Physics 114 A
Spring 2025

114A - AL-BINNI

Midterm 2
May 20th, 2025

Please use the boxes below to clearly print your name and UW NetID.
Please write within the boxes.

Printed Name	

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I certify that the work I shall submit is my own creation, not copied from any source.

Signature ________________________________ **Seat Number** _________________

Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

Do not open the exam until told to do so.
When prompted, clearly print the information required at the top of each page of this exam booklet.
You can remove the equation sheet(s). Otherwise, keep the exam booklet intact.
You will have 60 minutes to complete the examination.

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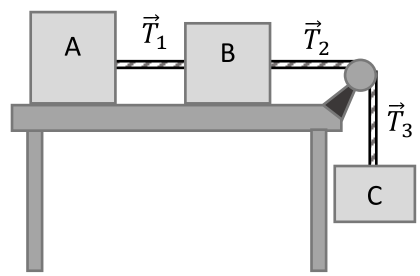
I. Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

Use the following situation to answer the next two questions:
A box of mass 20 kg is placed on a rough, flat, horizontal table. The coefficient of static friction between the box and the table is 0.2 and that of kinetic friction is 0.1.

1. [5 pts] A person acts with a horizontal force of 30 N on the box. Does the box move due to that applied force?
   A. Yes, it moves with a constant velocity.
   B. Yes, it moves with a constant acceleration.
   C. No, it does not move.
   D. The information provided is not enough to answer.

2. [5 pts] Now the person is pushing with a different force from question 1. The box accelerates on the rough table at $1.1\ \mathrm{m/s^2}$, calculate the applied force.
   A. 20 N
   B. 22 N
   C. 39 N
   D. 42 N
   E. 61 N

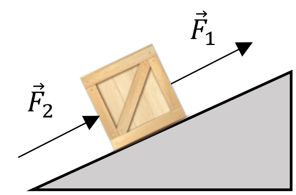
Use the following situation to answer the next two questions:
Three boxes are connected with ropes, as shown at right. Boxes A and B are placed on a frictionless table, while box C hangs over the edge. The ropes are massless and inextensible, and the pulley is massless and frictionless.



3. [5 pts] Choose the correct ranking of the tension forces T_1, T_2 and T_3. Assume that $m_\mathrm{A} > m_\mathrm{B} > m_\mathrm{C}$.
   A. $T_1 < T_2 = T_3$
   B. $T_1 < T_2 < T_3$
   C. $T_3 < T_2 < T_1$
   D. $T_1 = T_2 = T_3$
   E. $T_3 = T_2 < T_1$

4. [5 pts] Which of the following describes the acceleration of the system a_sys made of the blocks and ropes?
   A. $a_\mathrm{sys} = g$
   B. $a_\mathrm{sys} < g$
   C. $a_\mathrm{sys} > g$
   D. $a_\mathrm{sys} = 0$
   E. The information provided is not enough to answer.

5. [5 pts] You and your friend are trying to move a 200 kg crate up a ramp that makes an angle of 10° with the horizontal. Fortunately, the surface of the ramp is very smooth that you don't have to worry about friction. You pull using a rope with a force $F_1 = 160$ N. What is the magnitude of the force that you friend needs to push with F_2 to ensure the crate moves at constant speed? Assume both forces are parallel to the ramp.

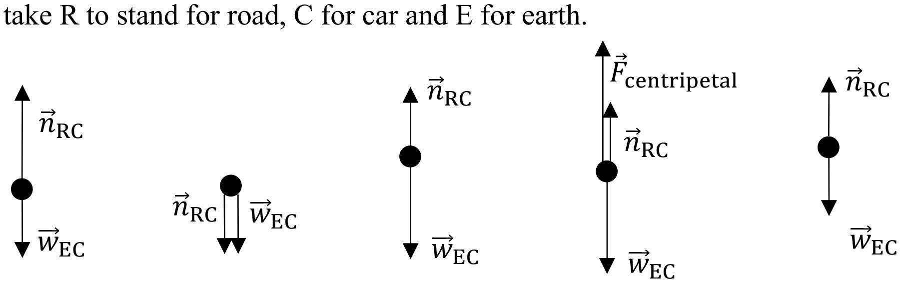


   A. 1800 N
   B. 500 N
   C. 120 N
   D. 280 N
   E. 180 N

6. [5 pts] Two identical balls are dropped straight down. Ball 1 is dropped in air and ball 2 is dropped in water. Both balls reach their terminal speeds. The density of water is approximately 1000 times the density of air. What is the ratio of terminal speed of ball 1 to that of ball 2, $v_{1,\text{term}}/v_{2,\text{term}}$? Assume a high Reynold's number.
   A. 1000
   B. 31
   C. 1
   D. 0.031
   E. 0.001

