Physics 121 B
Autumn 2025

121B - OLMSTEAD

Midterm 1
October 23rd, 2025

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

Printed Name	

first *last*

UW Net ID	

(part before @uw.edu)

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.

For multi-select questions, you receive partial credit for each correct answer choice as long as you select none of the incorrect answer choices.

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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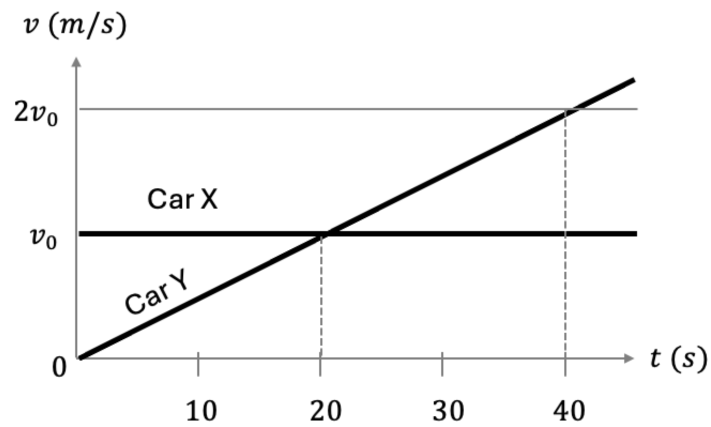
I. Lecture Multiple Choice (45 points – 9 questions)

All questions have one correct answer unless indicated.

Use the following scenario for the first two questions.

At time $t = 0$, Car X is moving at a constant speed v_o as it passes Car Y, which starts from rest at the same moment. Both cars then travel along parallel lanes of the same straight road. The velocity *vs* time graphs for both cars are shown at right.



1) Which car, if either, is farthest away from the origin at the time $t = 40s$?

   A. Car X
   B. Car Y
   C. Both cars are the same distance from the origin at $t = 40s$.
   D. It depends on the value of v_o.

2) Which of the following is true at time $t = 20s$?

   A. Car Y is behind Car X.
   B. Car Y is passing Car X.
   C. Car Y is ahead of car X.
   D. There is not enough information to determine the car's relative positions.

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3) A train starts from rest at one station and travels 800 meters to the next station. It speeds up at a constant rate of 0.5 m/s^2 for the first half of the distance, then slows down at the same rate for the second half, coming to rest at the next station. What is the maximum speed that the train reaches during the journey?

   A. 32 m/s
   B. 45 m/s
   C. 14 m/s
   D. 28 m/s
   E. 20 m/s

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4) An object's position is described by $x(t) = (-8 - 4t + 3t^2)m$. Which of the following statements is TRUE?

A. At $t = 0$, the object is at the origin.
B. The object slows down for all values of t.
C. It stops instantaneously at $t = 8.0\ s$
D. It stops instantaneously at $t = 0.67\ s$.
E. The object never stops because it is already moving at the time $t = 0$.

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5) Which of the following will remain in the air for the LEAST amount of time (neglecting air resistance)?

A. A marble launched straight up from the ground at 9.8 m/s
B. A marble launched from the ground with a speed of 9.8 m/s at an angle of 30° from the horizontal
C. A marble that is dropped straight down from a 50 m high building.
D. A marble that is launched horizontally from a 50 m high building

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6) The only forces acting on a 2.0-kg ball are shown below. What is the magnitude of the acceleration of the ball?

$$\vec{F}_1 = (2\hat{\imath} - 8\hat{\jmath})\text{N}$$
$$\vec{F}_2 = (5\hat{\imath} - 3\hat{\jmath})\text{N}$$

A. $5.2\ m/s^2$
B. $6.5\ m/s^2$
C. $3.0\ m/s^2$
D. $3.2\ m/s^2$
E. $4.3\ m/s^2$

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NOTE: Questions 7, 8 and 9 can have more than one correct answer. For each question, select all answers that are correct.

