Physics 121 A
Winter 2025

121A - FU

Midterm 1
February 6th, 2025

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

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

I. [45 points total] Lecture multiple-choice questions

1. [5 points] A car is moving in the negative direction, and it is slowing down steadily. Which of the following vector quantities could possibly be the quantities $\vec{v}_\mathrm{i}$, $\Delta\vec{v}$ and $\vec{a}$ for the car during its motion? Note that $\vec{v}_\mathrm{i}$ is the initial velocity, $\Delta\vec{v}$ is the change in velocity, and $\vec{a}$ is the acceleration.
   A. $\vec{v}_\mathrm{i}$ = + 20 mph, $\Delta\vec{v}$ = –5 mph, $\vec{a}$ = – 6 mph/s
   B. $\vec{v}_\mathrm{i}$ = + 20 mph, $\Delta\vec{v}$ = +5 mph, $\vec{a}$ = – 6 mph/s
   C. $\vec{v}_\mathrm{i}$ = – 20 mph, $\Delta\vec{v}$ = –5 mph, $\vec{a}$ = – 6 mph/s
   D. $\vec{v}_\mathrm{i}$ = – 20 mph, $\Delta\vec{v}$ = + 5 mph, $\vec{a}$ = + 6 mph/s
   E. $\vec{v}_\mathrm{i}$ = – 20 mph, $\Delta\vec{v}$ = –5 mph, $\vec{a}$ = + 6 mph/s

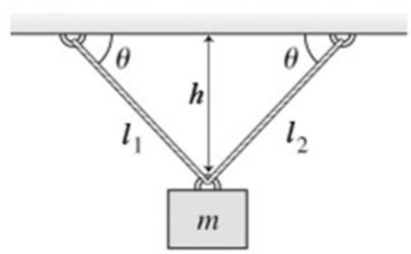
2. [5 points] A ball is thrown straight down from the top of a building, which is 24 m above the ground. One second later, a person reaches out of the window on the 1st floor of the building, just in time to catch the ball. The window is 4 m above the ground. What is the initial speed of the ball when it is thrown down?
   A. 13 m/s
   B. 15 m/s
   C. 19 m/s
   D. 20 m/s
   E. 24 m/s

3. [5 points] An astronaut on a newly explored planet Omega tosses a rock horizontally with a speed of 15.0 m/s. The rock falls to the ground through a vertical distance 1.2 m and lands a horizontal distance 7.0 m from the astronaut. Find the acceleration due to gravity on the planet Omega.
   A. 4.9 m/s^2
   B. 7.1 m/s^2
   C. 9.8 m/s^2
   D. 11 m/s^2
   E. 15 m/s^2

4. [5 points] A Ferris wheel of radius *R* speeds up with a constant angular acceleration of α starting from rest. Find the expression for the centripetal acceleration of a rider after the Ferris wheel has rotated through an angle $\Delta\theta$.
   A. αR
   B. α
   C. $2\alpha\Delta\theta$
   D. $\sqrt{2\alpha\Delta\theta}R$
   E. $2\alpha\Delta\theta R$

5. [5 points] A swimmer swims at 5.0 km/h in still water. The swimmer aims directly across a flowing river. An observer on the bank notes the swimmer's speed is 13 km/h. What is the speed of the river with respect to the bank?
   A. 7.0 km/h
   B. 8.0 km/h
   C. 12 km/h
   D. 17 km/h
   E. 18 km/h

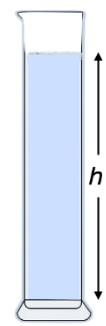
6. [5 points] A loudspeaker with mass $m = 20.0\ \mathrm{kg}$ is suspended $h = 2.00\ \mathrm{m}$ below the ceiling by two cables with length $l_1 = l_2 = 4.00\ \mathrm{m}$, each of which makes an angle θ with the ceiling as shown. What is the tension in each of the cables?



