Answers to Exercises
Chapter 7

Exercise 7.1

(a) Using Eq. (7.16), $p_4/p_1 = 78$.

(b) Use Eq. (7.16) by trial and error to get $M_s = 1.316$ which is equivalent to $v_s = 434$ m s^{-1}. Use Eq. (7.14) to get shock strength $p_2/p_1 = 1.85$.

Exercise 7.2

(a) Use Eq. (7.11) to obtain $u_f = 549$ m s^{-1} for $p_4/p_1 = 78$; $u_f = 493$ m s^{-1} for $p_4/p_1 = 50$.

(b) Use Eq. (7.18). For $p_4/p_1 = 50$, $p_2/p_1 = 1.85$, and $c_1 = 330$ m s^{-1}, $\gamma_1 = 1.4$. $u_f = 152$ m s^{-1}.

(c) Use Eq. (7.13) to get $u_f = 537$ m s^{-1} for $p_4/p_1 = 78$; $u_f = 484$ m s^{-1} for $p_4/p_1 = 50$.

(d) The non-isothermal Woods solution produces slightly lower velocities than the isothermal case due to imperfect thermal coupling between the particle and gas phases. Better thermal coupling leads to greater/faster gas expansion.
The shock tube relations produce solutions that are different from the Woods solutions in part because the unsteady terms in the mass and momentum equations (d/dt) are ignored in their derivation. Furthermore, the shock tube relations do not explicitly account for the high temperature of the expanding mixture.

Exercise 7.3

From Eject!:

(a) 25 m reduced drag zone Initial velocity (m s^{-1})		**(b) 50 m reduced drag zone Initial velocity (m s^{-1})**
$C_d = 0.5$	$C_d = 0.1$	$C_d = 0.5$
228	151	227
1700	205	1700
214	157	213
900	202	900

Note that Eject! produces unrealistic values for the second and fourth clasts, for $C_d = 0.5$. These non-physical answers may suggest that these clasts (9 and 17 cm in diameter) were not truly ballistic. In other words, they may have had some significant interaction with the plume and expanding gases during the early stages of transport. Using Fagents and Wilson (1993), calculated launch velocities are < 100 m s^{-1}, which supports the idea that the blocks are small enough to be significantly accelerated by drag interactions with the expanding gases.

Exercise 7.4

(a) The best fit to the velocity–time data is $\sim t^{-1/2}$, so the eruption is driven by buoyancy and is classified as a thermal.

(b) Although the eruption does not look like a perfect thermal (a nearly spherical detached vortex ring, as in Figure 7.8), one can examine the video closely and note a few features that are consistent with thermals. For example, throughout its duration, the flow is dominated by large-scale circulation structures, similar to a spherical vortex, near the flow front. Also, at ~1:54 into the video, the flow appears to detach from the vent, and shortly thereafter the tail begins to be pulled into the center of the head vortex structure, while at the same time the leading vortex structure grows in diameter.