7) A rotating disk is slowing down during a time interval of one second. Which of the following combinations of the initial angular velocity, ω_i , final angular velocity, ω_f, and angular acceleration, α , could describe this motion? **Select all that are correct.**

A. $\omega_i = -3\ s^{-1}$ $\omega_f = -5\ s^{-1}$ $\alpha = -2\ s^{-2}$
B. $\omega_i = -5\ s^{-1}$ $\omega_f = -3\ s^{-1}$ $\alpha = +2\ s^{-2}$
C. $\omega_i = +3\ s^{-1}$ $\omega_f = +5\ s^{-1}$ $\alpha = -2\ s^{-2}$
D. $\omega_i = -3\ s^{-1}$ $\omega_f = -5\ s^{-1}$ $\alpha = +2\ s^{-2}$
E. $\omega_i = +5\ s^{-1}$ $\omega_f = +3\ s^{-1}$ $\alpha = -2\ s^{-2}$

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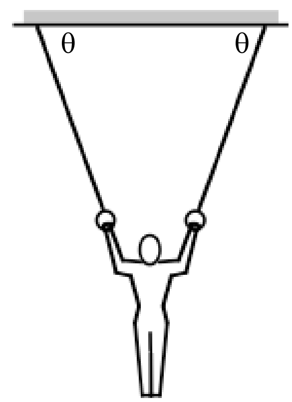
8) A gymnast weighing 500 N is suspended by two ropes from the ceiling as shown. The gymnast is at rest. The lengths and angle, θ, indicated are the same for the two ropes. **Select all that are correct.**

A. The magnitude of the tension in the rope on the left is greater than 250 N.
B. The magnitude of the tension in the rope on the left is less than 250 N.
C. The magnitude of the tension in the rope on the left is equal to 250 N.
D. The magnitude of the tension in the two ropes are the same.
E. The magnitude of the tension in the two ropes are different.



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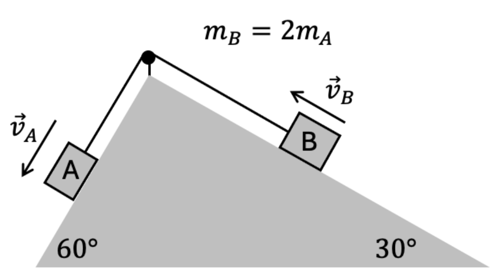
9) Two blocks, A and B, where $m_B = 2m_A$, are connected by a massless, inextensible string that passes over a frictionless pulley. The blocks are sliding on frictionless surfaces. At the instant shown, block A is moving down its ramp, while B is moving up. **Select all that are correct**.

A. At this instant, Block A is slowing down.
B. At this instant, Block A is speeding up.
C. At this instant, Block A is moving with constant speed.
D. At this instant, the blocks' accelerations have the same magnitude.
E. At this instant, the blocks' velocities have the same magnitude.



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II. Lab Multiple Choice (15 pts – 3 questions)

All questions have one correct answer unless indicated.

Use the following scenario for the next two questions.

A lab group conducts four trials of an object moving across a table. The data at right show their results for the position of the object at $t = 1\ s$ for each trial. The average is the value obtained from a calculator.

	Position (cm)
Trial 1	0.9
Trial 2	1.2
Trial 3	1.0
Trial 4	0.8
Average	**0.975**

10. The group wants to report the value to one significant digit in the uncertainty. Which of the following reported values for the measurement is consistent with the procedure in labs A1 and A2? (*e.g.*, using the maximum deviation from the average value.)

    A. 1 ± 1 cm

    B. 1.0 ± 0.2 cm

    C. 0.9 ± 0.2 cm

    D. 0.98 ± 0.23 cm

    E. 0.9 ± 1.0 cm

11. The uncertainty calculated for the answer above is:

    A. Instrumental uncertainty

    B. Random uncertainty

    C. Systematic uncertainty

    D. Both instrumental and random uncertainty

    E. Neither instrumental nor random uncertainty

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12. In Lab A1 and Lab A2, you used a cart that moved across a horizontal table. You placed a penny at the front of the cart when you heard each click of a metronome. Based on four trials of the experiment, you then plotted a graph of position vs time. Suppose you were systematically late by 0.1 s in placing each penny next to the cart. Which of the following describes how this would have affected your graph?

    A. The slope of the graph would be greater than it should have been.

    B. The slope of the graph would be less than it should have been.

    C. The graph of position vs time would be **shifted downward**. (It would intersect the vertical axis at a point below $x = 0$.)

    D. The graph of position vs time would be **shifted upward**. (It would intersect the vertical axis at a point above $x = 0$.)

    E. More than one of the answers above could be correct

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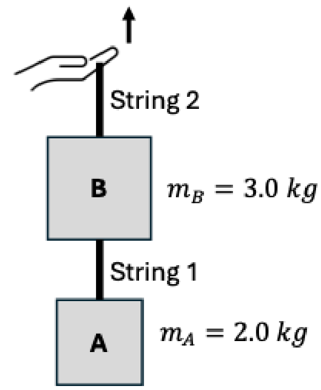
III. Lecture Free Response (25 points – 4 questions)

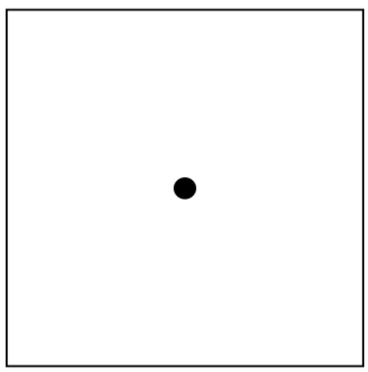
Use the following scenario for the next two questions.

