Physics 121A
Autumn 2024

121A - K.TOLICH

Midterm 1
October 24th, 2024

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.

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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.
For multi-select questions, you earn partial credit for each correct answer that you choose, but you receive no credit if you choose any incorrect answers.

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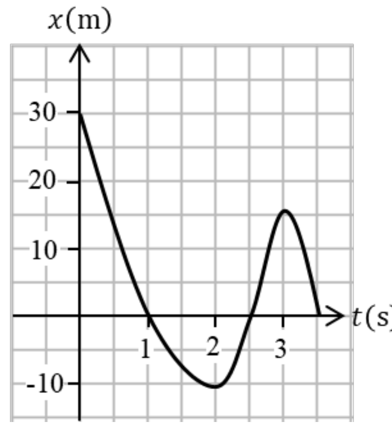
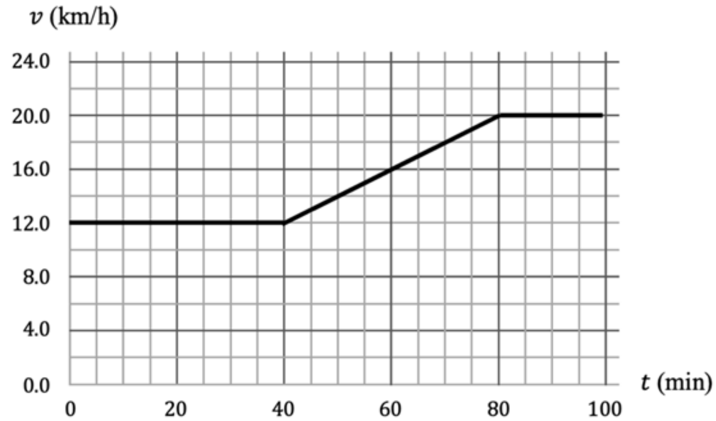
I. [45 points total] Lecture multiple-choice questions

1. [5 points] The figure at right shows the position versus time graph for a ball moving in the x-direction. Choose all correct statements about the motion of the ball.
   A. At $t = 1.0$s, the ball has a negative velocity.
   B. The ball is moving faster at $t = 1$s than at $t = 2.5$s.
   C. Between $t = 1.0$s and $t = 2.5$s the displacement of the ball is 0.
   D. The ball changes direction at $t = 3.0$s
   E. None of these is correct.

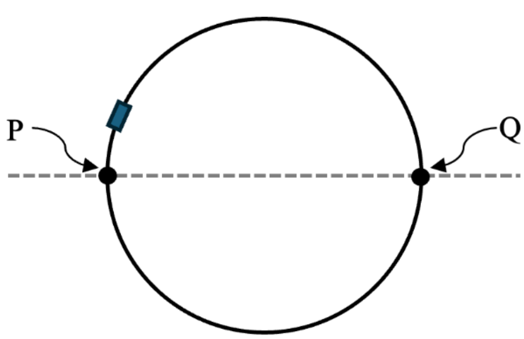


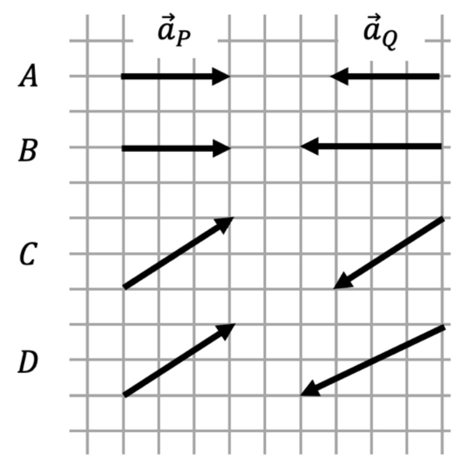
2. [5 points] A ball on the ground is launched straight up. When the ball has a speed of 9.0 m/s, it is 3.2 m above the ground. When it has a speed of 6.0 m/s, how high above the ground is it?
   A. 6.4 m
   B. 2.1 m
   C. 5.5 m
   D. 8.2 m
   E. Not enough information is given.