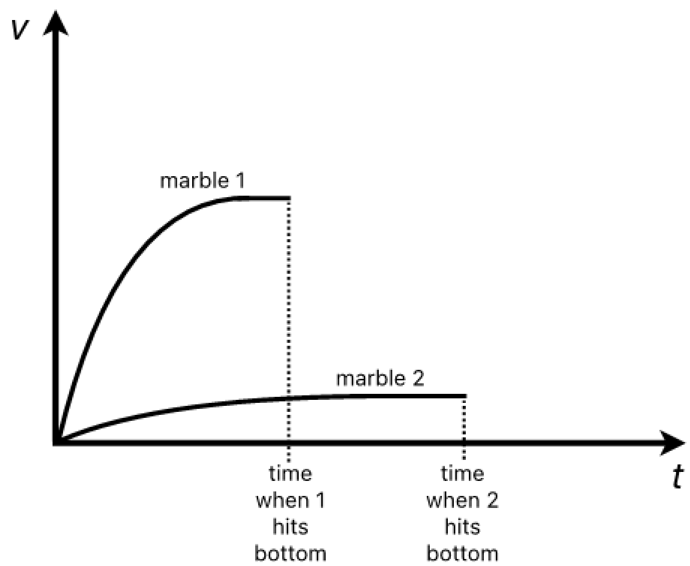
   A. 98.0N
   B. 113N
   C. 196N
   D. 339N
   E. 392N

7. [5 points] Suppose that a box with mass of 3.0 kg is sitting at rest on a level rough surface. The coefficients of static friction and kinetic friction between the surface and the box are 0.65 and 0.55, respectively. When your hand pushes horizontally on the box with a 13-N force, the box remains at rest. What is the friction acting on the box by the surface?
   A. 1.7N
   B. 2.0N
   C. 13N
   D. 16N
   E. 19N

8. [5 points] Two identical marbles, 1 and 2, are dropped from rest into separate cylinders and fall through a fluid to the bottom. The two cylinders contain different fluids. Both cylinders are like the one shown, though the height of the fluids, h_1 and h_2 respectively, may or may not be the same.

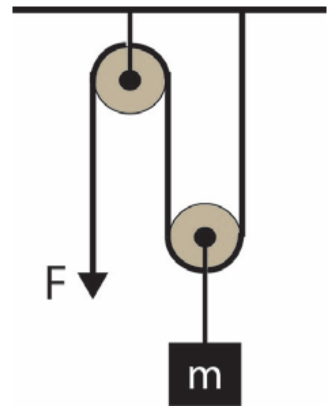


   The graph of their velocity as a function of time as they fall from the top of the fluid until they hit the bottom is shown below. Note that downward is defined as the positive velocity direction here.



   How do the heights of the two columns of fluid compare?
   A. $h_1 = h_2$
   B. $h_1 > h_2$
   C. $h_1 < h_2$
   D. In order to compare the heights, we need to know how the viscosities of the fluids compare.

9. [5 points] A cord runs around two massless, frictionless pulleys. A canister with mass m hangs from one pulley and you exert a force $\vec{F}$ on the free end of the cord. What must be the magnitude of $\vec{F}$ if you are to lift the canister at a constant speed? Note that g is the free-fall acceleration.
   - A. 0 mg
   - B. 2mg
   - C. ½ mg
   - D. Not enough information



II. [15 points total] Lab multiple-choice questions

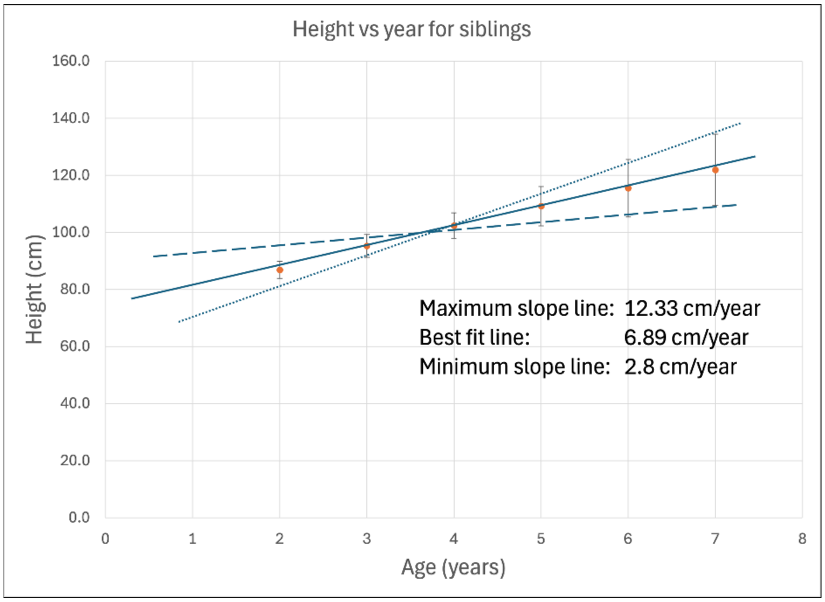
10. [5 points] A group of students has made multiple measurements of a quantity and calculated the average as 1.884 ± 0.912 cm. Which of the following choices represents a correct reporting of the data (to 1 or 2 significant figures) using the rules developed in lab? **Select all that apply.**
    A. 1.9 ± 0.9 cm
    B. 1.9 ± 1 cm
    C. 2 ± 0.9 cm
    D. 2 ± 1 cm
    E. 1.88 ± 0.91 cm

11. [5 points] In a family, the oldest child decides to find out whether there is a relationship between the age and height of their younger siblings. They come up with two experiments:

    Experiment 1: Measure the height of each child on their birthday for several years.
    Experiment 2: When each child reaches a certain height, record the age of the child.

