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

••41 In the Olympiad of 708 B.C., some athletes competing in the standing long jump used handheld weights called *halteres* to lengthen their jumps (Fig. 9-57). The weights were swung up in front just before liftoff and then swung down and thrown backward during the flight. Suppose a modern 78 kg long jumper similarly uses two 5.50 kg halteres, throwing them horizontally to the rear at his maximum height such that their horizontal velocity is zero relative to the ground. Let his liftoff velocity be $\vec{v} = (9.5\hat{i} + 4.0\hat{j})$ m/s with or without the halteres, and assume that he lands at the liftoff level. What distance would the use of the halteres add to his range?

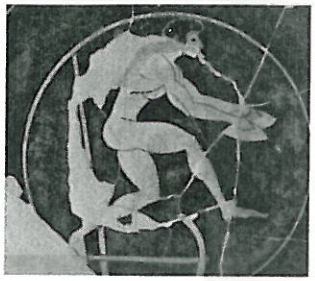
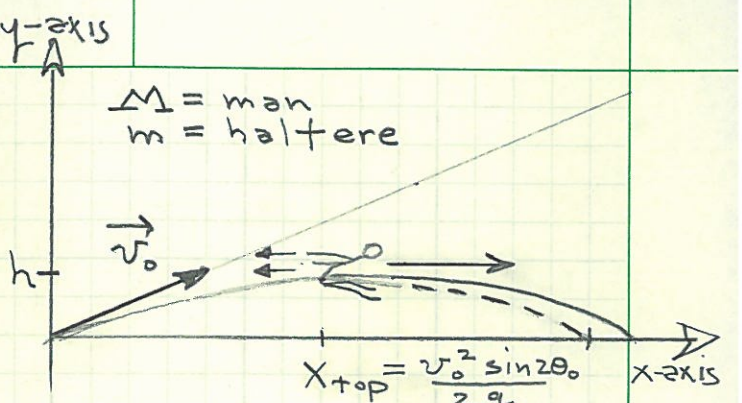


FIG. 9-57 Problem 41. *(Réunion des Musées Nationaux/Art Resource)*



THE FIRST HALF OF THE MOTION IS SIMPLE PROJECTILE MOTION

$v_y = v_{oy} - gt \Rightarrow t_{up} = \frac{v_{oy}}{g} = \frac{v_0 \sin\theta_0}{g}$

t_{up} = TIME TO GO UP $= 4/9.8 = 0.408$ s

$v_y^2 = v_{oy}^2 - 2g(y - y_0) \Rightarrow h = v_{oy}^2/2g = 4^2/2(9.8) = 0.816$ m HE RISES TO

$x_{top} = v_{ox} t_{up} = 9.5(0.408) = 3.88$ m HORIZONTAL DISTANCE AT TOP TRAJ

$= v_0 \cos\theta_0 (v_0 \sin\theta_0 / g) = v_0^2 \sin 2\theta_0 / 2g$

AT THE TOP OF THE TRAJECTORY - AT THAT MOMENT - APPLY CONSERVATION OF MOMENTUM: $\vec{P}_{total@TOP} = (M+2m) v_{ox} \hat{x}$

$\vec{P}_{initial}^{total} = \vec{P}_{final}^{total} \Rightarrow (M+2m) v_{ox} \hat{x} = (M v_{ox}' + 2m v_{hx}) \hat{x}$

WHERE v_{ox}' = NEW HORIZONTAL VELOCITY OF MAN

v_{hx} = HORIZONTAL VELOCITY OF A HALTERE $\equiv 0$

THEREFORE: $v_{ox}' = \frac{M+2m}{M} v_{ox} - \frac{2m}{M} v_{hx} = \left(1 + \frac{2m}{M}\right) v_{ox}$

THE TIME FOR HIM TO COME DOWN $= t_d = t_u =$ TIME TO GO UP

DURING THIS TIME HE TRAVELS HORIZONTALLY

$\Delta x = v_{ox}' t_{up} = \left(1 + \frac{2m}{M}\right) v_{ox} \frac{v_{oy}}{g} = \left(1 + \frac{2m}{M}\right) \frac{v_0^2 \cos\theta_0 \sin\theta_0}{g}$

$\Delta x = \left(1 + \frac{2m}{M}\right) \frac{v_0^2 \sin 2\theta_0}{2g} = \left(1 + \frac{2m}{M}\right) X_{top}$

THE EXTRA DISTANCE THE HALTERES ADD

$= \frac{2m}{M} X_{top} = \frac{m v_0^2 \sin 2\theta_0}{M g}$

$\frac{\text{EXTRA DISTANCE}}{X_{top}} = \frac{2m}{M} = \frac{2(5.5)}{78} = \frac{11}{78} \approx 0.14 = \frac{1}{7}$

EXTRA DISTANCE $= \frac{1}{7} 3.88$ m $= 0.55$ m

(THE DIAGRAM IS DRAWN TO SCALE!)