Physics 114 A
Winter 2026

114A - DEPIES

Midterm 2
February 24th, 2026

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

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

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

Do <u>not</u> open the exam until told to do so.
When prompted, clearly print the information required at the top of <u>each page</u> of this exam booklet.

You can remove the equation sheet(s). Otherwise, keep the exam booklet intact. You will have <u>60 minutes</u> to complete the examination.

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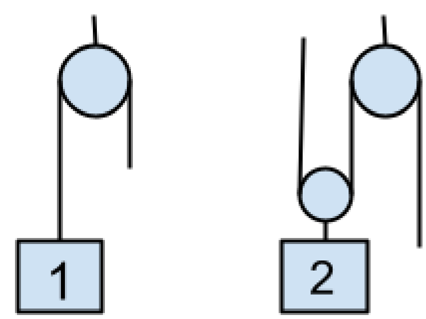
I. Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

1. [5 pts] A stubborn elephant of mass 4,200 kg refuses to move. You push the elephant with a force of 890 N. The elephant still doesn't move. What is the frictional force on the elephant from the ground while you push on it?
   A. You need $\boldsymbol{\mu}_s$ to solve for friction.
   B. 890 N
   C. 41 kN
   D. You need your mass to solve for friction.
   E. None of these.

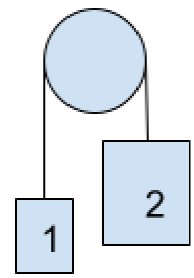
2. [5 pts] From the previous problem, assume the elephant is now sliding on a horizontal surface under a horizontal push of $F = 9,232$ N. Assume $\mu_s = 0.3$, $\mu_k = 0.2$ and $m = 4,200$ kg.
   What is the acceleration of the elephant?
   A. 0.24 m/s^2
   B. 2.4 m/s^2
   C. 3.4 m/s^2
   D. 2.0 m/s^2
   E. No acceleration.

3. [5 pts] In the figure at right all blocks are stationary and of equal mass, all ropes are massless and inextensible, and all pulleys are massless and frictionless. The ropes are free to move around the pulleys.

   Choose the correct ranking of the magnitudes of the tension forces T_1 and T_2
   A. $T_1 = T_2$
   B. $T_1 < T_2$
   C. $T_1 > T_2$
   D. The ropes need to have mass to have tension.
   E. None of these.



4. [5 pts] Block 1 of mass 3.0 kg is attached to a massless string over a massless pulley and connected with a massless inextensible string to block 2 of 5.0 kg. They start at rest in the orientation shown. When released, what direction do they start to move?
   A. Block 2 falls and block 1 rises.
   B. Block 1 falls and block 2 rises.
   C. Stay in equilibrium, at rest.
   D. Depends on the relative heights.
   E. None of these



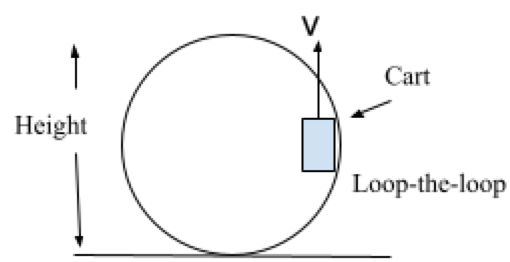
5. [5 pts] From question 4., what is the acceleration of the blocks?
   A. 1.45 m/s^2
   B. 12.5 m/s^2
   C. 3.60 m/s^2
   D. 2.45 m/s^2
   E. Not enough information was given to solve.

6. [5 pts] A bacterium of radius 10^{-6} m and mass of 4.0 x 10^{-15} kg falls in water at the surface of the earth; assume it is approximately spherical for calculations. It falls very slowly due to the viscosity of water. What is the terminal velocity as it does so? If needed the density of water is 1000 kg per cubic meter and the viscosity of water is about 1.0 x 10^{-3} Pa s.
   A. 0.21 x 10^{-12} m/s
   B. 2.1 x 10^{-6} m/s
   C. 2.1 m/s
   D. 1.2 x 10^{-16} m/s
   E. None of these.

7. [5 pts] A merry-go-round of radius 2.5 m spins in a circle. It is found it moves through 1.5 rotations in 3.0 s. What is the angular speed of the merry-go-round?
   A. 0.51 rad/s
   B. 1.6 rad/s
   C. 2.0 rad/s
   D. 3.1 rad/s
   E. None of these are correct

8. [5 pts] A person in an elevator is moving down and *speeding up*. Which is greater, the normal force on the person from the elevator or the weight of the person?
   A. Normal force on the person is greater
   B. The weight of the person is greater
   C. They are both equal
   D. It depends on the initial velocity.
   E. None of the above.

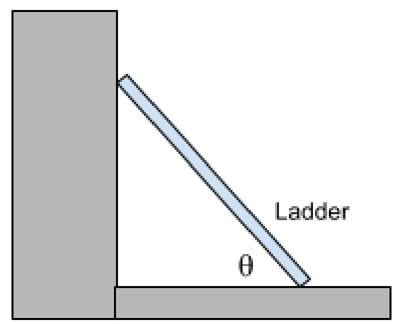
9. [5 pts] A cart moves around a loop-the-loop as shown at right. At the instant shown it is on the right side ascending the track. At that moment, what is the force that supplies the "centripetal force" and centripetal acceleration, allowing it to move in a circle?
   A. Weight force
   B. Frictional force
   C. Normal force
   D. Tension force
   E. None of these.



