

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**  
**Department of Physics**

**Physics 8.01 TEAL**

**Fall Term 2004**

**Exam 1: Equation Summary**

**One Dimensional Kinematics:**

$$\vec{v} = d\vec{r} / dt, \quad \vec{a} = d\vec{v} / dt \qquad v_x(t) - v_{x,0} = \int_{t'=0}^{t'=t} a_x(t') dt' \qquad x(t) - x_0 = \int_{t'=0}^{t'=t} v_x(t') dt'$$

**Constant Acceleration:**

$$x(t) = x_0 + v_{x,0}(t - t_0) + \frac{1}{2} a_x (t - t_0)^2 \qquad v_x(t) = v_{x,0} + a_x (t - t_0)$$
$$y(t) = y_0 + v_{y,0}(t - t_0) + \frac{1}{2} a_y (t - t_0)^2 \qquad v_y(t) = v_{y,0} + a_y (t - t_0)$$

where  $x_0, v_{x,0}, y_0, v_{y,0}$  are the initial position and velocities components at  $t = t_0$

**Law of Addition of Velocities :**  $\vec{v}_{object, frame 1} = \vec{v}_{object, frame 2} + \vec{V}_{relative}$

**Newton's Second Law: Force, Mass, Acceleration**

$$\vec{F} \equiv m\vec{a} \quad \vec{F}^{total} = \vec{F}_1 + \vec{F}_2 \quad F_x^{total} = ma_x \quad F_y^{total} = ma_y \quad F_z^{total} = ma_z$$

**Newton's Third Law:**  $\vec{F}_{1,2} = -\vec{F}_{2,1}$

**Force Laws:**

Universal Law of Gravity:  $\vec{F}_{1,2} = -G \frac{m_1 m_2}{r_{1,2}^2} \hat{r}_{1,2}$ , attractive

Gravity near surface of earth:  $\vec{F}_{grav} = m_{grav} \vec{g}$ , towards earth

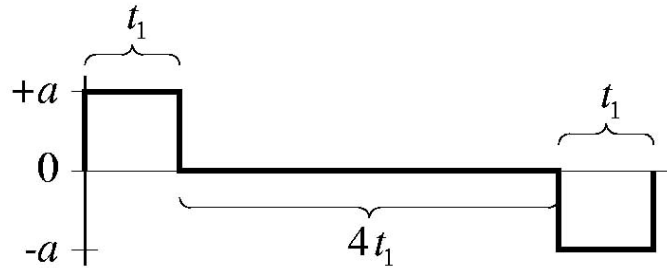
Contact force:  $\vec{F}_{contact} = \vec{N} + \vec{f}$ , depends on applied forces

Static Friction:  $0 \leq f_s \leq f_{s,max} = \mu_s N$  direction depends on applied forces

Kinetic Friction:  $f_k = \mu_k N$  opposes motion

Hooke's Law:  $F = k |\Delta x|$ , restoring

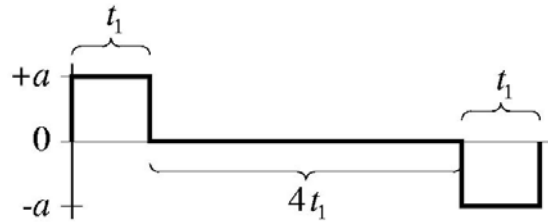
**Problem 4: (30 points)** A person of given mass  $m$  is standing on a scale in an elevator in Building 24. Initially the elevator is at rest. The elevator then begins to ascend to the sixth floor that is a given distance  $h$  above the starting point. The elevator undergoes an unknown constant acceleration  $a$  for a given time  $t_1$ . Then the elevator moves at a constant velocity for a time  $t_2 = 4t_1$ . Finally the elevator brakes with a deceleration of the same magnitude as the initial acceleration for a time  $t_3 = t_1$  until stopping at the sixth floor. Assume the gravitational constant is given as  $g$ . The goal of this problem is to find the magnitude of the acceleration and the readings on the scale.



- Briefly explain how you intend to model this problem.
- What is the magnitude of the acceleration and deceleration of the elevator? Express your answer in terms of the given quantities.
- When the elevator is accelerating upwards, what is the magnitude of the contact force between the person's feet and the scale?
- When the elevator is braking, what is the magnitude of the contact force between the person's feet and the scale?

**Answer:**

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**Answer:**

model: three stages of motion

stage (1): constant acceleration, starting from rest  
distance:  $y_1 = \frac{1}{2} a t_1^2$ ,  $v_1 = a t_1$

stage (2) constant velocity with  $v_0 = v_1 = a t_1$   
distance:  $y_2 = v t_2 = 4 a t_1^2$  since  $t_2 = 4 t_1$

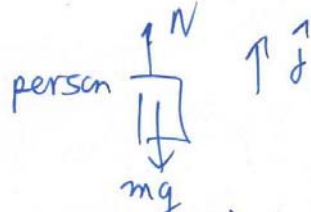
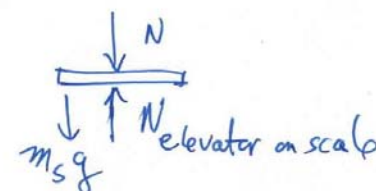
stage (3) constant deceleration with  $v_0 = v_1 = a t_1$   
distance:  $y_3 = v_1 t_3 - \frac{1}{2} a t_3^2 = v_1 t_1 - \frac{1}{2} a t_1^2 = a t_1^2 - \frac{1}{2} a t_1^2$

total distance:  $y^T = y_1 + y_2 + y_3$

$$h = \frac{1}{2} a t_1^2 + 4a t_1^2 + a t_1^2 - \frac{1}{2} a t_1^2 = 5a t_1^2$$

$$\Rightarrow a = \frac{h}{5t_1^2}$$

The scale indicates normal force  $N$

person  scale 

$\uparrow$   $\vec{F}$   $m\vec{a}$

$$N - mg = ma \Rightarrow N = mg + ma$$

stage (1)  $N = m(g + \frac{h}{5t_1^2}) > mg$  goes up (increases)

stage (2)  $N = mg$  doesn't change

stage (3)  $N = m(g - \frac{h}{5t_1^2}) < mg$  goes down (decreases)