General Instructions: For each question or problem that requires a calculation, you must show a complete solution, including starting equations and intermediate steps (enough to follow your solution method). Put a box around any final numerical answers. For questions requiring a written answer, write in complete sentences. Write legibly or risk not having it graded.

Part 1 - Short Questions. Do the 5 short questions. Worth 8 points each.

1) A rocket moves with a constant acceleration of 6.0 m/s². Its initial velocity is 1.0 km/s and it travels a total distance of 2.0 x 10⁴ km. What is the rocket’s velocity when it has traveled this distance?

\[ V^2 = V_0^2 + 2a(x-x_0) \]

\[ V = \sqrt{(10 \times 10^3 \text{ km/s})^2 + 2(6.0 \text{ m/s}^2)(2.0 \times 10^4 \text{ m})} \]

\[ = 4.9 \times 10^3 \text{ km/s} \]

2) A speed is given as 2.0 inches per millisecond. Using only prefixes and constants given on the equation sheet, convert this to meters per second.

\[ \frac{2.0 \text{ inches}}{\text{millisecond}} = \frac{2.54 \text{ cm}}{\text{in}} \cdot \frac{10^{-2} \text{ m}}{\text{cm}} \cdot \frac{\text{m}}{10^{-3} \text{ m/s}} = 50.8 \text{ m/s} \]

3) If \( \vec{A}, \vec{B}, \) and \( \vec{C} \) are vectors with \( \vec{C} = \vec{A} + \vec{B} \) and also \( C^2 = A^2 + B^2 \) how are \( \vec{A} \) and \( \vec{B} \) oriented with respect to each other? Explain.

\( \vec{A} \) is perpendicular to \( \vec{B} \).

If \( C^2 = A^2 + B^2 \), the 3 vectors form a right triangle.
4) A person walks in a straight line with a speed of 3.0 m/s for 200 s, then drops to 2.0 m/s for an additional 100 s. What is this person’s average speed for the entire 300 s interval?

\[ \text{Total } \Delta x = \frac{3.0}{3} \cdot 200 \text{s} + 2.0 \frac{\text{m}}{\text{s}} \cdot 100 \text{s} = 600 \text{m} + 200 \text{m} = 800 \text{m} \]

\[ V_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{800 \text{m}}{300 \text{s}} = 2.7 \text{ m/s} \]

5) The plots below show “something” vs time for one dimensional motion. The “something” could be position, velocity, or acceleration. Use the letters indicating each plot to answer the following questions.

(A) (B) (C) (D) (E) (F)

A + B a) Which plot(s) would represent velocity vs time for a constant non-zero acceleration?
C + D b) Which plot(s) would represent position vs time for a constant non-zero acceleration?
F c) Which plot(s) would represent acceleration vs time for a constant negative acceleration?
A d) Which plot(s) would represent velocity vs time for a ball thrown straight upwards, assuming ‘up’ is positive and no air resistance acts?
A + D e) Which plot(s) would represent position vs time for zero acceleration but non-zero velocity?
Part 2 - Longer Problems. Do the 3 problems. Worth 20 points each.

1) A crate of mass $M$ is on an inclined plane which makes an angle $\theta$ with the horizontal, as shown. A force $\mathbf{F}_{app}$ is exerted on the crate parallel to the incline. It is large enough that the box accelerates up the incline. No friction acts.

a) Draw a free body diagram, showing and labeling all the forces that act on the crate. Indicate a suitable coordinate system.

b) Use the diagram and coordinate system that you’ve selected to write Newton’s second law in component form.

c) Find an expression for the acceleration of the crate.
2) Vector \( \vec{A} \) is given by \( \vec{A} = 4.0 \, \text{m} \hat{i} - 2.0 \, \text{m} \hat{j} \). Vector \( \vec{B} \) is given by \( 3.0 \, \text{m} \hat{i} + 5.0 \, \text{m} \hat{j} \).

a) What is \( \vec{B} - \vec{A} \) in unit vector form (component form)?

b) What are the magnitude and direction of \( \vec{B} - \vec{A} \)?

c) If vector \( \vec{C} \) is added to \( \vec{B} - \vec{A} \) such that the total is zero (that is \( \vec{C} + (\vec{B} - \vec{A}) = \vec{0} \)) What is \( \vec{C} \)?

