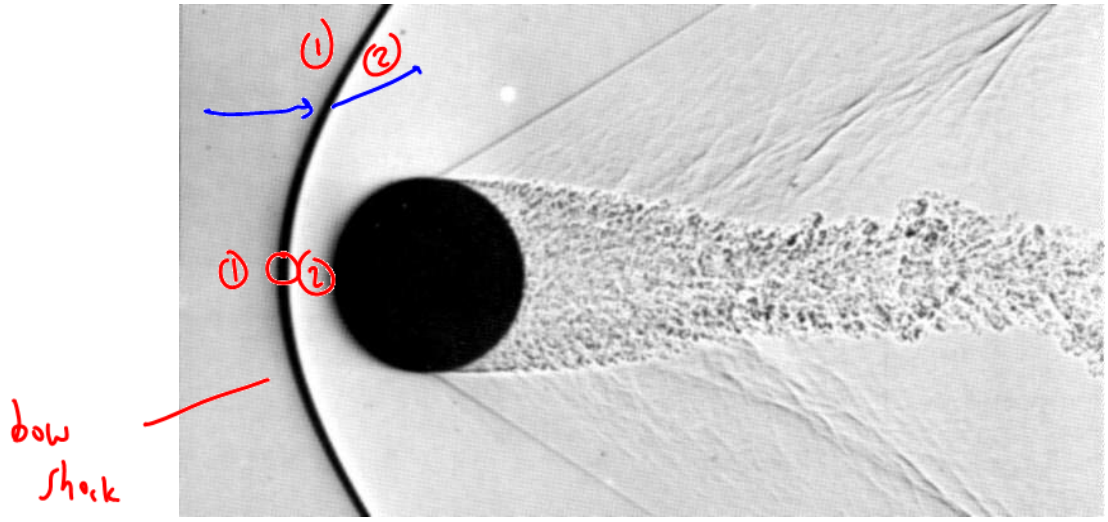
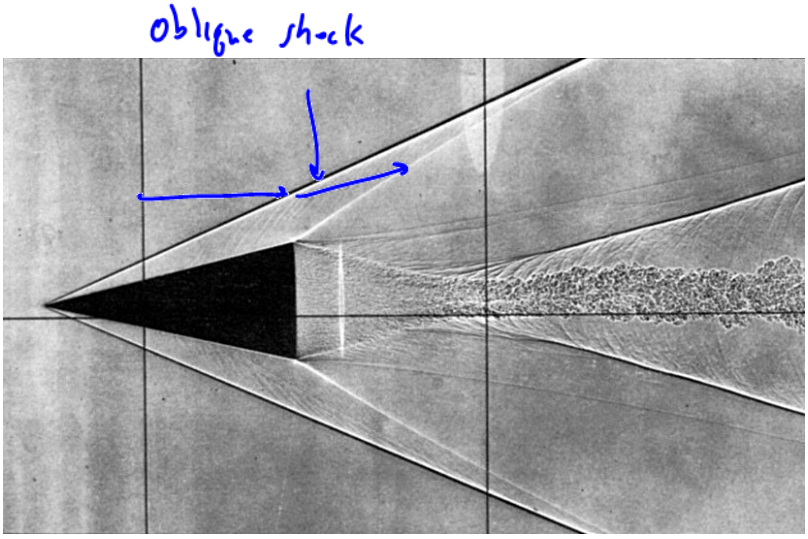
Today, we will:

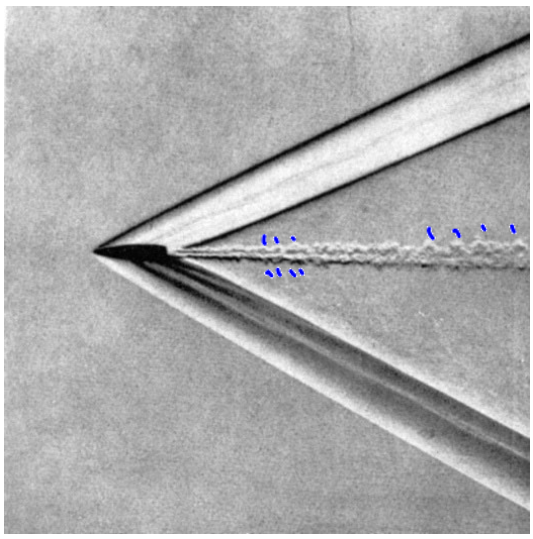
- Continue to ***qualitatively*** discuss the occurrence of normal shocks
- Discuss blast waves (moving spherical shocks)
- If time, begin to discuss equations for Pitot tubes: incompressible flow, subsonic compressible flow, and supersonic compressible flow
- Do Candy Questions for Candy Friday

