Physics 114 A
Summer 2025

114A - AL-BINNI

Midterm 2
August 4th, 2025

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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 90 minutes to complete the examination.

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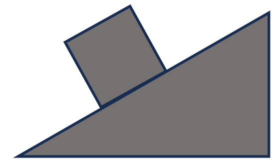
I. **Lecture Multiple Choice [60 pts]. Choose only one answer for each question and fill it out on your bubble sheet.**

Use the following scenario to answer the next three questions

A block of mass m is placed on a rough inclined ramp that makes an angle of θ with the horizontal. Take the coefficients of static and kinetic friction between the block and the ramp to be μ_s and μ_k, respectively.



1. [4 pts] The block is released at the top of the ramp, and it slides down with acceleration $a \neq 0$. What is the magnitude of frictional force experienced by the block?

   A. $\mu_s mg \sin\theta$

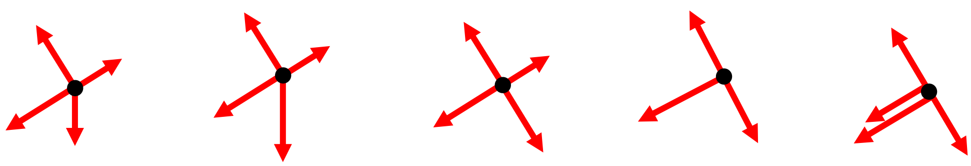
   B. $\mu_k mg \cos\theta$

   C. $\mu_k mg \sin\theta$

   D. $\mu_s mg \cos\theta$

   E. Zero, because the block is accelerating.

2. [4 pts] Choose the correct free-body diagram representing the block as it slides down the ramp.



A. B. C. D. E.

3. [4 pts] Now suppose a hand pushes down perpendicular to the ramp with a force n_{HB} just enough to keep the block from sliding. What is the magnitude of the force of friction acting on the block?

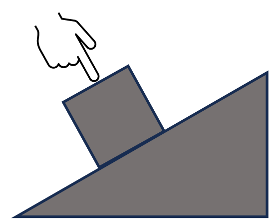
   A. $\mu_s(mg\cos\theta - n_{\text{HB}})$

   B. $\mu_s mg \cos\theta$

   C. $\mu_s mg \sin\theta$

   D. $\mu_s(mg\cos\theta + n_{\text{HB}})$

   E. $\mu_s n_{\text{HB}}$



4. [3 pts] A sphere and a cylinder of equal masses are dropped from a very large height. Both reach the same terminal speed, $v_{\text{sphere,term}} = v_{\text{cylinder,term}}$. Given that $C_{\text{D,sphere}} = 0.50$ and $C_{\text{D,cylinder}} = 0.80$, what is the ratio of cross-sectional area of the sphere to that of the cylinder?

   A. 1.6

   B. 1.0

   C. 0.63

   D. 1.2

   E. Information provided is not enough to answer.

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5. [3 pts] A fire caused a large amount of smoke in the air. Assume an average smoke particle has a mass of 4.3×10^{-15}kg and a radius of 2.7×10^{-6}m. How long would it take such a smoke particle falling from a height of 2.0 m to settle to the ground? Assume air is perfectly still and take $\eta_{\text{air}} = 1.8 \times 10^{-5}\text{Pa} \cdot \text{s}$.

   A. 0.64 seconds
   B. 2.9 hours
   C. 6.0 hours
   D. 12 hours
   E. 24 hours

6. [3 pts] You fell into a pit of mud. Thankfully there is a tree with a branch hanging right above you, and because you fall every day in mud you had your rope as usual with you. You throw the rope over the branch, tie one end around your waist and pull on the other end. If your mass is m, what is the minimum amount of force needed for you to pull yourself up? Neglect the viscosity of mud.

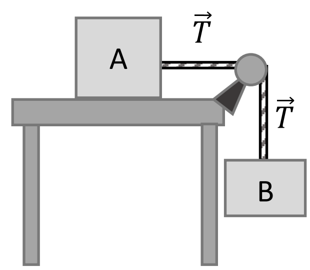
   A. $2mg$
   B. mg
   C. $mg/2$
   D. Zero
   E. None of the above is correct.

Note: OK, don't laugh, the AI I used to generate the illustration couldn't understand that you can't pull on both ends. The picture above is its best attempt. You don't want to see the failed ones!

Use the following situation to answer the next two questions:

7. [3 pts] Block A of mass m_{A} is placed on a horizontal rough table connected to a massless inextensible rope draped over a pulley and holding block B of mass m_{B} **<u>at rest</u>**. What is the tension T in the rope?