You may give \( \vec{C} \) in either unit vector or magnitude and direction form.
3) A stone is projected at a cliff of height \( h \) with an initial speed of 42.0 m/s at an angle of 60.0° above the horizontal. It strikes at point A, 5.50 s after launching.

a) Find the height of the cliff, \( h \).

b) Find the speed of the stone just before it hits point A.

c) Find the maximum height \( H \) that the stone reaches above the ground.

\[
y = y_0 + v_{0y}t - \frac{1}{2}gt^2
\]

\[
v_{0y} = v_0 \cos \theta = 42.0 \text{ m/s} \sin 60° = \frac{36.4 \text{ m/s}}{3}
\]

\[
y_0 = 0
\]

\[
y = 0 + 36.4 \text{ m/s} (5.5 \text{ s}) - \frac{1}{2} (9.8 \text{ m/s}^2) (5.5 \text{ s})^2
\]

\[
y = 200 \text{ m} - 148 \text{ m}
\]

\[
y = 51.8 \text{ m}
\]

b) \( v_x = v_{0x} = 42.0 \text{ m/s} \cos 60° = 21.0 \text{ m/s} \)

\[
v_{y} = v_{0y} - gt = 36.4 \text{ m/s} - 9.8 \text{ m/s}^2 \times 5.5 \text{ s} = -17.5 \text{ m/s}
\]

\[
V = \sqrt{(21.0 - 1.1)^2 + (-17.5 - 1.1)^2} = 27.3 \text{ m/s}
\]

c) \( a + H, \) \( v_y = 0 \) so \( v_y = v_{0y} - gt \) \( \rightarrow 0 = \frac{36.4 \text{ m/s}}{9.8 \text{ m/s}^2} \times 3.71 \text{ s} \at \ H
\]

\[
y = y_0 + v_{0y}t - \frac{1}{2}gt^2
\]

\[
H = 0 + \frac{36.4 \text{ m/s}}{3} \times 3.71 \text{ s} - \frac{1}{2} (4.8 \text{ m/s}^2) (3.71 \text{ s})^2
\]

\[
H = 67.4 \text{ m}
\]
Physics 201-01 Exam #1b  29 September 2004  Name__**KEY**__

**General Instructions:** For each question or problem that requires a calculation, you must show a complete solution, including starting equations and intermediate steps (enough to follow your solution method). Put a box around any final numerical answers. For questions requiring a written answer, write in complete sentences. Write legibly or risk not having it graded.

**Part 1 - Short Questions.** Do the 5 short questions. Worth 8 points each.

1) If \( \vec{A}, \vec{B}, \) and \( \vec{C} \) are vectors with \( \vec{C} = \vec{A} + \vec{B} \) and also \( C = A + B \) how are \( \vec{A} \) and \( \vec{B} \) oriented with respect to each other? Explain.

\[ \vec{A} \quad \vec{B} \quad \vec{C} \] are pointing in the same direction, as shown.

in the head to tail sketch.

2) A person walks in a straight line with a speed of 4.0 m/s for 300 s, then drops to 3.0 m/s for an additional 200 s. What is this person's average speed for the entire 500 s interval?

\[ v_{avg} = \frac{\Delta x}{\Delta t} = \frac{4.0 \text{ m/s} \times 300 \text{ s} + 3.0 \text{ m/s} \times 200 \text{ s}}{500 \text{ s}} = \frac{1200 + 600}{500} \text{ m/s} = 3.6 \text{ m/s} \]

3) A rocket moves with a constant acceleration of 5.0 m/s\(^2\). Its initial velocity is 2.0 km/s and it travels a total distance of 3.0 x 10\(^5\) km. What is the rocket's velocity when it has traveled this distance?

\[ v^2 = v_i^2 + 2a(x - x_0) \]

\[ v = \sqrt{(2.0 \times 10^3 \text{ m/s})^2 + 2(5.0 \text{ m/s}^2)(3.0 \times 10^8 \text{ m})} \]

\[ = 54.8 \text{ km/s} \]
4) A speed is given as 4.0 inches per millisecond. Using only prefixes and constants given on the equation sheet, convert this to meters per second.

\[
\frac{4.0 \text{ in}}{\text{millisecond}} \times \frac{2.54 \text{ cm}}{\text{in}} \times \frac{10^{-2} \text{ m}}{1 \text{ cm}} \times \frac{10^{-3} \text{ m}}{1 \text{ cm}} = 102 \text{ m/s}
\]

5) The plots below show "something" vs time for one dimensional motion. The "something" could be position, velocity, or acceleration. Use the letters indicating each plot to answer the following questions.

