OPERATION LIFESAVER

PHYSICS TEACHER'S GUIDE: SOLUTIONS TO PROBLEMS (Page One of Two)

All problems are based on kinetic energy formulas and/or laws of momentum.

$KE = Fd$ $\quad KE = 1/2\ mv^2$ $\quad Momentum = m_1v_1 + m_2v_2$

Terms

d = Distance (ft) $\quad W_T$ = Weight of train (tons) $\quad v$ = velocity (mph)

F_b = braking force (lbs) $\quad t$ = time (sec)

Braking Force (F_b) is an average calculated from the weight of the car x braking ratio x efficiency of braking system x coefficient of friction of steel wheels on rail. Average values are 10,200 lbs for a freight car and 20,500 lbs for a passenger car. (THIS IS PER CAR)

Railroad specific formulas based on kinetic energy are:

$$d = \frac{70 \times W_T \times v^2}{F_b} \qquad t = \frac{95.6 \times W_T \times (v_i - v_f)}{F_b}$$

Constants

$\frac{70 \text{ lbs ft hr}^2}{\text{tons miles}^2}$ Derived from unit conversions mph to ft/sec and tons to lbs.

$\frac{95.6 \text{ lb hr sec}}{\text{ton miles}}$ Derived from unit conversions similar to proceeding constant.

To convert mph to ft/sec, multiply mph x 1.46

ANSWERS

1. (a) $d = 70 \times W_T \times v^2 / F_b$

$d = 70 \times 15{,}000$ tons $\times (50 \text{ mph})^2 / 500$ tons $\times$ 2000 lbs/ton

$d = 2625$ ft.

Distance traveled before brakes apply = v(ft/sec) x time (sec)

$d = 73$ ft/sec x 15 sec = 1095 ft

Total distance = 2625 ft + 1095 ft = 3720 ft

(b) $t = 95.6 \times W_T \times v / F_b$

$t = 95.6 \times 15{,}000$ tons x 50 mph / 500 tons x 2000 lbs/ton

$t = 71.7$ sec $\qquad$ Total time = 71.7 sec + 15 sec =86.7 sec

2. Rearranging distance formula $F_b = 70 \times W_T \times v^2 / d$

$F_b = 70 \times 650$ tons $\times (79 \text{ mph})^2 / 1300$ ft = 218,435 lbs

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3. W_T = 50 x 80 tons + 20 x 30 tons + 3 x 200 tons = 5200 tons

   $d = 70 \times W_T \ X \ v^2 / F_b$

   d = 70 x 5200 tons x $(60 \text{ mph})^2$ / 70 cars x 10,200 lbs = 1836 ft

   Distance before brakes apply = 18 sec x 88 ft/sec = 1584 ft

   Total distance = 1836 ft **+** 1584 ft = 3420 ft

4. $(v_f - v_i)^2 = 2\ a \times d$ $(182.5 - 0 \text{ ft/sec})^2 = 2\ a \times 5500$ ft

   a = -3.0 ft/sec^2

5. $m_1v_1 + m_2v_2 = m_{1A}v_{iA} + m_{2A}v_{2A}$

   30 tons x 2 ft/sec **+** 55 tons x 0 = 30 tons x v_{iA} **+** 55 tons x 1.2 ft/sec

   60 tons ft/sec - 66 tons ft/sec = 30 tons x v_{iA}

   - 6 tons ft/sec = 30 tons x v_{iA}

   - 0.2 ft/sec = V_{iA}