    Which of the following are the dependent and independent variables in each experiment? **Select all that apply.**
    A. For Experiment 1, height is the dependent variable, and age is the independent variable.
    B. For Experiment 1, age is the dependent variable, and height is the independent variable.
    C. For Experiment 2, height is the dependent variable, and age is the independent variable.
    D. For Experiment 2, age is the dependent variable, and height is the independent variable.
    E. None of the above

12. [5 points] In the scenario from Q11, the oldest child conducts **Experiment 1** and finds the best fit line and lines of maximum and minimum slope as shown.



How would they report the slope of the best fit line to 1 and 2 significant figures using the rules from labs A1 and A2? **Select all that apply.**

A. 6.89 ± 5.44 cm/year
B. 6.9 ± 5.4 cm/year
C. 7 ± 5 cm/year
D. 6.8 ± 4.8 cm/year
E. 6.89 ± 4.8 cm/year

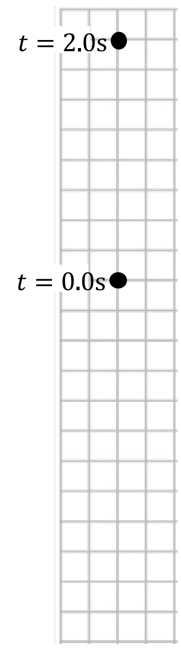
III. [25 points total] Lecture free response questions

<u>You must show your work to get the full credit.</u>

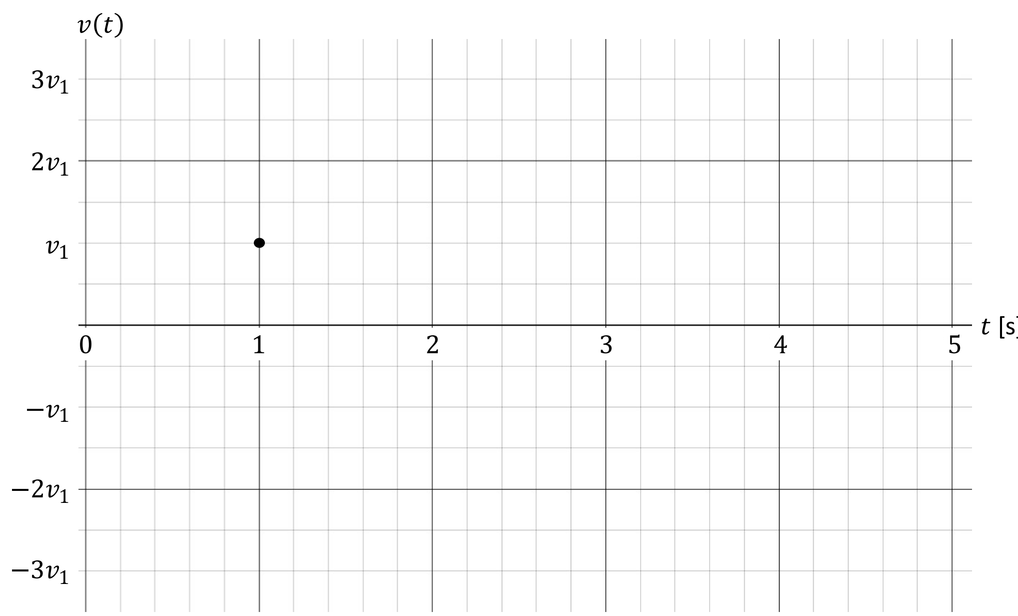
Consider the following scenario for the next two questions.

You throw a small ball upward. At time $t = 0.0$ s, it leaves your hand, and at $t = 2.0$ s, it reaches its maximum height. Neglect air resistance.

13. [6 points] An incomplete motion diagram for the ball is shown at right. Complete the diagram by indicating the positions of the ball at $t = 1.0$ s, $t = 3.0$ s, $t = 4.0$ s, and $t = 5.0$ s using the grid. Make sure to label each dot with corresponding time.