10. [5 pts] A see-saw has a person of mass 45 kg at a distance of 1.8 m from the fulcrum. If a dog of mass 20 kg runs on to the see-saw, what distance would it need to be from the fulcrum (axis) to have the system in static equilibrium?
   A. 4.1 m
   B. 2.2 m
   C. 1.8 m
   D. 0.82 m
   E. None of these are correct.

11. [5 pts] An outstretched arm has a center of gravity about ⅓ the total length of the arm, closest to the shoulder. Let us assume that location is about 25 cm from the shoulder joint, with the total length of the arm being 75 cm. If the mass of this arm is about 4.0 kg, what is the torque applied by gravity to the arm and shoulder?
    A. 4.9 Nm
    B. 9.8 Nm
    C. 11.2 Nm
    D. 19.6 Nm
    E. The total length of the arm is the key, so none of these solutions is correct.

12. [5 pts] A stationary ladder of mass 20 kg makes an angle of 55 degrees from the horizontal as seen at right. The ladder has a length of 5.0 m. The wall has no friction, but the floor has friction. What is the magnitude of the frictional force from the *floor* on the ladder?



    A. $f = 198$ N
    B. $f = 120$ N
    C. $f = 105$ N
    D. $f = 68.6$ N
    E. None of these could be the frictional force; you need the coefficient of friction.

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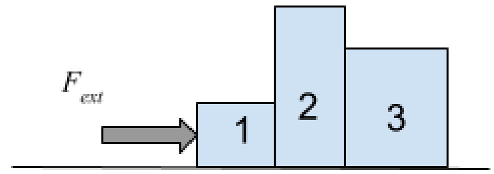
II. Lecture Free Response [20 pts total]: Show work and/or explain reasoning where indicated.

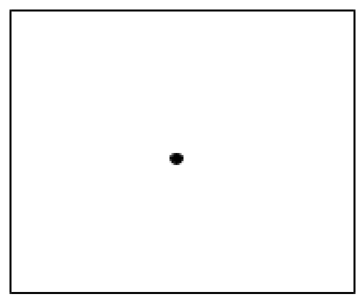
For problems 13-16 the following situation applies: Three blocks are sliding to the right on a frictionless surface. There is a force acting on the left block, 1, pushing to the right. The mass of block 3 is greater than block 2 which is greater than block 1.

13. [5 pts] On which block is the net force greatest? If it is zero, state this explicitly. Explain your answer.



14. [5 pts] How do the accelerations of each block compare? If they are the same, state this explicitly. Explain your answer.

15. [4 pts] Draw the *free body diagram* for **block 1** in the box:

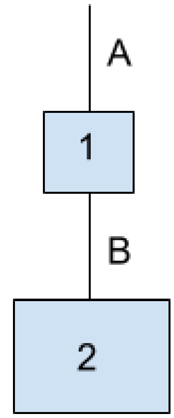


16. [6 pts] Block 1 has a mass of 1.0 kg, block 2 has a mass of 2.5 kg, and block 3 has a mass of 4.0 kg. If the external force applied is 15 N, what is the normal force between blocks 1 and 2? Show work for full credit.

$N_{12}=$

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

For 17 and 18 the system shown is <u>moving down</u> in an elevator but <u>slowing down</u>. Here the strings *A* and *B* are massless, and mass 2 is greater than mass 1.



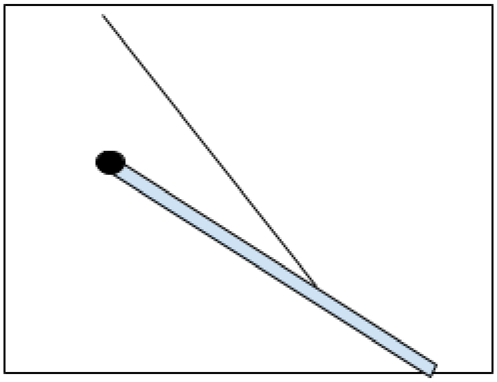
17. [5 pts] Again, the system is moving down and slowing down. Rank the tensions in *A* and *B*. If they are the same state this explicitly. Explain your answer for full credit.

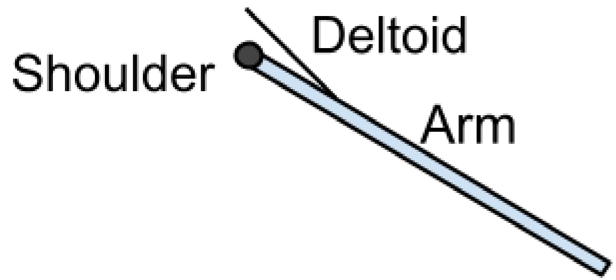
18. [5 pts] Now assume mass 2 is 5.0 kg and mass 1 is 2.5 kg. If the acceleration of the system has a magnitude of 1.5 m/s^2 find the tension in string *A*.

T_A =

For 19. and 20. use the diagram below.

19. [5 pts] The deltoid attaches to the upper arm as shown below. On the exploded diagram to the left, draw the lever (moment) arm extending from the shoulder (our axis in this situation).





20. [5 pts] Assuming the connection point above the shoulder joint remains fixed, what happens to the lever (moment) arm as the arm is lowered from the position shown? Does it get longer or shorter, or stay the same? *Explain your reasoning or show work for full credit*.

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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	$(v_x)_\mathrm{f} = (v_x)_\mathrm{i} = \text{constant}$
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_app = 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	$(F_{sp})_x = -k\Delta x$
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	$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = Fv$