3. [5 points] A cyclist travels west on a long straight road. They have a device that keeps track of their speed. The cyclist produces the following graph. What was their average velocity for the period from 0 to 100 minutes? (Note the units on the graph.)
   A. 10.4 km/h
   B. 9.6 km/h
   C. 16.0 km/h
   D. 15.2 km/h
   E. 16.8 km/h



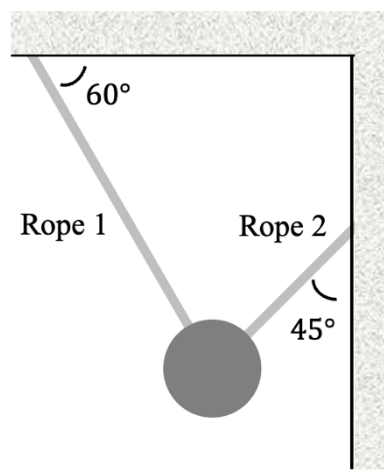
4. [5 points] A car travels clockwise around a circular track, as shown in the top-view diagram. Its speed increases at a constant rate. Which pair of vectors best describes the accelerations of the car at points P and Q? (Note that it reaches point Q after point P.) Choose "E" if none of the pairs is correct.





5. [5 points] A boat takes 3.0 h to travel 10 km down a river and 4.5 h to return. How fast is the river flowing? Assume that the boat's speed with respect to the water is constant.
   A. 2.78 km/h
   B. 3.13 km/h
   C. 0.56 km/h
   D. 1.33 km/h
   E. 1.50 km/h

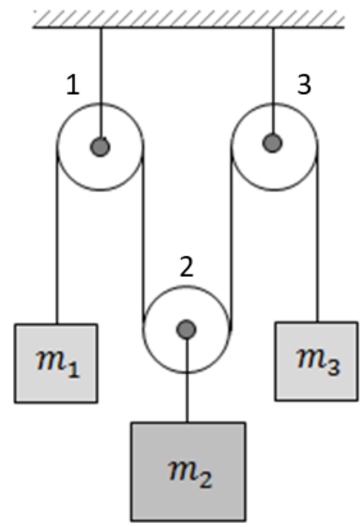
6. [5 points] A ball is suspended by two ropes, as shown. If the mass of the ball is 5.1 kg, what is the tension in Rope 1?
   A. 26 N
   B. 25 N
   C. 50 N
   D. 37 N
   E. 35 N



7. [5 points] Suppose that a box full of 10 identical books is on a level table. Each book has a mass of 1.0 kg. You push horizontally on the box with a force of 10.0 N, but the box does not move. You remove the books one by one, and when you have removed 6 books, the box begins to move. Which of the following is a possible value for the coefficient of static friction between the box and the table? You can ignore the mass of the box itself.
   A. 0.26
   B. 0.24
   C. 0.17
   D. 6.0
   E. 10.0

8. [5 points] Two spherical dust particles falling through the air have reached terminal speed. Particle 1 has the same radius but twice the mass as particle 2. How does the drag force on particle 1 (F_1^{drag}) compare to the drag force on particle 2 (F_2^{drag})? You can assume that the Reynold's number for this situation is low.
   A. $F_1^{drag} > F_2^{drag}$
   B. $F_1^{drag} < F_2^{drag}$
   C. $F_1^{drag} = F_2^{drag}$
   D. Not enough information is given.

9. [5 points] Three blocks with masses of m_1, m_2, and m_3, and three massless pulleys 1, 2, and 3 with negligible friction on their axles are assembled using massless inextensible ropes as shown. If the blocks are stationary, which of the following is a correct description of the relative masses of the blocks?