Blocks A and B are connected by string 1 and are suspended by string 2. Both strings are massless. A student pulls on string 2 such that the blocks are moving upward with increasing speed while maintaining a constant distance between them.

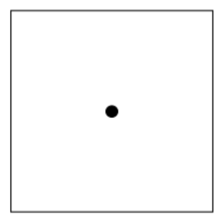


13) (7 pts.) In the box below left, draw a free body diagram for block B. Label each force using the notation $\vec{A}_{pq}$ where A denotes the type of force (e.g., F^G for gravitational, n for normal, T for tension, f for friction); p denotes the agent that exerts the force (e.g., E for Earth, A for box A, etc.), and q denotes the object on which the force is acting. In the box below right, draw an arrow to indicate the direction of the net force on block B.

Free-body diagram for block B



Net force on block B



14) (6 pts.) At time t_o, the blocks are accelerating upward with acceleration $a = 0.1\ g$, where the gravitational acceleration $g = 9.8\ m/s^2$. Find the magnitudes of:
(i) the tension in string 1, T_1
(ii) the tension in string 2, T_2
Write your answers in the boxes provided and justify your answers with words, pictures, and/or equations.

$T_1\ =\qquad N; T_2 =\qquad N$

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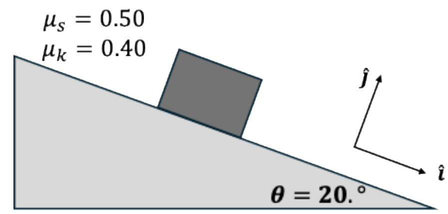
Use the following scenario for the next two questions.

A box of mass 4.0 kg is on a ramp that makes an angle of 20° with the horizontal. The positive *x*-axis points down the ramp. The coefficients of friction between the box and ramp are $\mu_s = 0.50$ (static) and $\mu_k = 0.40$ (kinetic).



15) (6 pts.) At time t_o, the box is stationary. Find the frictional force $\vec{f}_{RB}$ exerted by the ramp on the box at time $t = t_o$. Use the format $\vec{f}_{RB} = f_x\,\hat{\imath} + f_y\,\hat{\jmath}$. Justify your answer with words, pictures, and/or equations.

16) (6 pts.) The box is given a brief push in the $+x$ direction and starts to slide down the ramp. At time t_1 it is moving down the ramp with a speed $v_1 = 1.0\,{}^{m}/_{s}$. At time $t_2 > t_1$, is its speed v_2 *greater than*, *less than*, or *equal to* v_1? (Assume that the box is still on the ramp at time t_2). Explain your reasoning.

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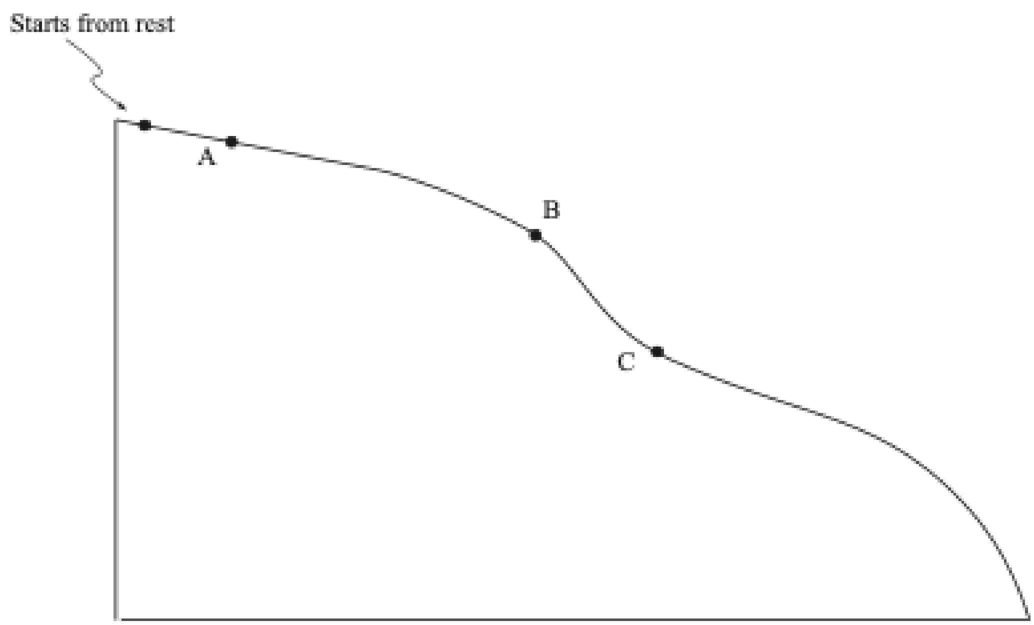
IV. Tutorial Free Response (15 pts – 3 questions)