Examples of normal shocks (continued)**:**

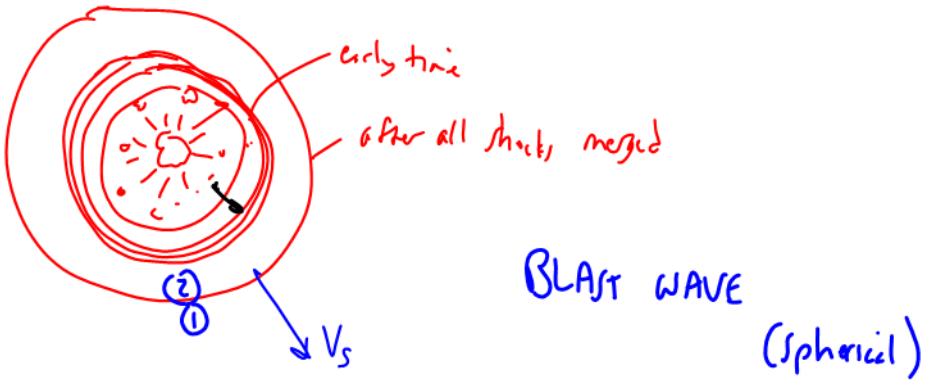
1) In a converging-diverging nozzle
2) In a shock tube
3) In front of a blunt object moving supersonically:



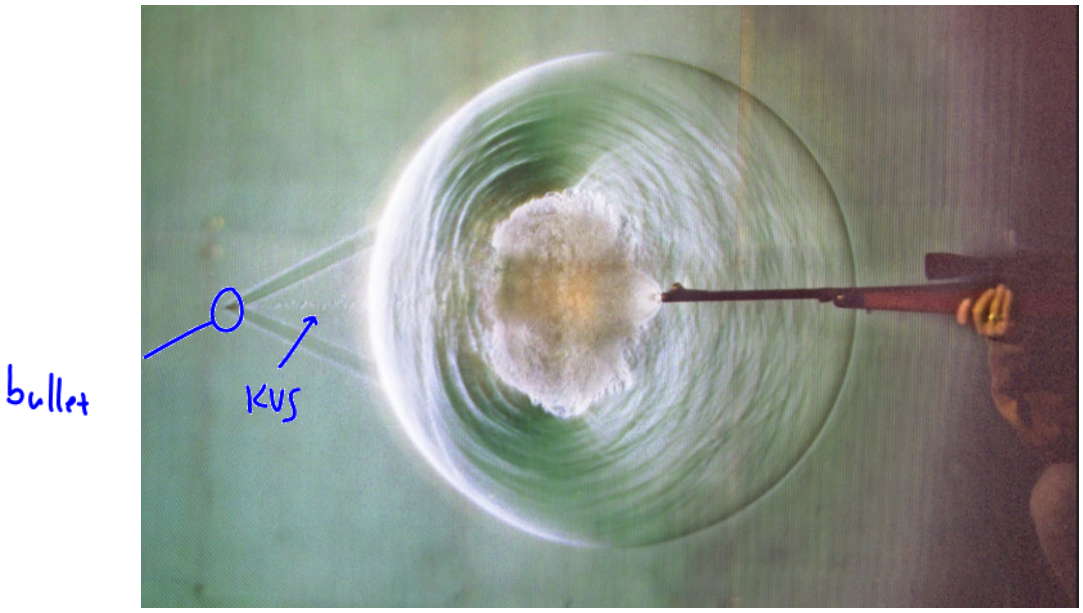




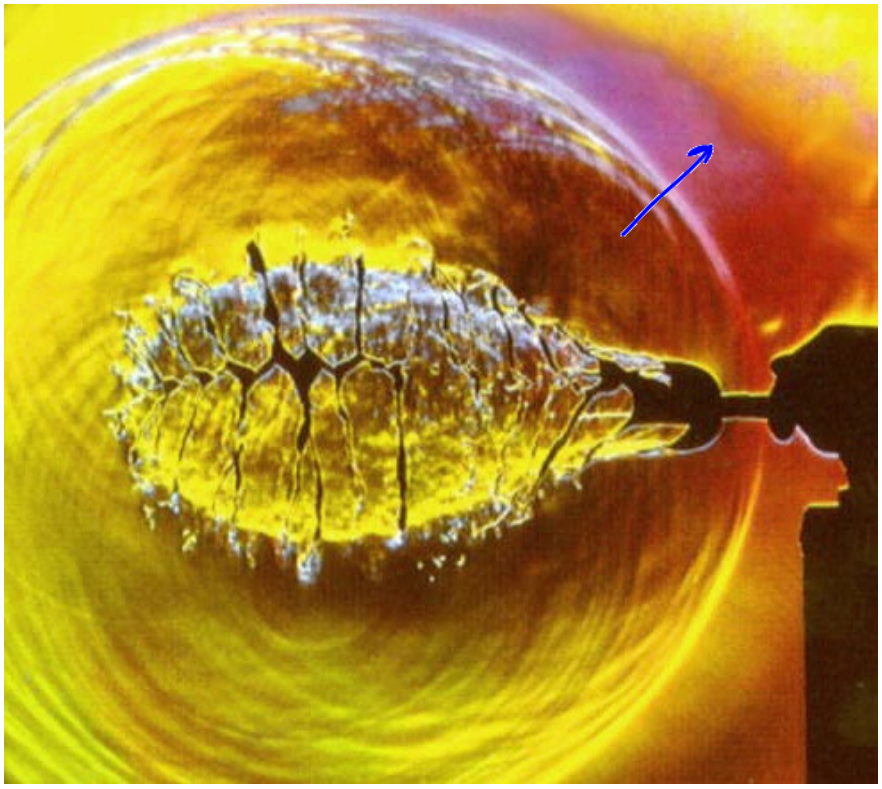
4) Explosions:



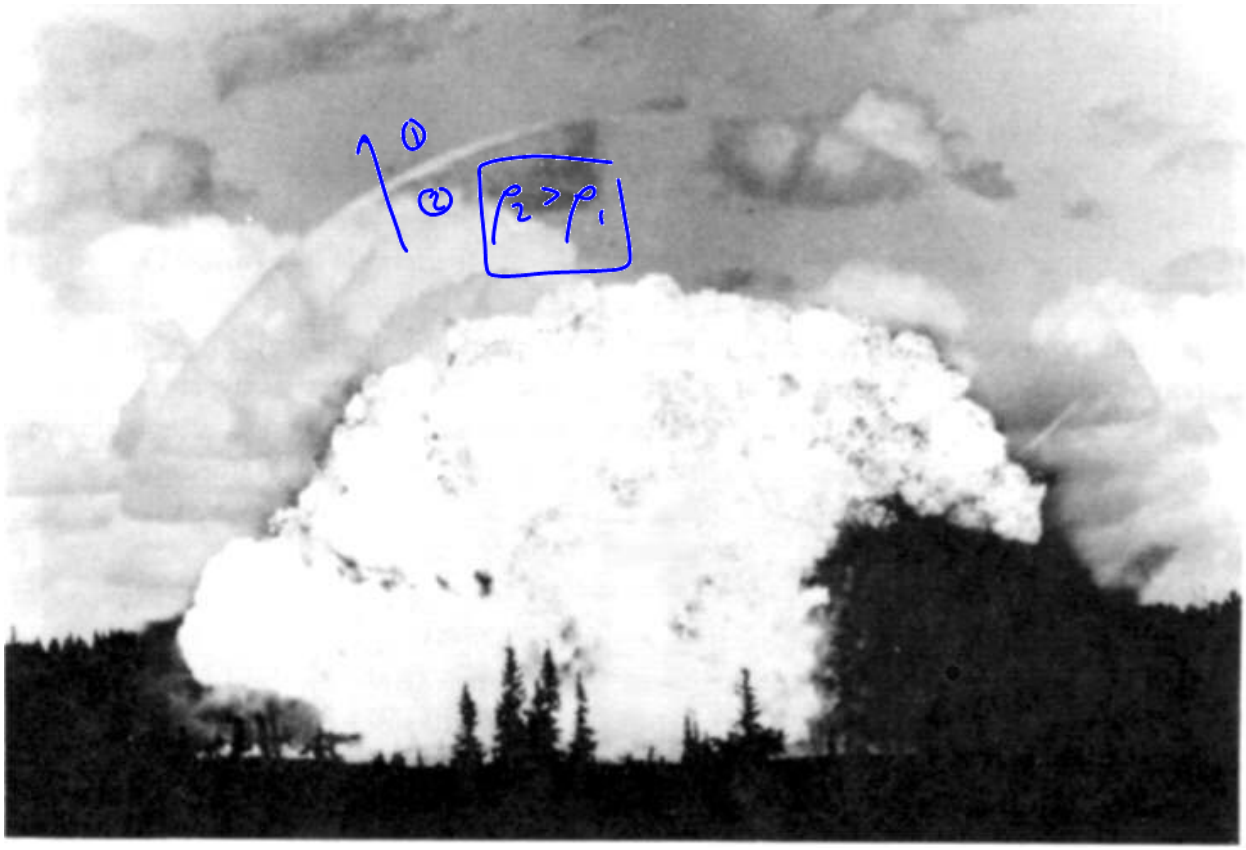
Spherical shock from an explosive gun shot; bullet emerging on left.



Spherical shock from an explosive gun shot; bullet fully emerged on left.