   A. $m_3 = m_2 = m_1$
   B. $m_1 = m_3 = \frac{1}{2}m_2$
   C. $m_1 < m_2 < m_3$
   D. $m_1 = m_2 = \frac{1}{4}m_3$
   E. Not enough information is given.

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

The next two questions are based on an experiment conducted by a group of students. They placed 5 pieces of tape at specific locations on a table and recorded the instant at which an object passed each tape. They conducted three runs of the experiment.

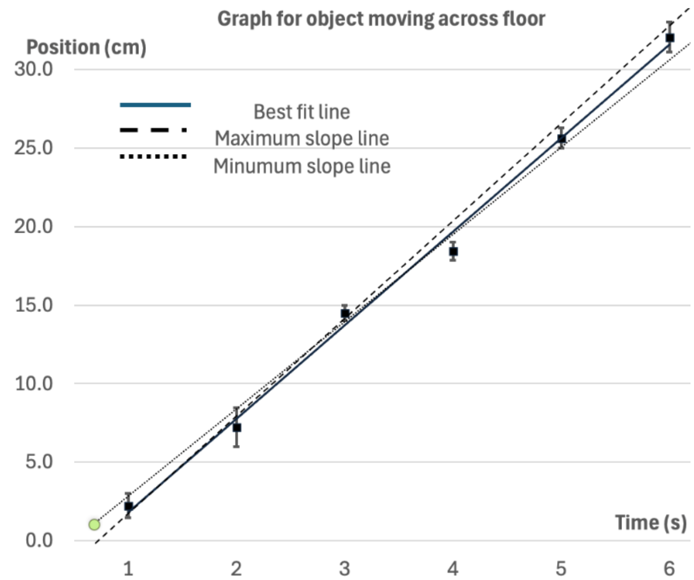
10. [5 points] For this experiment, what are the dependent and independent variables?
    A. Position is the dependent variable, and time is the independent variable.
    B. Time is the dependent variable, and position is the independent variable.
    C. Time is the independent variable, but there is no dependent variable.
    D. Position is the independent variable, but there is no dependent variable.
    E. The experiment was not correctly planned, so there are no independent and dependent variables.

11. [5 points] The table at right shows the clock readings when the object passed the first piece of tape for each of the three runs. (The clock face shows hundredths of a second.)

Run	Clock reading (s)
1	2.20
2	1.90
3	2.05

The students use the maximum deviation method to determine the random uncertainty in their measures. How much larger is the random uncertainty compared to the instrumental uncertainty?
    A. The random uncertainty is equal to the instrumental uncertainty.
    B. The random uncertainty is 10 times greater than the instrumental uncertainty.
    C. The random uncertainty is 20 times greater than the instrumental uncertainty.
    D. The random uncertainty is 30 times greater than the instrumental uncertainty.
    E. The random uncertainty is 40 times greater than the instrumental uncertainty.

12. [5 points] The graph at right shows a plot of data obtained by a student for a **different** experiment. A best fit line and lines of maximum and minimum slope are shown. The student has calculated the following values:



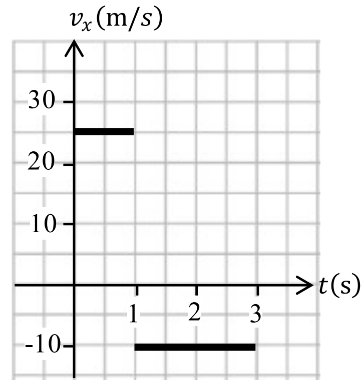
Line	Slope
Best fit	5.916 cm/s
Max. slope	6.534 cm/s
Min. slope	5.445 cm/s

Which of the following is how the student could report the slope and its uncertainty based on the methods developed in lab?

