Physics 114 A
Summer 2025

114A - AL-BINNI

Midterm 1
July 14th, 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.**

1. [4 pts] Two runners wish to compare their speeds. Runner A likes to measure distances in kilometers, and Runner B measures distances in miles. Runner A runs a distance of 5.00 km in 35.0 minutes, while Runner B runs a distance of 3.00 miles in 32.0 minutes. Which of them is faster?
Note 1 mile = 1.609 km.

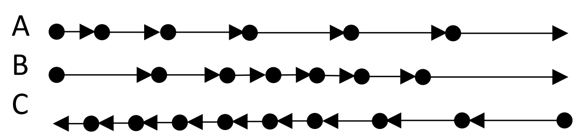
   A. Runner A
   B. Runner B
   C. They are both equally fast.
   D. We cannot compare speeds when distances and times are different.

$v_A = \frac{5.00\,km}{35.0\,min} = 0.143\ km/min$

$v_B = \frac{(3.00\,mi)(1.609\,km)}{32.0\,min} = 0.151\ km/min$

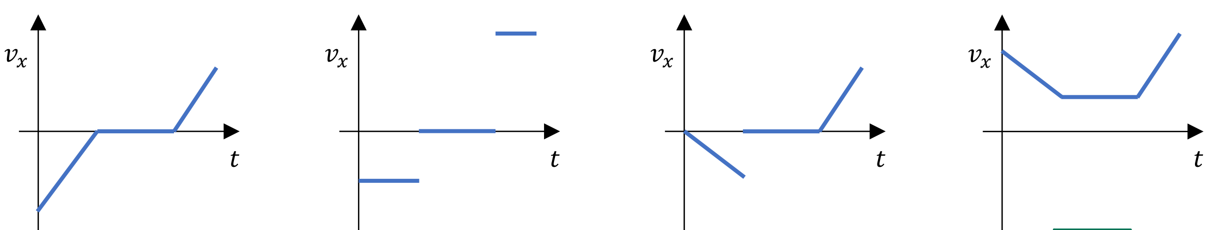
$\Rightarrow v_B > v_A$

2. [4 pts] As a car moves, it first experiences acceleration to the left, then moves with no acceleration and finally accelerates to the right. Which of the motion diagrams at right represent(s) the motion of the car?



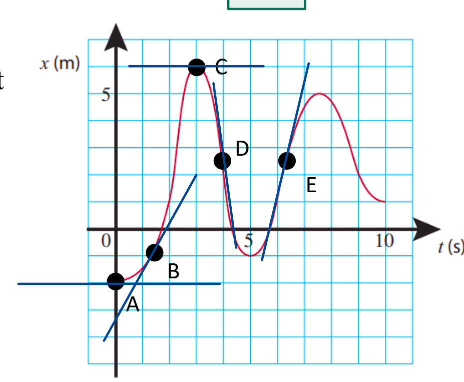
   ✗ A. Diagram A only — car first accelerates to the right and then no acceleration
   B. Diagram B only — car slows down (accelerates left), then no acceleration then speeds up (accelerates right)
   ✗ C. Diagram C only — accelerates right then no acceleration
   ✗ D. More than one diagram satisfies this description
   ✗ E. None of the diagrams satisfies this description

3. [4 pts] Which one of the following velocity vs. time graphs represents the description of the car's motion in the previous question? Assume "right" points in the $+x$-direction.



A B C D

4. [3 pts] The position of an object as a function of time is plotted at right. Choose the correct ranking of the **magnitudes** of velocity at the labeled points.



   A. $v_A < v_B < v_D = v_E < v_C$
   B. $v_B < v_A < v_D = v_E < v_C$
   C. $v_A = v_C < v_B < v_E < v_D$
   D. $v_B < v_A < v_D < v_E < v_C$
   E. $v_D < v_A = v_C < v_B < v_E$

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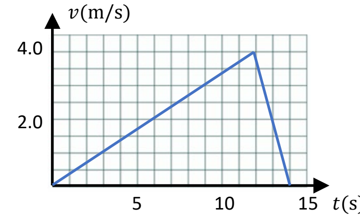
5. [4 pts] The velocity vs. time graph of a runner is shown at right. What is the distance between the start and finish points of this run?



