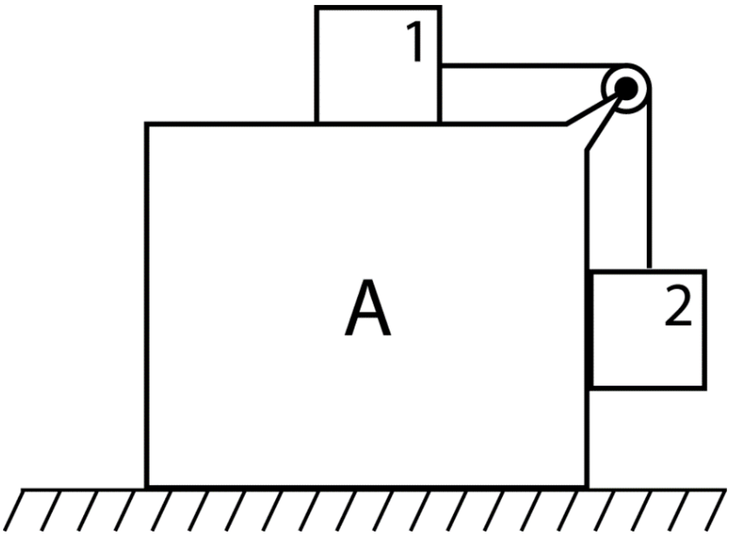
Physics Questions

(Multiple Choice)

Instructions: The Physics questions are multiple-choice. For these questions, please indicate your chosen answer directly in this exam booklet by marking the corresponding square with an "X" using a black or blue pen. Do not use this exam booklet for elaborating on your answers or as a draft. You may use the provided Notepaper for developing your answers or as a draft paper. **The answers considered for correction will be the ones marked in the exam booklet.**

Question 1:

In the given figure, the masses of bodies 1 and 2 are equal, and the coefficient of static friction between body A and bodies 1 and 2 is represented by μ. The masses of the pulley and ropes are negligible, and there is no friction in the pulleys. What is the minimum acceleration at which body A must be horizontally displaced to keep bodies 1 and 2 stationary relative to it?



Place an 'X' in the square that corresponds to the correct answer.

□ $a_{min} = [(1-2\mu)/(1+\mu)]g$

□ $a_{min} = [(1+\mu)/(1-\mu)]g$

□ $a_{min} = [(1-\mu)/(1+2\mu)]g$

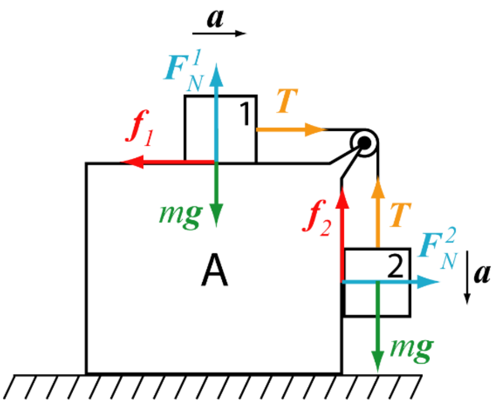
■ $a_{min} = [(1-\mu)/(1+\mu)]g$

□ $a_{min} = [(1-2\mu)/(1+2\mu)]g$

Answer:

Bodies 1 and 2 will remain at rest with respect to body A for $a_{min} \leq a \leq a_{max}$, where a_{min} is the minimum aceleration of body A. Beyond these limits there will be relative movement between body A and the bodies 1 and 2. For $0 \leq a \leq a_{min}$ the tendency of body 1 is to move to the right in relation to body A. Based on this argument, for the purposes of calculating a_{min}, the static friction force in body 2 is directed upward and in body 1 it is directed to the left.

The force diagram for bodies 1 and 2 is then.



