STAEDTLER® No. 937 811E Engineer's Computation Pad

84 *Pancake collapse of a tall building.* In the section of a tall building shown in Fig. 9-77*a*, the infrastructure of any given floor K must support the weight W of all higher floors. Normally the infrastructure is constructed with a safety factor s so that it can withstand an even greater downward force of sW. If, however, the support columns between K and L suddenly collapse and allow the higher floors to free-fall together onto floor K (Fig. 9-77*b*), the force in the collision can exceed sW and, after a brief pause, cause K to collapse onto floor J, which collapses on floor I, and so on until the ground is reached. Assume that the floors are separated by $d = 4.0$ m and have the same mass. Also assume that when the floors above K free-fall onto K, the collision lasts 1.5 ms. Under these simplified conditions, what value must the safety factor s exceed to prevent pancake collapse of the building?

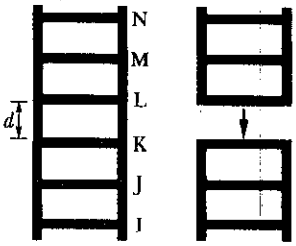


FIG. 9-77 Problem 84.

ASSUME THERE ARE N FLOORS AND CONSIDER THE i^{th} FLOOR — THERE ARE $(N-i)$ FLOORS ABOVE IT.

m = mass of a floor

$\Rightarrow$ THE I^{th} FLOOR SUPPORTS THE WEIGHT:

$W_I = (N-i)mg$.

IF THESE FLOORS COLLAPSE DOWN ONTO THE I^{th} FLOOR

THEN THEIR CENTER OF MASS FALLS 4 meters

$\Delta E_{mec\ of\ (N-i)\ FLOORS} = \Delta K + \Delta U = 0$

$\Rightarrow \Delta K = -\Delta U \Rightarrow \frac{1}{2}M v_f^2 - \frac{1}{2}M 0^2 = -(Mgy_f - Mgy_i)$

$\frac{1}{2}(N-i)m v_f^2 = (N-i)mg\,[(y_i - y_f) = 4m]$

$v_f = \sqrt{8g} \Rightarrow \vec{P}_{upper\ (N-i)\ FLOORS} = (N-i)m\left(v = \sqrt{8g}\right)\hat{down}$

$\vec{J}_{to\ lower\ i\ floors} = \Delta\vec{P}_{lower\ floors}$ = that GAINED FROM THE UPPER FLOORS FALLING ON THEM

$= (N-i)m\sqrt{8g}\,\hat{down}$

$= \vec{F}_{AVG\ on\ lower\ Floors}\,\Delta t_{collision}^{of} = (N-i)m\sqrt{8g}\,\hat{down}$

$\Rightarrow \vec{F}_{impulse\ on\ lower\ i\ floors} = \left\{\frac{(N-i)m\sqrt{8g}}{\Delta t = 1.5\times10^{-3}\,s} = \frac{4000(N-i)m\sqrt{2g}}{3}\right\}\hat{d}$

SAFETY FACTOR $= S = F/W_I = \frac{4000}{3}\sqrt{\frac{2}{g}} = 602$