   A. Zero
   B. $(m_{\text{B}} + m_{\text{A}})g$
   C. $m_{\text{A}}g$
   D. $(m_{\text{B}} - m_{\text{A}})g$
   E. $m_{\text{B}}g$



8. [3 pts] Is the magnitude of the force of static friction between block A and the table *greater than*, *less than* or equal to the weight of block B?

   A. Greater than
   B. Less than
   C. Equal to
   D. Information provided is not enough to answer.

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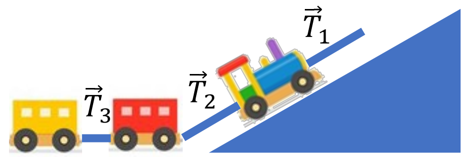
Use the following situation to answer the next two questions.
A kid is pulling a toy train up a ramp as shown. The train is moving with an acceleration of $0.50\ \text{m/s}^2$ in the direction of the pull $\vec{T}_1$. The masses of the cars and locomotive are all equal to $m = 0.20$ kg. The strings used are massless and inextensible. Neglect friction.



9. [3 pts] Choose the correct ranking of the forces of tensions T_1, T_2 and T_3.

   A. $T_1 > T_2 > T_3$

   B. $T_2 > T_1 > T_3$

   C. $T_3 > T_2 > T_1$

   D. $T_1 = T_2 > T_3$

   E. $T_3 > T_1 = T_2$

10. [3 pts] If $T_2 = 0.25$ N and acts at the same angle as the incline and $T_3 = 0.10$ N, what is the angle of the incline?

    A. 72°

    B. 15°

    C. 24°

    D. 53°

    E. 37°

11. [3 pts] It takes the Earth 365 days to complete one revolution around the sun in approximately circular orbit or radius R. Mars completes one revolution around the sun in 687 Earth days. Mars' orbit is also approximately circular but with a radius of $1.52R$. What is the ratio of the centripetal acceleration of Mars to that of Earth?

    A. 0.25

    B. 0.43

    C. 0.67

    D. 1.00

    E. 1.52

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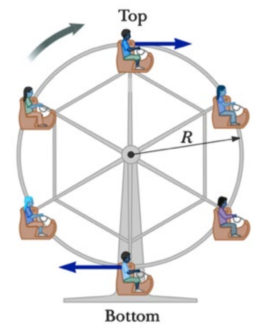
12. [3 pts] The figure shows a Ferris wheel of radius $R = 3.1$ m rotating at a speed of 0.45 m/s. What is the normal force by the seat on the top-most rider whose mass is 27 kg?



   A. 72 N
   B. 340 N
   C. 38 N
   D. 150 N
   E. 260 N

13. [3 pts] Tarzan is swinging on a vine of length 10.0 m. It takes a tension force of 900 N to break the vine. If Tarzan's mass is 70.0 kg, at what maximum speed can he swing before the vine breaks?

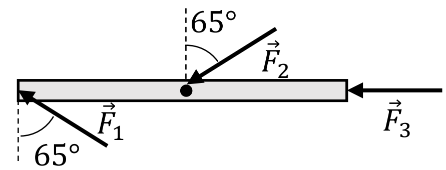
   A. 5.53
   B. 3.91
   C. 9.06
   D. 11.3
   E. Since Tarzan weighs less than the maximum tension, the vine would not break at any speed.

14. [3 pts] When you're inside a car going around a circular path, you feel as though you're being pushed outward, away from the center of the circle. How should this sensation be understood?

   A. There is a real outward force (centrifugal force) acting on you, pushing you away from the center.
   B. Your body wants to continue in a straight line due to inertia, but the car (and seat) exerts an inward force to keep you moving in a circle.
   C. Both A and B are correct explanations of the sensation.
   D. Neither A nor B is correct.

Use the following situation to answer the next two questions.

15. [3 pts] A uniform thin stick of length 4.5 m has three forces acting on it, each of magnitude 20 N, with its center fixed, as shown. Neglecting gravity, what is the net torque acting on the stick around its center?



A. 82 N

B. 41 N

C. 38 N

D. 19 N

E. Zero

16. [4 pts] Let us refer to the situation in the previous question as Case 1. Let Case 2 have the same stick and the same forces but assume the left endpoint is now fixed while the center point is no longer fixed. Is the angular acceleration of the stick in Case 2 *greater than*, *less than*, or *equal to* the angular acceleration in Case 1?

A. Greater than.

B. Less than.

C. Equal to.

D. Information provided is not enough to answer.

17. [4 pts] Two particles of masses 1.4 kg and 4.7 kg are connected with a rigid massless rod of length 3.8 m. How far is the center of gravity of the two particles from the smaller particle?