A. Zero
B. 14 m
C. 28 m
D. 18 m
E. 4.0 m

Since the velocity is +ve ⇒ distance equals displacement = area under curve = area of triangle

$\Rightarrow \Delta x = \frac{1}{2}(14s)(4.0\frac{m}{s}) = 28\,m$

6. [3 pts] Choose the correct description of the motion depicted in the previous question. (Choose only one).

A. The start and finish points are same location. $\Delta x \neq 0 \Rightarrow$ not same location

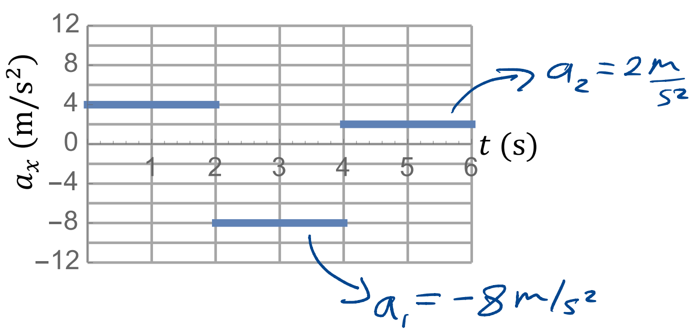
B. The magnitude of acceleration between $t = 0$ s and $t = 12$ s is greater than the magnitude of acceleration between $t = 12$ s and $t = 15$ s. 0 → 12s slope is shallower than 12 → 15s

C. The distance traveled between $t = 0$ s and $t = 12$ s is equal to the distance traveled between $t = 12$ s and $t = 15$ s. Area under curve is not the same

D. The runner first moved in the $+x$-direction then changed to moving in the $-x$-direction.

E. None of the above is correct.

7. [3 pts] The acceleration vs. time graph for the motion of an object is shown at right. If at $t = 2.0$ s the object was moving at $v_x = +7.0$ m/s, what is its velocity at $t = 6.0$ s?



A. −12 m/s
B. −5.0 m/s
C. −4 m/s
D. +3 m/s
E. −17 m/s

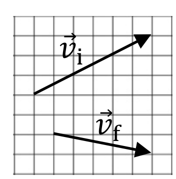
Δv = area under curve

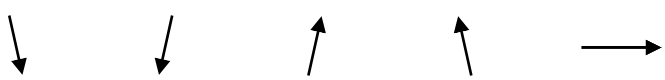
$= v_{6.0s} - v_{2.0s}$

$= a_1(4-2)s + a_2(6-4)s = (-8\frac{m}{s^2})(2s) + (2\frac{m}{s^2})(2s)$

$= -12\,m/s \Rightarrow v_{6.0s} = -12\frac{m}{s} + 7.0\frac{m}{s} = -5.0\frac{m}{s}$

8. [3 pts] The two vectors shown represent the velocity vectors of an object at times t_i and t_f. Which one of the choices shown represents the direction of the object's average acceleration during that time interval, that is $\vec{a} = \Delta\vec{v}/\Delta t$?

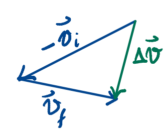




A B C D E

$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$

$\Rightarrow$ we need $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$



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9. [3 pts] A person throws a ball straight up in the air where it reaches a height h above the hand, then falls back again a distance h, where the person catches it. Choose the true statement about the motion in the period **right after** it leaves the hand and **right before** it is caught again and neglect air resistance.