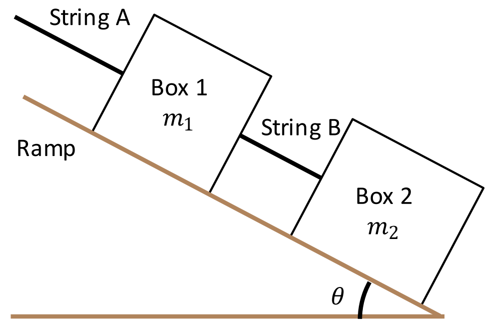


14. [4 points] In the space below, draw a velocity-versus-time graph for the duration between $t = 0.0$ s and $t = 5.0$ s. Note that the velocity at $t = 1.0$ s, v_1, is already indicated. Consider upward direction to be positive.



Use the following scenario for the next two questions.

Consider the situation shown in the figure at right. String A is pulling on Box 1, and String B is connected to Box 1 and Box 2. Box 1 has mass m_1, and Box 2 has mass m_2. The boxes are accelerating up a ramp with negligible friction that makes angle θ above horizontal. The strings have negligible mass and are parallel to the ramp surface. The tension in String A has magnitude T_A.



15. [7 points] Draw free-body diagrams for Box 1, Box 2, and the system of two boxes and String B. Make sure to label all the forces indicating the type of force, the object exerting the force, and the object on which the force is exerted.

Box 1

Box 2

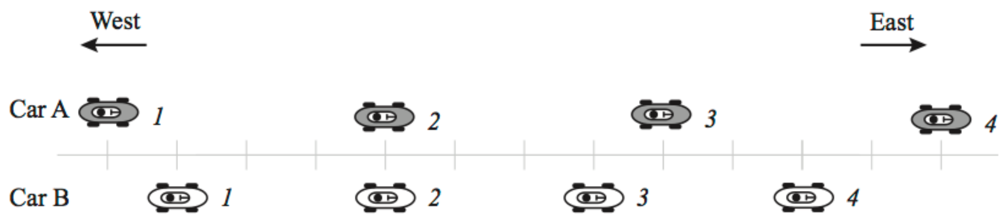
System of two boxes and String B

16. [5 points] What is the expression for the magnitude of the acceleration of the boxes in terms of the variables given and g, the free-fall acceleration?

17. [3 points] A horse is standing on a level ground. What force forms the Newtons' 3rd law pair with the gravitational force exerted on the horse by the earth? Specify the type of the force, the object exerting the force, and the object on which the force is exerted.

IV. [15 points total] Tutorial free response questions

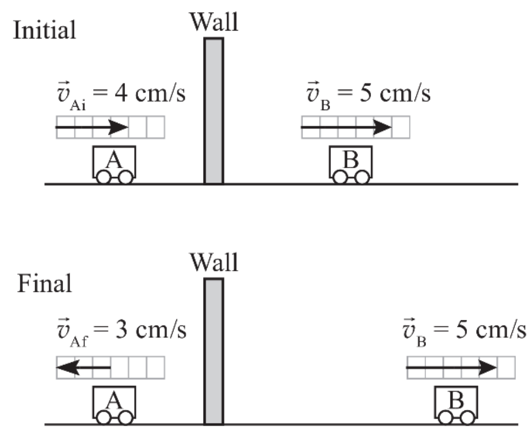
18. [4 points] Two cars, A and B, move along a straight road. The strobe diagram below shows the locations of the cars at instants 1-4, separated by equal time intervals. Ignore the north-south separation between the cars (*i.e.,* consider one dimension only).



Draw a vector in each of the boxes below to represent the velocity of car B *in the reference frame of car A* at instants *1, 2,* and *3.* Draw your vectors to make clear the relative directions and magnitudes of the vectors. If any vector has zero magnitude, state so explicitly. No explanation is required.

Instant 1	Instant 2	Instant 3

The situation below applies to the following two questions.



Two carts, A and B, are moving on a track as shown. Cart A is approaching a fixed wall. The initial and final velocities (before and after cart A hits the wall) are shown (to scale).

19. [6 points] Find the *change in velocity of cart A* *in the reference frame of the ground* between the two instants shown. Explain your reasoning in words or through a diagram.

20. [5 points] Find the *change in velocity of cart A* *in the reference frame of cart B*. Explain your reasoning.

This page intentionally left blank.

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	$\lvert\vec{A}\times\vec{B}\rvert = AB\sin\alpha$ $\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$

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)

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

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	$\Delta E_{\mathrm{sys}} = \Delta E_{\mathrm{mech}} + \Delta E_{\mathrm{th}}$ $\Delta E_{\mathrm{sys}} = W_{\mathrm{ext}}$