A sled on snow moves along a hill as shown. At point A, the hill is a straight line. Assume there is negligible friction between the sled and the snow and the sled speeds up throughout the motion.



17) [6 pts] At each of points A, B, and C, draw vectors to show the velocity and acceleration of the sled.

For point B:

18) [4 pts] Explain your reasoning for how you decided to draw the ***velocity*** vector at point B.

19) [5 pts] Explain your reasoning for how you decided to draw the ***acceleration*** vector at point B.

Constants

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

Gravitational constant $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2/kg^2}$

Mathematics

Vector components $\vec{A} = \vec{A}_x + \vec{A}_y = A_x\hat{\imath} + A_y\hat{\jmath}$

Vector magnitude $A = \sqrt{A_x^2 + A_y^2}$

θ ccw from x-axis $A_x = A\cos\theta$
$A_y = A\sin\theta$
$\theta = \tan^{-1}(A_y/A_x)$

Adding vectors $\vec{C} = \vec{A} + \vec{B}$ $C_x = A_x + B_x$

$C_y = A_y + B_y$

Dot product $\vec{A}\cdot\vec{B} = AB\cos\alpha$

$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y$

Cross product $|\vec{A}\times\vec{B}| = AB\sin\alpha$
$\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$

Standard deviation $s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{\mathrm{ave}})^2}{n-1}}$

Linear motion

Average velocity $\vec{v}_{\mathrm{ave}} \equiv \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_{\mathrm{f}} - \vec{r}_{\mathrm{i}}}{t_{\mathrm{f}} - t_{\mathrm{i}}}$

Instantaneous velocity $\vec{v} = \frac{d\vec{r}}{dt}$

Instantaneous acceleration $\vec{a} = \frac{d\vec{v}}{dt}$

Constant acceleration (in "s" direction)

$v_{\mathrm{fs}} = v_{\mathrm{is}} + a_s\Delta t$
$s_{\mathrm{f}} = s_{\mathrm{i}} + v_{\mathrm{is}}\Delta t + \frac{1}{2}a_s(\Delta t)^2$
$v_{\mathrm{fs}}^2 = v_{\mathrm{is}}^2 + 2a_s\Delta s$

Motion on inclined plane $a_s = \pm g\sin\theta$

Relative motion $\vec{v}_{\mathrm{CB}} = \vec{v}_{\mathrm{CA}} + \vec{v}_{\mathrm{AB}}$

Circular motion

Angular position $\theta = \frac{s}{r}$

Angular velocity $\omega = \frac{d\theta}{dt}$

Angular acceleration $\alpha = \frac{d\omega}{dt}$

Tangential velocity $v_t = \omega r$

Centripetal acceleration $a_r = \frac{v_t^2}{r} = \omega^2 r$

Tangential acceleration $a_t = \alpha r$

Period $T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$

Const. angular acceleration $\omega_{\mathrm{f}} = \omega_{\mathrm{i}} + \alpha\Delta t$

$\theta_{\mathrm{f}} = \theta_{\mathrm{i}} + \omega_{\mathrm{i}}\Delta t + \frac{1}{2}\alpha(\Delta t)^2$