(A) \hspace{1cm} (B) \hspace{1cm} (C) \hspace{1cm} (D) \hspace{1cm} (E) \hspace{1cm} (F)

\[\text{(A) \hspace{1cm} (B) \hspace{1cm} (C) \hspace{1cm} (D) \hspace{1cm} (E) \hspace{1cm} (F)}\]

\[\text{a) Which plot(s) would represent position vs time for a constant non-zero acceleration?}\]

\[\text{b) Which plot(s) would represent acceleration vs time for a constant negative acceleration?}\]

\[\text{c) Which plot(s) would represent velocity vs time for a constant non-zero acceleration?}\]

\[\text{d) Which plot(s) would represent position vs time for zero acceleration but non-zero velocity?}\]

\[\text{e) Which plot(s) would represent velocity vs time for a ball thrown straight upwards, assuming ‘up’ is positive and no air resistance acts?}\]
Part 2 - Longer Problems. Do the 3 problems. Worth 20 points each.

1) Vector \( \vec{A} \) is given by \( \vec{A} = 6.0 \text{ m} \hat{i} - 3.0 \text{ m} \hat{j} \). Vector \( \vec{B} \) is given by \( 4.0 \text{ m} \hat{i} + 7.0 \text{ m} \hat{j} \).

a) What is \( \vec{B} - \vec{A} \) in unit vector form (component form)?

b) What are the magnitude and direction of \( \vec{B} - \vec{A} \)?

c) If vector \( \vec{C} \) is added to \( \vec{B} - \vec{A} \) such that the total is zero (that is \( \vec{C} + (\vec{B} - \vec{A}) = \vec{0} \)) What is \( \vec{C} \)? You may give \( \vec{C} \) in either unit vector or magnitude and direction form.

\[
\begin{align*}
\text{a)} \quad \vec{B} - \vec{A} &= 4.0 \text{ m} \hat{i} + 7.0 \text{ m} \hat{j} - (6.0 \text{ m} \hat{i} - 3.0 \text{ m} \hat{j}) \\
&= (2.0 \text{ m} \hat{i} + 10.0 \text{ m} \hat{j}) \\
\end{align*}
\]

\[
\begin{align*}
\text{b)} \quad \text{m.} \vec{C} &= \sqrt{(-2.0)^2 + (10.0)^2} \\
&= 10.2 \text{ m} \\
\theta &= \tan^{-1}\left(\frac{10.0}{-2.0}\right) = -78.7^\circ + 180^\circ = 101^\circ \\
\end{align*}
\]

\[
\begin{align*}
\text{c)} \quad \vec{C} &= - (\vec{B} - \vec{A}) \\
&= (-2.0 \text{ m} \hat{i} - 10.0 \text{ m} \hat{j}) \\
\end{align*}
\]

or \( 10.2 \text{ m} \hat{A} - 79^\circ \)
2) A stone is projected at a cliff of height \( h \) with an initial speed of 54.0 m/s at an angle of 50.0° above the horizontal. It strikes at point A, 4.50 s after launching.

a) Find the height of the cliff, \( h \).

b) Find the speed of the stone just before it hits point A.

c) Find the maximum height \( H \) that the stone reaches above the ground.

\[ y = y_0 + v_{0y} t - \frac{1}{2} g t^2 \]

\[ v_{0y} = v_0 \sin \theta_0 = 54.0 \cdot \frac{1}{3} \sin 50° = 41.4 m/s \]

\[ y = 0 + (41.4m/s)(4.50s) - \frac{1}{2} (9.8 m/s^2)(4.50 s)^2 \]

\[ y = 186.3 m - 99.2 m \]

\[ h = 87.1 m \]

\[ v = \sqrt{v_x^2 + v_y^2} \]

\[ v_x = v_m \cos 50° = 34.7 m/s \]

\[ v_y = v_{0y} - gt = 41.4 m/s - 9.8 m/s^2(4.50 s) = -2.7 m/s \]

\[ v = \sqrt{(34.7 m/s)^2 + (-2.7 m/s)^2} = 34.8 m/s \]

\[ x = \text{max height} \]

\[ v_y^2 = v_{0y}^2 - 2g(H-h) \]

\[ H = \frac{v_{0y}^2}{2g} = \frac{(41.4 m/s)^2}{2(9.8 m/s^2)} = 87.4 m \]
3) A crate of mass $M$ is on an inclined plane which makes an angle $\theta$ with the horizontal, as shown. A force $\vec{F}_{\text{app}}$ is exerted on the crate parallel to the incline (to "help it get to the bottom faster"). No friction acts.