Let's write Newton's second law for bodies 1 and 2 in the horizontal direction.

$$T - f_1 = ma \rightarrow f_1 = T - ma \qquad (1)$$
$$F_N^2 = ma \qquad (2)$$

As body 2 has no vertical acceleration, then:

$$f_2 = mg - T \qquad (3)$$

From (1) and (3)

$$f_1 + f_2 = mg - ma \qquad (4)$$

For the situation without sliding of the bodies in relation to body A, we must have:

$$f_1 + f_2 \leq \mu(F_N^1 + F_N^2) \rightarrow f_1 + f_2 \leq \mu(mg + ma) \qquad (5)$$

Then, from (4) and (5):

$$mg - ma \leq \mu(mg + ma) \qquad (6)$$

Solving to a:

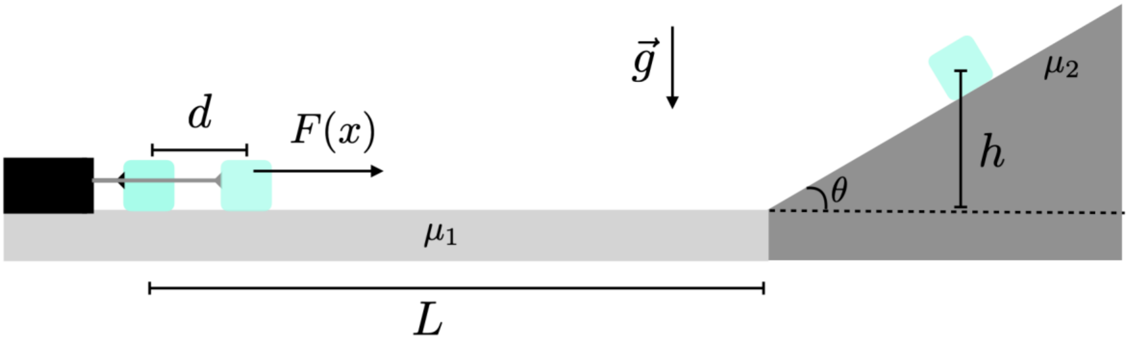
$$a \geq \frac{(1-\mu)}{(1+\mu)} g \qquad (7)$$

Therefore:

$$\boxed{a_{min} = \frac{(1-\mu)}{(1+\mu)} g}$$

Question 2:

A motor equipped with a mechanical arm pushes a block of mass $m = 1{,}0\,kg$ for a distance $d = 0{,}3\,m$, impressing on it a force $F(x) = Cx^2$ starting from the origin of the coordinate system and with the constant $C = 1000\,N/m^2$. In the first section, $L = 1{,}0\,m$ long, the coefficient of kinetic friction between the block and the surface is $\mu_1 = 0{,}1$. The block then moves up an inclined plane at an angle θ , with a coefficient of kinetic friction such that $\mu_2/tg(\theta) = 1$. Use $g = 10\,m/s^2$. The height h that the block rises before starting its descent is:



Place an 'X' in the square that corresponds to the correct answer.

- ☐ 0,10m
- ☐ 0,15m
- ☐ 0,20m
- ■ 0,40m
- ☐ 0,50m

Answer:

The work done by the force during the displacement d is obtained by integration, and is $Cd^3/3$. As the block slides on the plane, the force of kinetic friction does negative work against the motion, of $-\mu_1 mgL$. Then, we know the kinetic energy of the block when it starts to climb the ramp. Taking into account the work of friction in the ascent, it reaches the maximum height given by:

$$h = \frac{(Cd^3/3 - \mu_1 mgL)}{\left(mg\left(1 + \frac{\mu_2}{tg\theta}\right)\right)} = 0{,}4\ m$$

Question 3:

A simple pendulum 1 m long stays in equilibrium at an angle of $1°$ with the vertical when a fan that produces horizontal wind with speed $V = \sqrt{10}/2$ m/s is on. Here we assume that the drag force is of the type $-bV$. The fan is turned off and this pendulum then oscillates, with damping due to the drag force. Assume, throughout this question, that the oscillations are small and use appropriate approximations. Use $g = 10 m/s^2$ and consider that ω_0 represents the free oscillation frequency of this pendulum.

What is the oscillation frequency of the damped pendulum for small oscillations?

Hint: for a generic oscillator with equation of motion

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \omega_0^2 x = 0$$

the oscillation frequency is $\omega = \sqrt{\omega_0^2 - (b/2m)^2}$.

Place an 'X' in the square that corresponds to the correct answer.