   ✗ A. The acceleration of the ball is initially large then becomes zero and then increases again. $a_y = -g$

   B. When the ball reaches the maximum height, it momentarily stops moving.

   ✗ C. The time it takes the ball to reach maximum height is smaller than the time needed for it to come back from the maximum height to the hand. The way up is symmetrical with the way down

   ✗ D. The speed with which the ball leaves the hand is smaller than the speed with which it lands on the hand. Same reason why C is wrong.

10. [3 pts] Assume now the person throws the ball up again but fails to catch it. If that the ball was launched from the hand at a height of 1.3 m above ground and it reaches the ground at a speed of 7.3 m/s, at what speed was the ball thrown up initially?

   A. 8.9 m/s

   B. 12 m/s

   C. 7.3 m/s

   D. 5.3 m/s

   E. 9.8 m/s

$(v_y)_i = ?$ $\Delta y = -1.3\,m$; $(v_y)_f = 7.3\,m/s$

$(v_y)_f^2 = (v_y)_i^2 - 2g\Delta y \Rightarrow (v_y)_i = \sqrt{(v_y)_f^2 + 2g\Delta y}$

$\Rightarrow (v_y)_i = \sqrt{(7.3\frac{m}{s})^2 + 2(9.8\frac{m}{s^2})(-1.3m)} = 5.3\frac{m}{s}$

11. [3 pts] A plane flies 230 miles north, then 170 miles west and finally 110 miles south. What is the magnitude of the plane's displacement during the entire trip?

   A. 510 miles

   B. 170 miles

   C. 290 miles

   D. 210 miles

   E. 310 miles

$|\Delta\vec{r}| = \sqrt{(\Delta x)^2 + (\Delta y)^2}$

$= \sqrt{(-170mi)^2 + (230mi - 110mi)^2}$

$= 210\,mi$

12. [3 pts] A ball is kicked over a flat horizontal field at an angle of 34° above the horizontal. It reaches a maximum height of 7.8 m above the field. At what initial speed was the ball kicked? Neglect air resistance.

   A. 15 m/s

   B. 12 m/s

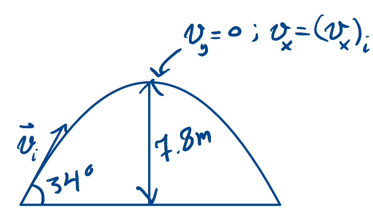
   C. 16 m/s

   D. 22 m/s

   E. 10 m/s

$(v_y)_i = v_i \sin 34°$

$(v_y)_f^2 = (v_y)_i^2 - 2g\Delta y$



$\Rightarrow (v_y)_i = \sqrt{2(9.8)(7.8)} = 12\frac{m}{s} = v_i \sin 34°$

$\Rightarrow v_i = \frac{12}{\sin 34°} = 22\frac{m}{s}$

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13. [3 pts] If the ball in the previous problem is kicked with the same initial speed but at an initial angle greater than 34° but less than 90°, does the time needed for the ball to reach the maximum height *increase*, *decrease*, or *stay the same* compared to the previous situation?

   A. Increase
   B. Decrease
   C. Stay the same
   D. Information provided is not enough to answer.

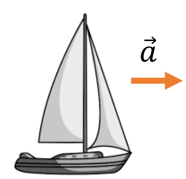
$(v_y)_f = 0 = (v_y)_i - g\Delta t$

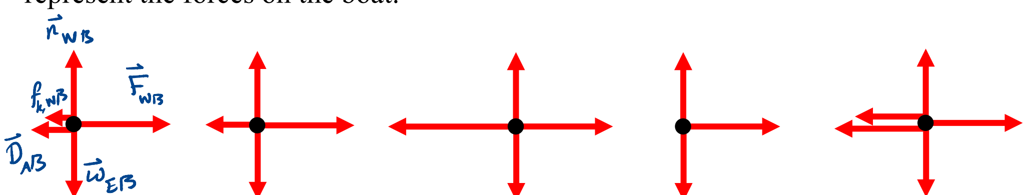
$\Rightarrow \Delta t = \frac{(v_y)_i}{g} = \frac{v_i \sin\theta_i}{g}$

14. [3 pts] Which of the following is NOT a characteristic of projectile motion? (Ignore air resistance and take downward direction to be negative.)