A. 0.87 m

B. 1.9 m

C. 2.9 m

D. 1.1 m

E. 3.4 m

18. [4 pts] A motor is used to spin the blades of a fan. As the fan is switched on it speeds up with an angular acceleration of $\alpha = 4\ \mathrm{rad/s^2}$. The motor exerts a torque of $\tau_{\mathrm{motor}} = 10\ \mathrm{N \cdot m}$ but there is a torque due to friction of amount $\tau_f = 2\ \mathrm{N \cdot m}$. What is the moment of inertia of the fan?

A. $1\ \mathrm{kg \cdot m^2}$

B. $2\ \mathrm{kg \cdot m^2}$

C. $3\ \mathrm{kg \cdot m^2}$

D. $4\ \mathrm{kg \cdot m^2}$

E. None of the above.

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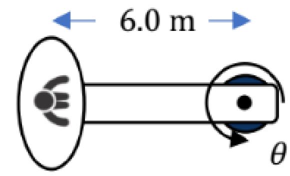
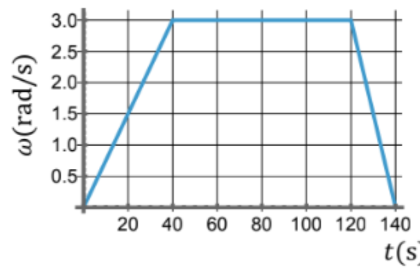
II. Lecture Free Response [20 pts]

Show details in all the following questions.

A human centrifuge is a device used to study the effects of acceleration on the human body. A schematic diagram is shown at right. Below that is a graph showing the angular velocity of the device as a function of time for one run.

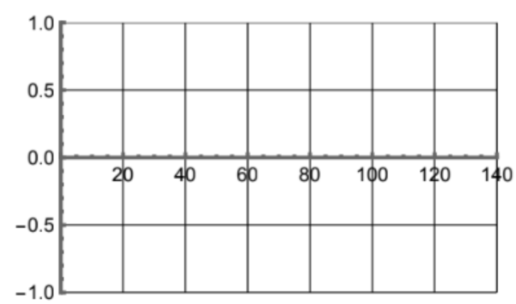


19. [5 pts] Calculate the total angular displacement completed by the device.



20. [5 pts] What is the maximum centripetal acceleration experienced by the person inside?

21. [5 pts] On the graph below plot the tangential acceleration a_t as a function of time. Label the axes and show any calculations you do. Hint: recall $a_t = r\alpha$.



22. [5 pts] If the length of the device is doubled from 6.0 m to 12 m while the angular velocity is still given by the graph above, what happens to the centripetal force acting on a person of mass m; would it double, get halved or stay the same? Support your answer with a calculation.

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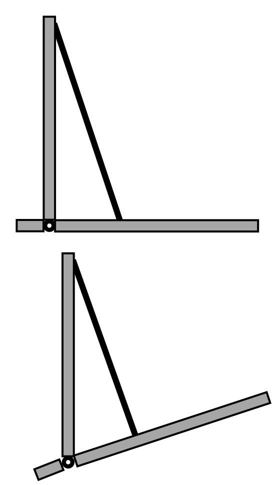
III. Tutorial Free Response [20 pts] Explain your answer where required.

23. [7 pts] Two blocks, P and Q, are connected by a string as shown. The whole system is placed on a level, frictionless surface. The mass of block P is greater than the mass of block Q. A student pulls a string attached to block Q to the right with a force of magnitude F_0. Both strings are massless. Is the magnitude of the net force on block P greater than, less than, or equal to that on block Q? Explain.

24. [6 pts] In case 2, the student pulls a string attached to block P to the left with a force of magnitude F_0. Is the magnitude of the tension in the string, T_2, in case 2 greater than, less than, or equal to the magnitude of the tension in the string, T_1, in case 1? Explain.

25. [7 pts] The upper figure at right shows a model of the arm as two rods connected with a string (tendon). Assume that the arm is held at rest in the position shown with the tendon exerting a force T. If the arm is lifted up and held at rest in the position shown in the lower figure at right and the force by the tendon on the arm stays as T, does the torque of the tension force increase, decrease or stay the same? Explain your answer.



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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:	$(v_x)_f = (v_x)_i + a_x \Delta t$
	$x_f = x_i + (v_x)_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$
	$(v_x)_f^2 = (v_x)_i^2 + 2 a_x \Delta x$

Forces

Newton's second law	$\vec{F}_\mathrm{net} = \sum \vec{F} = m\vec{a}$
Newton's second law Component form	$F_{\mathrm{net},x} = \sum F_x = m a_x$
	$F_{\mathrm{net},y} = \sum F_y = m a_y$
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	$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = Fv$