■ $\omega_0\sqrt{1 - \pi^2/32400}$

□ $\omega_0\sqrt{1 - \pi^2/11200}$

□ $\omega_0\sqrt{1 - \pi^2/5200}$

□ $\omega_0\sqrt{1 - \pi^2/1800}$

□ $\omega_0\sqrt{1 - \pi^2/64000}$

Answer:

First, we can find the value of b in this problem given the equilibrium condition of the pendulum. We have

$$b = \frac{mg\ \tan\theta_0}{V}$$

θ_0 is the equilibrium angle, m is the mass of the pendulum, V and g are defined in the statement.

We can write the tangential acceleration and velocity of the pendulum as a function of the angle $\theta(t)$ done with respect to vertical. We have $a = l\frac{d^2\theta}{dt^2}$ e $V = l\frac{d\theta}{dt}$, where l is the length of the pendulum. The tangential projection of the weight force is $-mg\ \text{sen}\theta$. With this we can write $F = ma$ for the pendulum considering the force of gravity and the drag force. The equation of motion becomes

$$\frac{d^2\theta}{dt^2} + \frac{b}{m}\frac{d\theta}{dt} + \frac{g}{l}\theta = 0$$

Where we used $\text{sen}\theta \approx \theta$. The free oscillation frequency is $\omega_0 = \sqrt{g/l}$

In the presence of the damping and using $\tan\theta \approx \theta$ t the oscillation frequency becomes,

$$\omega = \sqrt{\frac{g}{l} - \left(\frac{b}{2m}\right)^2} = \omega_0\sqrt{1 - \frac{lg\theta_0^2}{4V^2}} = \omega_0\sqrt{1 - \frac{\pi^2}{32400}}$$

Question 4:

A system consists of $0{,}32$ moles of a monatomic ideal gas, with $C_V = 3RT/2$, occupying a volume of $2{,}2\ L$ at a pressure of $2{,}4\ atm$ (point A). The system goes through a cycle that consists of three processes:

1. The gas is heated at constant pressure until its volume is $4{,}4\ L$ (point B).
2. The gas is cooled at constant volume until its pressure drops to $1{,}2\ atm$ (point C).
3. The gas undergoes an isothermal compression process until it returns to the starting point (point A).

Consider positive work as that done on the system and positive heat as that delivered to the system. What is the work, the heat, and internal energy change throughout the cycle?

Place an 'X' in the square that corresponds to the correct answer.

- ☐ None of the proposed answers.
- ☐ $+\ 0{,}96\ kJ;\ -\ 0{,}96\ kJ;\quad 0{,}00\ kJ$
- ☐ $+\ 0{,}32\ kJ;\ -\ 0{,}64\ kJ;\ +\ 0{,}32\ kJ$
- ☐ $-\ 0{,}32\ kJ;\ +\ 0{,}64\ kJ;\ +\ 0{,}32\ kJ$
- ■ $-\ 0{,}16\ kJ;\ +\ 0{,}16\ kJ;\quad 0{,}00\ kJ$

Answer:

The temperatures at points A, B e C are:

$$T_C = T_A = \frac{P_A V_A}{nR} = 200\ K; \qquad T_B = \frac{P_B V_B}{nR} = \frac{P_A(2V_A)}{nR} = T_A = 400\ K;$$

The work in process 1 is: $W_1 = -P_A \Delta V = -P_A(V_B - V_A) = -535\ J$
The heat in process 1 is: $Q_1 = C_P \Delta T = \frac{5}{2} nR\Delta T = 1337\ J$
The internal energy change in process 1 is: $\Delta E_{int1} = Q_1 + W_1 = 802\ J$

The work in process 2 is: $W_2 = 0\ J$
The heat in process 2 is: $Q_2 = C_V \Delta T = \frac{3}{2} nR\Delta T = -802\ J$
Because $W_2 = 0 \ \rightarrow \Delta E_{int2} = Q_2 = -802\ J$

The work in process 3 is: $W_3 = nRT_A ln\frac{V_A}{V_C} = 371\ J$
The internal energy change in process 3 is: $\Delta E_{int3} = 0\ J$
The heat in process 2 is 3 é: $Q_3 = \Delta E_{int3} - W_3 = -371\ J$

Therefore:

$W_{total} = W_1 + W_2 + W_3 = -164\ J$
$Q_{total} = Q_1 + Q_2 + Q_3 = 164\ J$
$\Delta E_{int-total} = \Delta E_{int1} + \Delta E_{int2} + \Delta E_{int3} = 0\ J$

Question 5:

Consider the harmonic wave function on a string:

$$y(x,t) = (0{,}030\ m)\mathrm{sen}[(2{,}2\ m^{-1})x - (3{,}5\ s^{-1})t]$$

What is its wavelength, period, and the maximum transversal speed of any point on the string?