7. [5 pts] A 24-kg kid is on a merry-go-round standing a distance of 0.85 m from the center. What is the fastest the merry-go-round can go without the kid's shoes slipping if the maximum possible static friction between their shoes and the merry-go-round is 94 N?
   A. 1.8 m/s
   B. 2.6 m/s
   C. 1.2 m/s
   D. 2.9 m/s
   E. 3.1 m/s

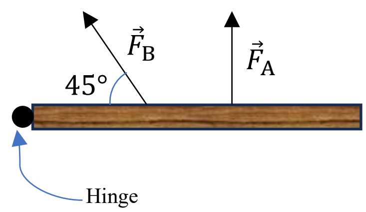
8. [5 pts] A car drives over a dip in the road at constant speed, as shown at right. Choose the correct free-body diagram representing the car when it is at the lowest point in the dip. Neglect friction and take R to stand for road, C for car and E for earth.



A. B. C. D. E.

9. [5 pts] A bike wheel is spinning at $\omega = 400$ rpm (revolutions per minute). If it takes the bike 5.5 seconds to come to a complete stop from that speed, what is the angular acceleration α of the wheel during that time, assuming it was constant? Recall: 1 revolution $= 2\pi$ rad.
   A. $12\ \mathrm{rad/s^2}$
   B. $72\ \mathrm{rev/s^2}$
   C. $24\ \mathrm{rad/s^2}$
   D. $7.6\ \mathrm{rad/s^2}$
   E. $2.9\ \mathrm{rad/s^2}$

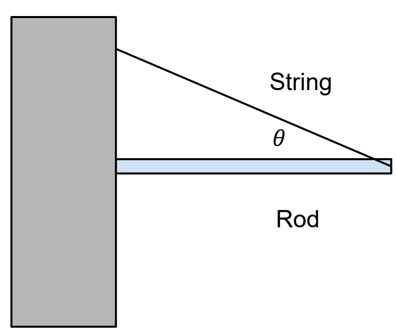
10. [5 pts] Two students are trying to open a stuck door by pushing on it. Student A pushes with a force $\vec{F}_A$ of 30 N at a distance of 0.8 m from the hinge, at an angle of 90° to the door. Student B pushes with a force $\vec{F}_B$ of 80 N at a distance of 0.5 m from the hinge, but at an angle of 45° to the door. The figure at right shows a top view of the situation. Who applies the greater torque, and why?



   A. Student A, because the force is applied farther from the hinge.
   B. Student B, because acting at an angle less than 90° is more effective.
   C. Student A, because acting at an angle of 90° is more effective.
   D. Student B, because the product of force and lever arm ($r_\perp$) is greater.
   E. Both apply the same torque.

11. [5 pts] Three masses are arranged along the x-axis: a mass of 2.0 kg at $x = -1.0$ m, a second of 2.0 kg at $x = 1.0$ m, and the last 1.0 kg at $x = 5.0$ m. What is the location of the center of gravity of this system?
   A. $x_{CG} = 1.0$ m
   B. $x_{CG} = 1.5$ m
   C. $x_{CG} = 2.5$ m
   D. $x_{CG} = 5.0$ m
   E. None of these are correct.

12. [5 pts] A uniform horizontal rod of mass 10.0 kg and length 5.0 m has a massless string attached to the far end at an angle of $\theta = 25°$, holding it up. What is the tension in the string?



   A. $T = 98$ N
   B. $T = 116$ N
   C. $T = 226$ N
   D. $T = 456$ N
   E. None of these could be the tension

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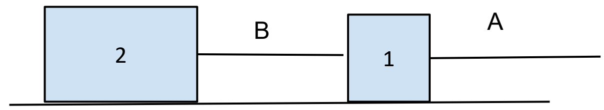
II. Lecture Free Response [20 pts total]: Show work and/or explain reasoning where indicated.

For problems 13-16 the following situation applies:
Two blocks are connected by massless strings and are being pulled to the right by a constant force on string A, on frictionless ground, as seen in the diagram below. They have been moving for some time. Block 2 has more mass than block 1.

13. [5 pts] Which is *greater*, the tension on block 2 from string *B*, or the tension on block 1 from string *A*? Explain your answer.



14. [5 pts] On which object is the *net force* greater? If they are the same state so explicitly. Explain your answer.