   A. The only force acting on the projectile is gravity.
   B. The projectile's horizontal velocity remains constant throughout its flight.
   C. The projectile's velocity is zero at the maximum height.
   D. The projectile's vertical velocity changes at a constant rate of –9.81 m/s².
   E. The projectile's path is a parabola.

15. [3 pts] A sailing boat moves on water at constant acceleration to the right. The boat is pushed by the wind with a horizontal force. In the presence of friction with the water and air drag (air resistance), choose the free-body diagram that could represent the forces on the boat.





A. B. C. D. E.

16. [3 pts] A person weighing 670 N stands on a scale in a moving elevator. The reading of the scale is 740 N while the elevator moves. Consider the following descriptions of the motion of the elevator:
   I. The elevator is going up and slowing down.
   II. The elevator is going down and slowing down.
   III. The elevator is going up and speeding up.
   IV. The elevator is going down and speeding up.

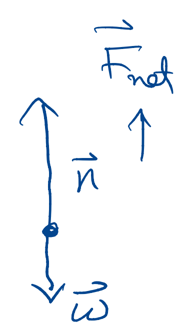
Which of the following combinations of statements correctly describes the motion of the elevator?

   A. (I) or (III)
   B. (II) or (IV)
   C. (I) or (II)
   D. (II) or (III)
   E. (III) or (IV)

$F_{net,y} = n - w = 740N - 670N$

acceleration is up

$\Rightarrow$ either II or III



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17. [4 pts] When a net force of magnitude F acts on an object of mass m, the object moves with an acceleration of magnitude a. If a net force of magnitude $0.37F$ acts on a second object of mass $0.12m$, what is the magnitude of the acceleration of that second object?

 A. $0.044a$
 B. $23a$
 C. a
 D. $0.32a$
 E. $3.1a$

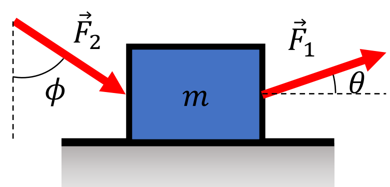
$F_{1,net} = ma = F$

$F_{2,net} = (0.12m)a_2 = 0.37F$

$\Rightarrow a_2 = \frac{0.37}{0.12m}F = \frac{0.37}{0.12}a = 3.1a$

18. [4 pts] Two people are pushing a box on a flat horizontal and frictionless surface with forces $\vec{F}_1$ and $\vec{F}_2$ as shown. The forces act at angles θ and ϕ. Choose the correct expression of the box's horizontal acceleration.

 A. $(F_1 \cos\theta - F_2 \cos\phi)/m$
 B. $(F_1 \sin\theta + F_2 \sin\phi)/m$
 C. $(F_1 \sin\theta - F_2 \sin\phi)/m$
 D. $(F_1 \cos\theta + F_2 \sin\phi)/m$
 E. $(F_1 \cos\theta + F_2 \cos\phi)/m$



Box accelerates only in the horizontal direction

$\Rightarrow F_{net,x} = ma_x$; $F_{net,y} = 0$

$F_{net,x} = F_{1,x} + F_{2,x} = F_1 \cos\theta + F_2 \sin\phi$

$\Rightarrow a_x = \frac{F_1 \cos\theta + F_2 \sin\phi}{m}$

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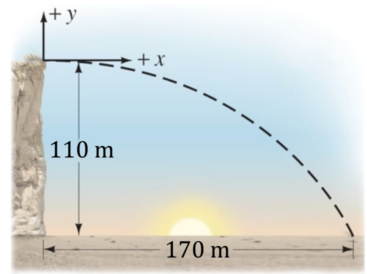
II. Lecture Free Response [20 pts]

Show details in all the following questions.