a) Draw a free body diagram, showing and labeling all the forces that act on the crate. Indicate a suitable coordinate system.

b) Use the diagram and coordinate system that you've selected to write Newton's second law in component form.

c) Find an expression for the acceleration of the crate.

\[
\begin{align*}
\overrightarrow{F}_N &= \text{normal force} \\
mg &= \text{weight} \\
\end{align*}
\]

\[
\begin{align*}
\Sigma F_x &= ma \\
F_{\text{app}} + mg \sin \theta &= ma \\
\Sigma F_y &= 0 \\
N - mg \cos \theta &= 0 \\
\end{align*}
\]

\[
\begin{align*}
\alpha &= \alpha_x \quad \alpha_y = 0 \\
ma &= F_{\text{app}} + mg \sin \theta \\
\end{align*}
\]

\[
\begin{align*}
\alpha &= \frac{F_{\text{app}}}{m} + g \sin \theta \\
\end{align*}
\]
Physics 201-01 Exam #1  29 September 2004

General Instructions: For each question or problem that requires a calculation, you must show a complete solution, including starting equations and intermediate steps (enough to follow your solution method). Put a box around any final numerical answers. For questions requiring a written answer, write in complete sentences. Write legibly or risk not having it graded.

Part 1 - Short Questions. Do the 5 short questions. Worth 8 points each.

1) A person walks in a straight line with a speed of 2.0 m/s for 600 s, then drops to 1.0 m/s for an additional 200 s. What is this person’s average speed for the entire 800 s interval?

\[
V_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{(2.0 \text{ m/s})(600 \text{ s}) + 1.0 \text{ m/s}(200 \text{ s})}{800 \text{ s}} = \frac{1200 \text{ m} + 200 \text{ m}}{800 \text{ s}}
\]

\[
V_{\text{avg}} = 1.75 \text{ m/s}
\]

2) A rocket moves with a constant acceleration of 7.0 m/s². Its initial velocity is 3.0 km/s and it travels a total distance of 1.0 x 10⁶ km. What is the rocket’s velocity when it has traveled this distance?

\[
v^2 = v_0^2 + 2a(x-x_0)
\]

\[
v = \sqrt{(3.0 \times 10^6 \text{ m/s})^2 + 2(7.0 \text{ m/s})(10^8 \text{ km})}
\]

\[
v = 37.5 \text{ km/s}
\]

3) A speed is given as 3.0 inches per millisecond. Using only prefixes and constants given on the equation sheet, convert this to meters per second.

\[
\frac{3.0 \text{ inches}}{\text{millisecond}} \cdot \frac{2.54 \text{ cm}}{\text{inch}} \cdot \frac{10^{-2}}{\text{cm}} \cdot \frac{\text{m}}{10^{-3}} = 76.2 \text{ m/s}
\]
4) If \( \vec{A}, \vec{B}, \) and \( \vec{C} \) are vectors with \( \vec{C} = \vec{A} + \vec{B} \) and also \( \vec{C} = \vec{A} \cdot \vec{B} \) how are \( \vec{A} \) and \( \vec{B} \) oriented with respect to each other? Explain.

\[
\begin{align*}
\vec{A} & \quad \vec{B} \\
\text{point in opposite directions, as can be seen by the head-to-tail addition diagram.}
\end{align*}
\]

5) The plots below show “something” vs time for one dimensional motion. The “something” could be position, velocity, or acceleration. Use the letters indicating each plot to answer the following questions.

\[\text{A} \quad \text{B} \quad \text{C} \quad \text{D} \quad \text{E} \quad \text{F}\]

\[\begin{align*}
\text{A} & \quad \text{B} & \quad \text{C} & \quad \text{D} & \quad \text{E} & \quad \text{F} \\
\text{a) Which plot(s) would represent velocity vs time for a constant non-zero acceleration?} \\
\text{b) Which plot(s) would represent position vs time for a constant non-zero acceleration?} \\
\text{c) Which plot(s) would represent acceleration vs time for a constant negative acceleration?} \\
\text{d) Which plot(s) would represent velocity vs time for a ball thrown straight upwards, assuming ‘up’ is positive and no air resistance acts?} \\
\text{e) Which plot(s) would represent position vs time for zero acceleration but non-zero velocity?}
\end{align*}\]
Part 2 - Longer Problems. Do the 3 problems. Worth 20 points each.