15. [4 pts] Draw the *direction* of the net force on block 1 and the *direction* of the acceleration on block 1 in the boxes below.

$\boldsymbol{F}_{\text{net}}$ on 1 $\boldsymbol{a}$ on 1

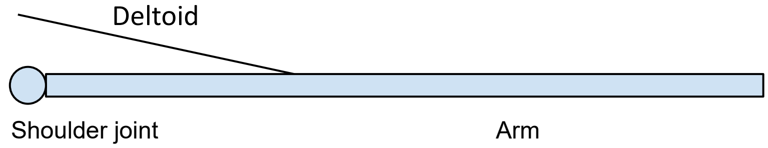
16. [6 pts] Block 1 has a mass of 3.0 kg, and block 2 has a mass of 5.0 kg. If they are accelerating at 2.5 m/s^2, what is the tension in string *A*? *Show work* for full credit.

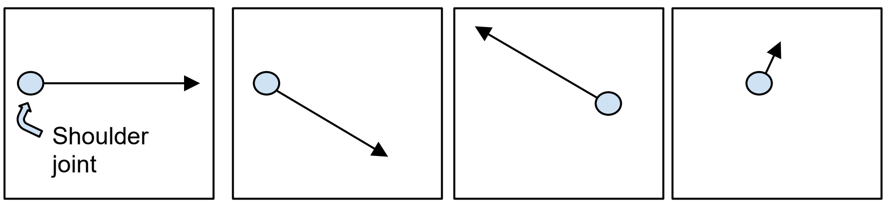
T_A=

III. Tutorial Free Response [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

For 17. and 18. use the diagram below. The deltoid muscle and tendon attach to the arm as shown in the diagram. The arm is horizontal and outstretched in this diagram.

17. [5 pts] Which of the following can represent the moment arm (lever arm) for the deltoid muscle if the pivot point (axis) is at the shoulder, on the far left in this diagram? Circle the most correct box.





Explain your answer:

18. [5 pts] If the arm lowers, what happens to the *length* of the moment arm? Does it increase, decrease, or remain the same? Explain and/or draw diagrams. Assume the attachment points of the deltoid remain the same as shown in the diagram, on both ends. (Since the torque equals the force times the moment arm, this gives an idea of the strength of the arm at different positions)

19. [5 pts] A dwarf siren salamander grows in such a way that it increases its size equally in all dimensions. An adult salamander is three times larger in every dimension than an infant salamander.

    What is the ratio of the adult's mass to the infant's mass? Explain your reasoning.

20. [5 pts] A contractor builds a swimming pool (pool A) that has length l, a width w, and a depth d. The contractor then tiles the walls and floor of the pool. It takes 20 boxes of tiles to complete the work.

    In a different project, the contractor needs to build a swimming pool (pool B) that has a length $2l$, a width $2w$, and a depth $2d$. If the contractor also needs to tile the walls and floor of pool B, how many boxes of tiles will they need? Assume the tiles used are identical for both pools. Show your work.

Physics 114 Final Exam Equation Sheet

Constants and Conversions

Free-fall acceleration	$g = 9.80\ \mathrm{m/s^2}$
Newton	$1\ \mathrm{N} = 1\ \mathrm{kg\ m/s^2}$

Mathematics, Scaling and Vectors

Logarithm	$b = a^x \leftrightarrow \log_a(b) = x$ $\log(ab) = \log(a) + log(b)$ $\log Ax^n = n \log x + \log A$
Volume of a sphere	$V = \frac{4}{3}\pi r^3$
Surface area of a sphere	$A = 4\pi r^2$
Volume of a cylinder	$V = \pi r^2 l$
Surface area of a cylinder	$A = 2\pi r^2 + 2\pi r l$
Mass density	$\rho = m/V$
Area of trapezoid	$A = \frac{1}{2}(b_1 + b_2)h$
x-component of a vector $\vec{A}$	$A_x = A\cos\theta$ (rel. to x– axis)
y-component of a vector $\vec{A}$	$A_y = A\sin\theta$ (rel. to x– axis)
Magnitude of vector $\vec{A}$	$A = \sqrt{A_x^2 + A_y^2}$
Direction of $\vec{A}$ relative to x-axis	$\theta = \tan^{-1}(A_y/A_x)$
Addition of two vectors	If $\vec{C} = \vec{A} + \vec{B}$, then $C_x = A_x + B_x$ $C_y = A_y + B_y$