$\omega_{\mathrm{f}}^2 = \omega_{\mathrm{i}}^2 + 2\alpha\Delta\theta$

Force and motion

Newton's 2nd law $\vec{a} = \frac{\vec{F}_{\mathrm{net}}}{m}$

Gravity $F_{\mathrm{G}} = mg$

$F_{\mathrm{G}} = \frac{GMm}{R^2}$

Maximum static friction $f_{\mathrm{s\,max}} = \mu_{\mathrm{s}}n$

Kinetic friction $f_{\mathrm{k}} = \mu_{\mathrm{k}}n$

Reynolds number $Re = \frac{\rho vL}{\eta}$

Drag (high Re) $F_{\mathrm{drag}} = \frac{1}{2}C_{\mathrm{d}}\rho Av^2$

Drag (low Re) $F_{\mathrm{drag}} = 6\pi\eta rv$

Newton's 3rd law $\vec{F}_{\mathrm{A\,on\,B}} = -\vec{F}_{\mathrm{B\,on\,A}}$

Circular motion $(F_{\mathrm{net}})_r = \frac{mv_t^2}{r} = m\omega^2 r$

$(F_{\mathrm{net}})_t = ma_t$

Work and energy

Kinetic energy $K = \frac{1}{2}mv^2$

Work by a constant force $W = \vec{F}\cdot\Delta\vec{r}$

Hooke's law $(F_{\mathrm{Sp}})_s = -k\Delta s$

Work done by a spring $W = -\frac{1}{2}k[(\Delta s_{\mathrm{f}})^2 - (\Delta s_{\mathrm{i}})^2]$

Dissipative force $\Delta E_{\mathrm{th}} = f_{\mathrm{k}}\Delta s$

Potential energy $\Delta U = -W_{\mathrm{int}}$

Grav. potential energy $U_{\mathrm{G}} = mgy$

Elastic potential energy $U_{\mathrm{Sp}} = \frac{1}{2}k(\Delta s)^2$

Mechanical energy $\Delta E_{\mathrm{mech}} = \Delta K + \Delta U$

System energy $\Delta E_{\mathrm{sys}} = \Delta E_{\mathrm{mech}} + \Delta E_{\mathrm{th}}$

$\Delta E_{\mathrm{sys}} = W_{\mathrm{ext}}$

Power $P = \frac{dE_{\text{sys}}}{dt}$

$P = \vec{F} \cdot \vec{v}$

Force and potential energy $F_s = -\frac{dU}{ds}$

Impulse and linear momentum

Momentum $\vec{p} = m\vec{v}$

Impulse $\vec{J} \equiv \int_{t_\text{i}}^{t_\text{f}} \vec{F}(t)dt$

Momentum principle $\Delta\vec{p} = \vec{J}$

Isolated system $\vec{P}_\text{f} = \vec{P}_\text{i}$

Force $\vec{F} = \frac{d\vec{p}}{dt}$

Elastic collision with $(v_{\text{i}x})_2 = 0$

$$(v_{\text{f}x})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{\text{i}x})_1$$

$$(v_{\text{f}x})_2 = \frac{2m_1}{m_1 + m_2}(v_{\text{i}x})_1$$

Rotation

Center of mass $x_{\text{cm}} = \frac{1}{M}\sum_i m_i x_i$

Moment of inertia $I = \sum_i m_i r_i^2$

Rod (center) $\frac{1}{12}ML^2$

Rod (end) $\frac{1}{3}ML^2$

Disk $\frac{1}{2}MR^2$

Hoop MR^2

Solid sphere $\frac{2}{5}MR^2$

Hollow sphere $\frac{2}{3}MR^2$

Parallel-axis theorem $I = I_{\text{cm}} + Md^2$

Rotational kinetic energy $K_{\text{rot}} = \frac{1}{2}I\omega^2$

Torque $\tau \equiv rF\sin\phi = rF_\perp = Fd$

$\vec{\tau} \equiv \vec{r} \times \vec{F}$

Gravitational torque $\tau_{\text{grav}} = -Mgx_{\text{cm}}$

Newton's second law for rotation

$$\alpha = \frac{\tau_{\text{net}}}{I}$$

Critical angle $\theta_\text{c} = \tan^{-1}\left(\frac{t}{2\text{h}}\right)$

Rolling $v_{\text{cm}} = R\omega$

$K_{\text{rolling}} = \frac{1}{2}I_{\text{cm}}\omega^2 + \frac{1}{2}Mv_{\text{cm}}^2$

Angular momentum $\vec{L} \equiv \vec{r} \times \vec{p}$

Angular momentum of a particle

$$L_z = mrv_t = mr^2\omega$$

Angular momentum of a rigid body

$$\frac{d\vec{L}}{dt} = \vec{\tau}_{\text{net}}$$

$$\vec{L} = I\vec{\omega}$$

Theory of gravity

Law of gravity $F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{Gm_1m_2}{r^2}$

Free-fall acceleration $g = \frac{GM}{r^2}$

Potential energy $U_\text{G} = -\frac{Gm_1m_2}{r}$

Satellite speed $v = \sqrt{\frac{GM}{r}}$

Kepler's third law $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

Escape speed $v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$

Geosynchronous orbit $r_{\text{geo}} = \left(\frac{GM}{4\pi^2}T^2\right)^{1/3}$