A. 6 ± 1 or 5.9 ± 0.6 cm/s
B. 6 ± 1 or 6.0 ± 1.0 cm/s
C. 5.9 ± 0.6 or 5.92 ± 0.62 cm/s
D. 5.9 ± 0.6 or 5.92 ± 0.61 cm/s
E. 6.0 ± 0.6 or 5.9 ± 0.62 cm/s

III. [25 points total] Lecture free response questions
<u>You must show your work to get the full credit.</u>

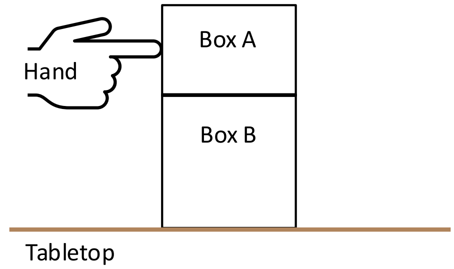
Consider the following scenario for the next two questions.
The velocity-versus-time graph of an object moving in the x-direction is shown at right. The object is at $x = 10\text{m}$ at $t = 0\text{s}$.



13. [5 points] In the space below, draw a position-versus-time graph for this object. Make sure to label the axes.

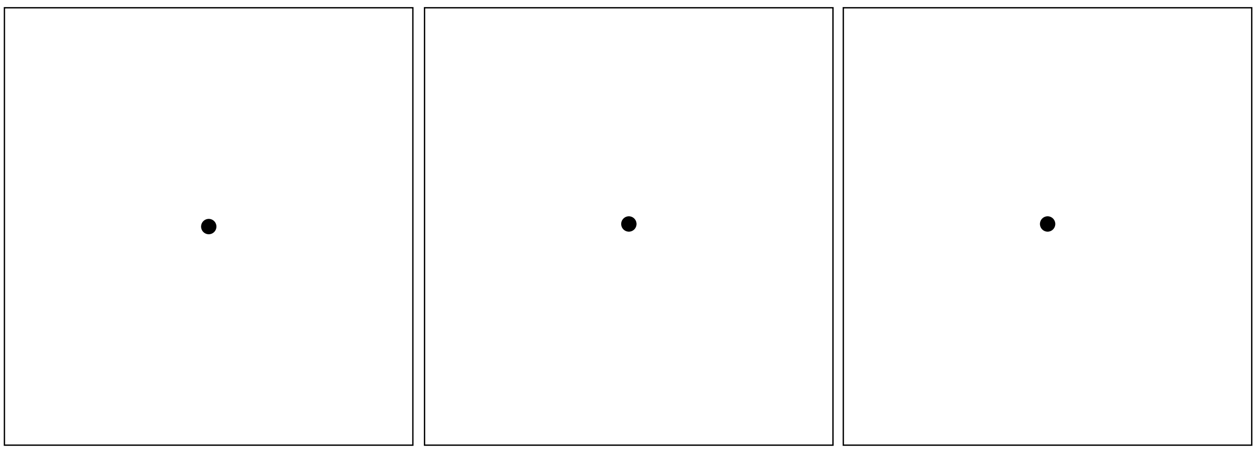
14. [5 points] In the space below, draw a motion diagram for this object at every second from $t = 0\text{s}$ to $t = 3\text{s}$. Make sure to label the positions and times.

Use the following scenario for the next three questions.
Box A with mass m_{A} is on top of Box B with mass m_{B}, which is on a horizontal tabletop with negligible friction. A hand pushes on Box A to the right causing both boxes to move with a constant acceleration a. Box A does not slip on Box B.



15. [7 points] Draw free-body diagrams for Box A, Box B, and the system of two boxes. 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 A | Box B | System of two boxes

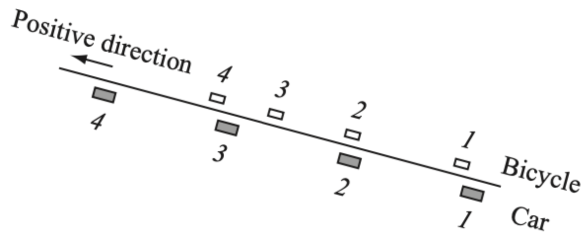


16. [4 points] Write an expression for the magnitude of the force that the hand exerts on Box A in terms of the variables given.