Kinematics

Displacement	$\Delta x = x_f - x_i$
Average Velocity	$v_{avg} = \frac{\Delta x}{\Delta t}$
Instantaneous Velocity	$v_{inst.} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$
Average Acceleration	$a_{avg} = \frac{\Delta v}{\Delta t}$

Kinematics Continued

Instantaneous Acceleration	$a_{inst.} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$
Uniform motion	$(v_x)_\mathrm{f} = (v_x)_\mathrm{i} = \mathrm{constant}$
Position in uniform motion	$x_f = x_i + (v_x)_i \Delta t$
Constant acceleration:	$(v_x)_f = (v_x)_i + a_x \Delta t$ $x_f = x_i + (v_x)_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$ $(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x$

Forces

Newton's second law	$\vec{F}_\mathrm{net} = \sum \vec{F} = m\vec{a}$
Newton's second law Component form	$F_{\mathrm{net},x} = \sum F_x = ma_x$ $F_{\mathrm{net},y} = \sum F_y = ma_y$
Newton's Third Law	$\vec{F}_\mathrm{A\ on\ B} = -\vec{F}_\mathrm{B\ on\ A}$
Weight	$w = mg$
Apparent weight	$w_\mathrm{app} = \mathrm{magnitude\ of\ supporting\ forces}$
Kinetic friction	$f_k = \mu_k n$
Static friction	$0 \le f_s \le \mu_s n$
Reynolds number	$Re = \rho v l/\eta$
Drag (high Reynolds number)	$D = \frac{1}{2} C_D \rho A v^2$
Drag (low Reynolds number)	$D = 6\pi\eta r v$

Circular Motion

Centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r$
Frequency	$f = \frac{1}{T} = \frac{v}{2\pi r}$

Physics 114 Final Exam Equation Sheet

Rotational Motion

Angular position	$\theta_{radians} = \frac{s}{r}$
Angular displacement	$\Delta\theta = \theta_f - \theta_i$
Average angular velocity	$\omega_{avg} = \frac{\Delta\theta}{\Delta t}$
Instantaneous angular velocity	$\omega_{inst.} = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$
Average angular acceleration	$\alpha_{avg} = \frac{\Delta\omega}{\Delta t}$
Instantaneous angular acceleration	$\alpha_{inst.} = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$
Period of uniform rotation	$T = \frac{2\pi}{\omega}$
Linear speed	$v = r\omega$
Tangential acceleration	$a_t = r\alpha$
Torque	$\tau = rF_{\perp} = r_{\perp}F = rFsin\theta$
Center of gravity	$x_{cg} = \frac{m_1x_1 + m_2x_2 + \cdots}{m_1 + m_2 + \cdots}$

Moment of inertia

Particles	$I = \sum m_i r_i^2$
Rod or plane (about center)	$I = \frac{1}{12}ML^2$
Rod or plane (about end)	$I = \frac{1}{3}ML^2$
Newton's 2nd law for rotation	$\alpha = \frac{\tau_{net}}{I}$

Stability and Elasticity

Critical angle	$\theta_c = tan^{-1}\left(\frac{(1/2)t}{h}\right)$
Hooke's Law	$\left(F_{sp}\right)_x = -k\Delta x$
Young's module	$\left(\frac{F}{A}\right) = Y\left(\frac{\Delta L}{L}\right)$
Tensile strength	$Tensile\ Strength = \frac{F_{max}}{A}$

Impulse and Momentum

Impulse	$\vec{J} = \vec{F}_{avg}\Delta t$
Momentum	$\vec{p} = m\vec{v}$
Impulse-momentum theorem	$\vec{J} = \vec{p}_f - \vec{p}_i = \Delta\vec{p}$
Total momentum	$\vec{p}_{total} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \cdots$
Conservation of momentum	$\vec{p}_f = \vec{p}_i$

Work and Energy

Work-energy equation	$W = \Delta E$
Work done by constant force	$W = F_{\parallel}d = Fdcos\theta$
Kinetic Energy	$K = \frac{1}{2}mv^2$
Rotational kinetic energy	$K = \frac{1}{2}I\omega^2$
Gravitational potential energy	$U_g = mgy$
Elastic potential energy	$U_s = \frac{1}{2}kx^2$
Thermal energy	$\Delta E_{th} = f_k\Delta x$
Elastic Collisions	$(v_{1x})_f = \frac{m_1 - m_2}{m_1 + m_2}(v_{1x})_i$ $(v_{2x})_f = \frac{2m_1}{m_1 + m_2}(v_{1x})_i$
Power	$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = Fv$