A stone is kicked horizontally from the top of a hill. It lands at the bottom of the hill 110 m below and 170 m to the right, as shown in the figure at right. Answer the next three questions and neglect air resistance.



19. [5 pts] Calculate how much time it took the stone to reach the bottom.

Solution:

We can use the vertical distance to find the time:

$$\Delta y = (v_y)_i \Delta t - \frac{1}{2} g (\Delta t)^2$$

Using $\Delta y = -110$ m and the fact the stone moves horizontally initially with $(v_y)_i = 0$:

$$-110\ \text{m} = 0 - \frac{1}{2}(9.8\ \text{m/s}^2)(\Delta t)^2$$

Solving for time:

$$\Delta t = \sqrt{\frac{2(110\ \text{m})}{9.8\ \text{m/s}^2}} = \boxed{4.7\ \text{s}}$$

Rubric:
1 pt: realizing the stone has no initial vertical velocity.
2 pts: choosing a suitable kinematics equation(s).
2 pts: substituting and solving for time.

20. [5 pts] What was the stone's initial speed? *If you couldn't answer the previous question assume* $\Delta t = 6$ s.

Solution:

Since we know the time it took the stone to reach the ground from the previous question, we can use the horizontal distance to find the horizontal velocity, and since the stone was kicked horizontally, the magnitude of the initial speed will be the magnitude of the horizontal velocity:

$$v_i = \sqrt{(v_x)_i^2 + (v_y)_i^2} = |(v_x)_i| = |v_x| = \left|\frac{\Delta x}{\Delta t}\right| = \frac{170\ \text{m}}{4.7\ \text{s}} = \boxed{36\ \text{m/s}}$$

Or $v_i = 28$ m/s if you couldn't answer the previous question.

Rubric:
2 pts: realizing the initial velocity has no vertical contribution and is only horizontal.
1 pt: for realizing the horizontal speed does not change.
2 pts: for calculating the horizontal speed and equating it to the initial speed.

21. [5 pts] Calculate the y-component of the stone's velocity right before hitting the ground.

Solution 1:

We can use the time found earlier to solve for $(v_y)_f$ with $(v_y)_i = 0$:

$$(v_y)_f = (v_y)_i - g\Delta t$$

$$(v_y)_f = 0 - (9.8\ \text{m/s}^2)(4.7\ \text{s}) = \boxed{-46\ \text{m/s}}$$

Solution 2:

We can use the vertical distance to solve for $(v_y)_f$ with $(v_y)_i = 0$:

$$(v_y)_f^2 = (v_y)_i^2 - 2g\Delta y \Rightarrow (v_y)_f = \sqrt{(v_y)_i^2 - 2g\Delta y}$$

$$(v_y)_f = \sqrt{0 - 2(9.8\ \text{m/s}^2)(-110\ \text{m})} = \boxed{-46\ \text{m/s}}$$

Where the minus sign was added because the stone is moving downward.

Rubric:

2 pts for setting up suitable kinematics equation(s)
2 pts for solving the equations for vertical velocity.
1 pt for getting a negative answer.

22. [5 pts] How fast was the stone moving right before it hit the ground?
Solution:
The speed of the stone at any instance is the magnitude of the vector sum of its horizontal and vertical velocities:

$$v_f = \sqrt{(v_x)_f^2 + (v_y)_f^2}$$

The horizontal velocity does not change, but the vertical velocity depends on position (or time). We have the values of velocity at the landing point:

$$(v_x)_f = (v_x)_i = v_x = 36 \text{ m/s}$$
$$(v_y)_f = -46 \text{ m/s}$$

Therefore:

$$v_f = \sqrt{(36 \text{ m/s})^2 + (-46 \text{ m/s})^2} = \boxed{58 \text{ m/s}}$$

Rubric:
2 pts for realizing the speed at any point is the magnitude of the velocity vector.
2 pts for correctly identifying the values of velocities that go into the expression for final speed.
1 pt for correctly calculating the final speed.