Place an 'X' in the square that corresponds to the correct answer.

☐ $0{,}4\ m;\ 1{,}7\ s;\ 1{,}1\ m/s$

☐ $5{,}8\ m;\ 0{,}9\ s;\ 3{,}5\ m/s$

■ $2{,}9\ m;\ 1{,}8\ s;\ 0{,}11\ m/s$

☐ $0{,}3\ m;\ 2{,}2\ s;\ 0{,}35\ m/s$

☐ None of the proposed answers.

Answer:

The general expression for a sinusoidal wave function is:

$$y(x,t) = A\mathrm{sen}[kx - \omega t]$$

By direct comparison we identify that for the wave function given in the problem $k = 2{,}2\ m^{-1}$ and $\omega = 3{,}5\ rad/s$.

The wavelength is $\lambda = \frac{2\pi}{k} = 2{,}9\ m$

The period is $T = \frac{2\pi}{\omega} = 1{,}8\ s$

The vertical speed is given by:

$$V_y = \frac{dy}{dt} = (-0{,}105\ m/s)\cos[(2{,}2\ m^{-1})x - (3{,}5\ s^{-1})t]$$

Therefore the maximum speed is: $V_{y,max} = 0{,}105\ m/s$

QUESTIONS ON BIOLOGICAL SCIENCE AND BIOCHEMISTRY

(Multiple Choice)

Instructions: The questions on biological science and biochemistry are multiple-choice. For these questions, please indicate your chosen answer directly in this exam booklet by marking the corresponding square with an "X" using a black or blue pen. Do not use this exam booklet for elaborating on your answers or as a draft. You may use the provided Notepaper for developing your answers or as a draft paper. **The answers considered for correction will be the ones marked in the exam booklet.**

Question 1:

Which one of the following statements about cholesterol is correct??

- ☐ It is a saturated fatty acid.
- ☐ It is present in the cell membranes of all living organisms.
- ■ Regulates the fluidity of the biological membranes.
- ☐ It is soluble in water.
- ☐ It is exclusively used as na energy source.

Question 2:

Cellulose and starch are glycose polysaccharides. Which is the main difference between them?

- [ ] The cellulose is branched while the starch is linear.
- [ ] The glycosidic bond in cellulose is α(1→4), while in the starch é β(1→4).
- [ ] The starch is soluble in water, but the cellulose is not.
- [ ] The cellulose is digested by humans, but the starch is not.
- [x] The glycosidic bond in the starch is α(1→4), while in the cellulose is β(1→4).

Question 3:

The " wobble code" in the translation refers to:

- [ ] Mutation in the DNA.
- [ ] An inaccuracy in the DNA replication.
- [x] Flexibility at the bond between the tRNA anticodon and the mRNA codon.
- [ ] Errors in the polymerization of nucleotides.
- [ ] Alternation of the DNA methylation pattern

Question 4:

Which one of the following phenomena is responsible for the formation and maintenance of the secondary structure of a protein?

- [ ] Hydrophobic interaction between lateral chains of the amino acids.
- [ ] Dissulfide bonds between cysteine residues.
- [ ] Peptide bonds between amino acids.
- [ ] Electrostatic interactions between carboxyl and amine groups.
- [x] Hydrogen bonds between the carbonyl group and the amine group of the proximal polypeptidic chain.

Questão 5:

Which one of the following amino acids is most likely to be phosphorylated in a reaction catalyzed by a kinase?

- [ ] Methionine
- [ ] Proline
- [ ] Phenylalanine
- [x] Threonine
- [ ] Valine