USEFUL INFORMATION

If \( f(x) = kx^n \), then \( \frac{df}{dx} = nkx^{n-1} \)

If \( f(x) = kx^n \), then \( \int f(x)dx = \frac{1}{n+1}kx^{n+1} + C \)

For the SPECIAL CASE:
CONSTANT ACCELERATION IN ONE DIMENSION

\[
x(t) = \frac{1}{2}a_0 t^2 + v(0)t + x(0).
\]

Do Not Spend Too Much Time on Algebra!
1. (25 points) A motorcycle policeman spots a speeding car when it is a distance $D$ away. At that instant the motorcycle is at rest and the car is approaching with a velocity of magnitude $v_1$. At that instant the motorcycle starts towards the car with a constant, unknown, acceleration, $a_2$, while the car reverses its electric engine so that it has a constant acceleration directed opposite to its initial velocity. The magnitude of this acceleration is $a_1$.

\[ \text{\includegraphics[width=0.5\textwidth]{motorcycle_and_car.png}} \]

a. Find the position of the car at the instant when it reverses its direction.

b. If the policeman catches up to the car a time $T_c$ after spotting it, what was the motorcycle's acceleration?
2. (25 points) A small block of mass $m_1$ is placed on top of a large mass, $m_2$. There is no friction between the blocks. They are pushed against a wall by a constant force of magnitude $P$ directed as shown.

\[ \begin{array}{c}
\text{m}_1 \\
\text{m}_2
\end{array} \]

Assume the blocks remain at rest and that the wall is frictionless.

a. Isolate each of the blocks and draw the free body diagrams for them.

b. If $\theta$, $m_1$ and $m_2$ are known, what does $P$ have to be in order for the blocks to remain at rest? In that case what is the force exerted by the wall on each of the blocks?

c. Suppose $P$ were such that the blocks were accelerating up the wall and there was a coefficient of friction $\mu$ between the blocks and the wall. Draw the free body diagrams for each of the blocks in this case.
3. (25 points) An object of mass $m$ can only move along a line which is defined to be the x axis. It has only two horizontal forces acting on it as shown below:

One of the forces has the constant magnitude $F_0$. The other force, indicated on the diagram, is unknown. The position of the object is observed to be a function of time given by

$$x(t) = \alpha t^4$$

where $\alpha$ is a known constant. Determine the unknown force.
4. (25 points) A terrorist is climbing a wall. She starts from rest and accelerates with acceleration $\alpha t$ where $\alpha$ is a known constant. A security guard is sitting on top of a building with height $H$ a distance $D$ away. He spots the terrorist and in his excitement falls off the building. By flapping his arms wildly he is able to obtain a horizontal acceleration given by $\beta t$ where $\beta$ is a known constant. His vertical acceleration is unaffected and is just the usual with magnitude $g$.

![Diagram](image)

a. How long does it take the guard to travel the horizontal distance $D$?

b. Find the relationship that must hold between $\alpha, \beta, D, H,$ and $g$ in order for the guard to collide with the terrorist.