57. (a) With $P = 1.5\,\text{MW} = 1.5\times10^6\,\text{W}$ (assumed constant) and $t = 6.0\,\text{min} = 360\,\text{s}$, the work-kinetic energy theorem (along with Eq. 7-48) becomes

$$W = Pt = \Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right) \ .$$

The mass of the locomotive is then

$$m = \frac{2Pt}{v_f^2 - v_i^2} = \frac{(2)(1.5\times10^6\,\text{W})(360\,\text{s})}{(25\,\text{m/s})^2 - (10\,\text{m/s})^2} = 2.1\times10^6\,\text{kg}\,.$$

(b) With t arbitrary, we use $Pt = \frac{1}{2}m\left(v^2 - v_i^2\right)$ to solve for the speed $v = v(t)$ as a function of time and obtain

$$v(t) = \sqrt{v_i^2 + \frac{2Pt}{m}} = \sqrt{(10)^2 + \frac{(2)(1.5\times10^6)t}{2.1\times10^6}} = \sqrt{100 + 1.5t}$$

in SI units (v in m/s and t in s).

(c) Using Eq. 7-48, the force $F(t)$ as a function of time is

$$F(t) = \frac{P}{v(t)} = \frac{1.5\times10^6}{\sqrt{100+1.5t}}$$

in SI units (F in N and t in s).

(d) The distance d the train moved is given by

$$d = \int_0^t v(t')\,dt' = \int_0^{360}\left(100 + \frac{3}{2}t\right)^{\frac{1}{2}}\,dt = \frac{4}{9}\left(100 + \frac{3}{2}t\right)^{\frac{3}{2}}\Bigg|_0^{360}$$

which yields 6.7×10^3 m.