17. [4 points] Identify all pairs of forces on your free-body diagrams that constitute Newton's 3rd law force pairs.

IV. [15 points total] Tutorial free response questions

Use the following scenario for the next two questions.
A bicycle coasts up a hill while a car drives up the hill at constant speed. The strobe diagram at right shows their positions at instants *1–4*, separated by equal time intervals. The bicycle comes to rest relative to the road at instant *4.*



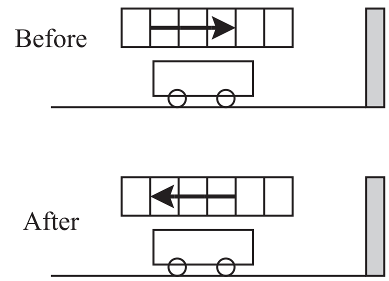
18. [5 points] As measured in the reference frame of the road is the acceleration of the bicycle in the positive direction, in the negative direction, or is its magnitude zero? Explain.

19. [5 points] Draw vectors to show the ***direction*** of the velocity of the bicycle *in the reference frame of the car* at instants *2* and *3.* Explain.

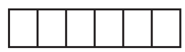
$\vec{v}_{BC}$ at instant *2*

$\vec{v}_{BC}$ at instant *3*

20. [5 points] A cart rolls toward a wall on a level, frictionless table. The diagram shows the velocity vector of the cart just before and just after it collides with the wall. The velocity vectors are drawn to scale.



In the space below, sketch a vector to show the change in velocity of the cart. Draw the vector using the same scale as for the velocity vectors. Explain your reasoning. If the change in velocity is zero, state so explicitly.



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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	$\vec{v}_{\text{ave}} \equiv \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_{\text{f}} - \vec{r}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$
Instantaneous velocity	$\vec{v} = \frac{d\vec{r}}{dt}$
Instantaneous acceleration	$\vec{a} = \frac{d\vec{v}}{dt}$

Constant acceleration (in "s" direction)

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

Motion on inclined plane	$a_s = \pm g\sin\theta$
Relative motion	$\vec{v}_{\text{CB}} = \vec{v}_{\text{CA}} + \vec{v}_{\text{AB}}$

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

Force and motion

Newton's 2nd law	$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$
Gravity	$F_{\text{G}} = mg$ $F_{\text{G}} = \dfrac{GMm}{R^2}$
Maximum static friction	$f_{\text{s max}} = \mu_{\text{s}}n$
Kinetic friction	$f_{\text{k}} = \mu_{\text{k}}n$
Reynolds number	$Re = \frac{\rho vL}{\eta}$
Drag (high Re)	$F_{\text{drag}} = \frac{1}{2}C_{\text{d}}\rho Av^2$
Drag (low Re)	$F_{\text{drag}} = 6\pi\eta rv$
Newton's 3rd law	$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$
Circular motion	$(F_{\text{net}})_r = \frac{mv_t^2}{r} = m\omega^2 r$ $(F_{\text{net}})_t = ma_t$

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	$(F_{\text{Sp}})_s = -k\Delta s$
Work done by a spring	$W = -\frac{1}{2}k[(\Delta s_{\text{f}})^2 - (\Delta s_{\text{i}})^2]$
Dissipative force	$\Delta E_{\text{th}} = f_{\text{k}}\Delta s$
Potential energy	$\Delta U = -W_{\text{int}}$
Grav. potential energy	$U_{\text{G}} = mgy$
Elastic potential energy	$U_{\text{Sp}} = \frac{1}{2}k(\Delta s)^2$
Mechanical energy	$\Delta E_{\text{mech}} = \Delta K + \Delta U$
System energy	$\Delta E_{\text{sys}} = \Delta E_{\text{mech}} + \Delta E_{\text{th}}$ $\Delta E_{\text{sys}} = W_{\text{ext}}$