1) A stone is projected at a cliff of height \( h \) with an initial speed of 35.0 m/s at an angle of 70.0° above the horizontal. It strikes at point A, 5.20 s after launching.

a) Find the height of the cliff, \( h \).

b) Find the speed of the stone just before it hits point A.

c) Find the maximum height \( H \) that the stone reaches above the ground.

\[
\begin{align*}
\text{a)} & \quad y = y_0 + V_{0y} t - \frac{1}{2} g t^2 \\
& \quad V_{0y} = V_0 \sin \theta_0 = 35.0 \text{ m/s} \sin 70° \\
& \quad = 32.9 \text{ m/s}
\end{align*}
\]

\[
y = h = 0 + 32.9 \text{ m/s} \cdot 5.20 \text{ s} - \frac{1}{2} (9.8 \text{ m/s}^2) (5.20 \text{ s})^2
\]

\[
h = 17 \text{ m} - 132 \text{ m} = 39 \text{ m}
\]

\[
\text{b)} \quad V_x = V_{0x} = V_0 \cos \theta_0 = 35.0 \text{ m/s} \cos 70° = 12.0 \text{ m/s}
\]

\[
V_y = V_{0y} - g t = 32.9 \text{ m/s} - 9.8 \text{ m/s}^2 \cdot 5.20 \text{ s} = -18 \text{ m/s}
\]

\[
V = \sqrt{V_x^2 + V_y^2} = \sqrt{(12.0 \text{ m/s})^2 + (-18 \text{ m/s})^2} = 21.7 \text{ m/s}
\]

\[
\text{c)} \quad \text{At } y = H, \quad V_y = 0
\]

\[
V_y^2 = V_{y0}^2 - 2 g (H - h)
\]

\[
l = \frac{V_y^2}{2 g} = \frac{(32.9 \text{ m/s})^2}{2 (9.8 \text{ m/s}^2)} = 55.2 \text{ m}
\]
2) A crate of mass $M$ is on an inclined plane which makes an angle $\theta$ with the horizontal, as shown. A force $F_{\text{app}}$ is exerted on the crate parallel to the incline. It has a large enough to cause the crate to accelerate up the incline. No friction acts.

a) Draw a free body diagram, showing and labeling all the forces that act on the crate. Indicate a suitable coordinate system.

b) Use the diagram and coordinate system that you've selected to write Newton's second law in component form.

c) Find an expression for the acceleration of the crate.

\[ \begin{align*}
\sum F_x &= m a_x \\
F_{\text{app}} - m g \sin \theta &= m a_x
\end{align*} \]

\[ \begin{align*}
\sum F_y &= m a_y \\
N - m g \cos \theta &= m a_y
\end{align*} \]

\[ a_x = \frac{F_{\text{app}}}{m} - g \sin \theta \]
3) Vector $\vec{A}$ is given by $\vec{A} = 5.0 \text{ m } \hat{i} - 6.0 \text{ m } \hat{j}$. Vector $\vec{B}$ is given by $4.0 \text{ m } \hat{i} + 2.0 \text{ m } \hat{j}$.

a) What is $\vec{B} - \vec{A}$ in unit vector form (component form)?

b) What are the magnitude and direction of $\vec{B} - \vec{A}$?

c) If vector $\vec{C}$ is added to $\vec{B} - \vec{A}$ such that the total is zero (that is $\vec{C} + (\vec{B} - \vec{A}) = 0$) What is $\vec{C}$?

You may give $\vec{C}$ in either unit vector or magnitude and direction form.

$$\vec{B} - \vec{A} = (4.0 \text{ m } \hat{i} + 2.0 \text{ m } \hat{j}) - (5.0 \text{ m } \hat{i} - 6.0 \text{ m } \hat{j})$$

$$= -1.0 \text{ m } \hat{i} + 8.0 \text{ m } \hat{j}$$

$$|\vec{B} - \vec{A}| = \sqrt{(-1.0)^2 + (8.0)^2} = 8.1 \text{ m}$$

$$\theta = \tan^{-1} \left( \frac{8.0}{-1.0} \right) = -83^\circ + 180^\circ = 97^\circ$$

$$\vec{C} = - (\vec{B} - \vec{A})$$

$$\vec{C} = +1.0 \text{ m } \hat{i} - 8.0 \text{ m } \hat{j}$$

or

$$\vec{C} = 8.1 \text{ m } \hat{j} - 83^\circ$$