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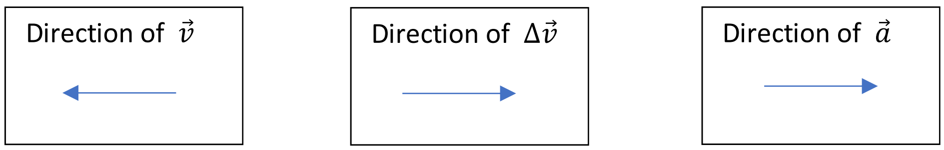
III. Tutorial Free Response [20 pts] Explain your answer where required.

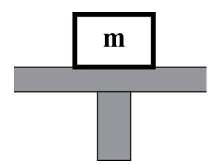
23. [7 pts] A car moves to the left on level horizontal ground, steadily slowing down with constant acceleration. In the boxes provided draw arrows showing the directions of the car's velocity $\vec{v}$, its change of velocity $\Delta\vec{v}$ and its acceleration $\vec{a}$. Explain your choice of directions briefly.



The velocity direction points in the direction of the car's movement, which is to the left. Since the car is slowing down, the magnitude of the velocity would be diminishing but the car would still be moving to the left. This means that the change of velocity vector must point to the right, as it is the difference between the new velocity (which is smaller) and the older one (which is larger). As for acceleration, it would match the direction of change of velocity, since the definition of a constant acceleration is the change of velocity divided by time, which is a positive scalar that wouldn't change the direction of change of velocity.

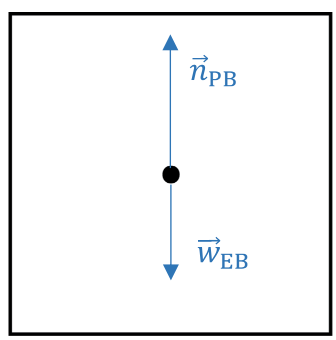
Rubric:
3 pts 1 for drawing each vector correctly.
1 pt for a correct explanation of the direction of velocity.
2 pts for a correct explanation of the direction of change of velocity
1 pt for a correct explanation of the direction of acceleration.

A block of mass m is placed on a platform as shown at right. The platform is at rest for times before $t = t_0$. From time $t = t_0$ until $t = t_1$ the platform moves upward with increasing speed. The block does not move relative to the platform.



24. [6 pts] Draw a qualitatively accurate free body diagram for the block at some instant between t_0 and t_1 in the space provided. Make sure that the label for each force in your free-body diagram contains the following information:

- the object exerting the force
- the object on which the force is exerted
- the type of force (normal, gravitational, *etc.*)



Rubric:

1 pt for drawing an arrow correctly representing the normal force

1 pt for labeling the normal force correctly

1 pt for drawing an arrow correctly representing the weight force

1 pt for labeling the weight force correctly

2 pt for ensuring that the normal force is greater in length than the weight force.

25. [7 pts] For each force on your free-body diagram, identify the corresponding action-reaction (3^{rd} law) pair force. *Describe the forces with words, not only with subscripts.*

Solution:

The first is normal force by the platform on the block $\vec{n}_{\mathrm{PB}}$ paired with the normal force by the block on the platform $\vec{n}_{\mathrm{BP}}$. The second pair is the weight force by Earth on the block $\vec{w}_{\mathrm{EB}}$ paired with the weight force by the block on Earth $\vec{w}_{\mathrm{BE}}$.

Rubric:

3 pts for specifying the first pair involving normal forces and labeling them correctly.

3 pts for specifying the second pair involving weight forces and labeling them correctly.

1 pt bonus

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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	$f = \frac{1}{T} = \frac{v}{2\pi r}$

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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	$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = Fv$