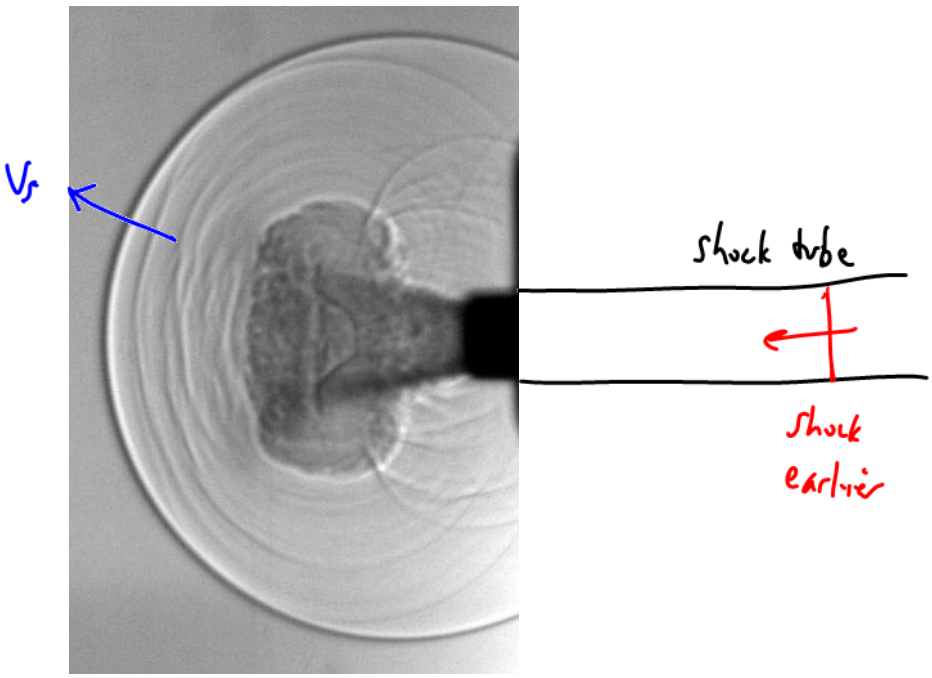


Popping a balloon.



If atmospheric conditions are just right, you can sometimes see shock waves without any equipment.

Color schlieren image of an explosion beneath a full size aircraft seat occupied by a dummy. This photo aided in the research (funded by the FAA) of aircraft hardening in response to incidents of international terrorism. Photos courtesy of G. S. Settles.

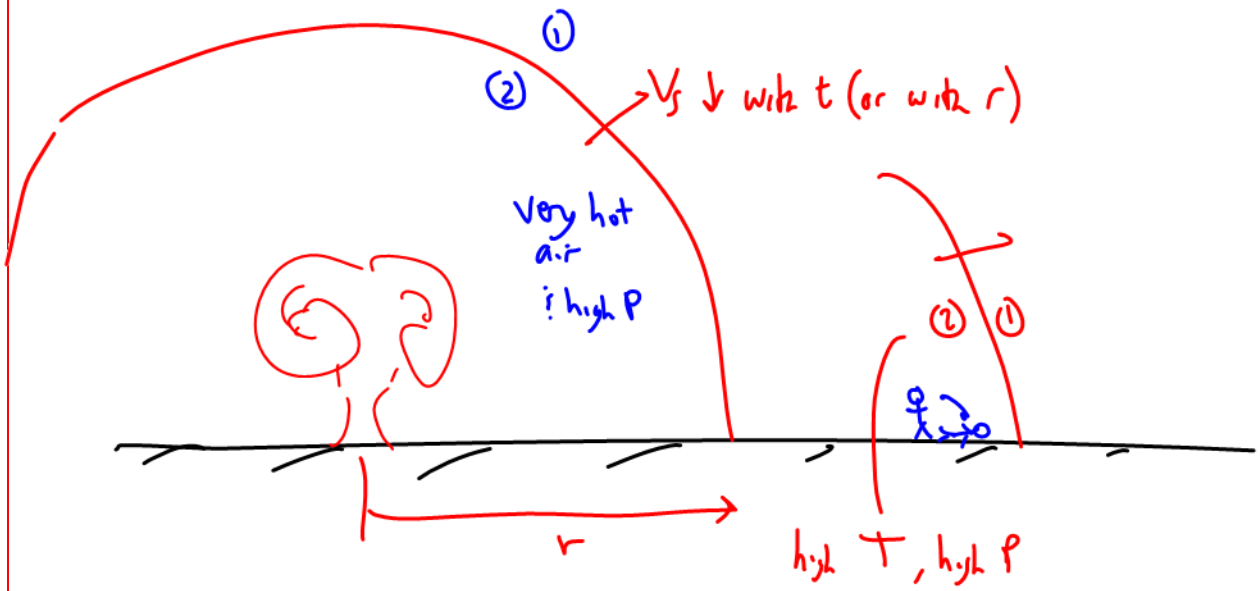


Spherical shock when the traveling shock from a shock tube exits the tube.

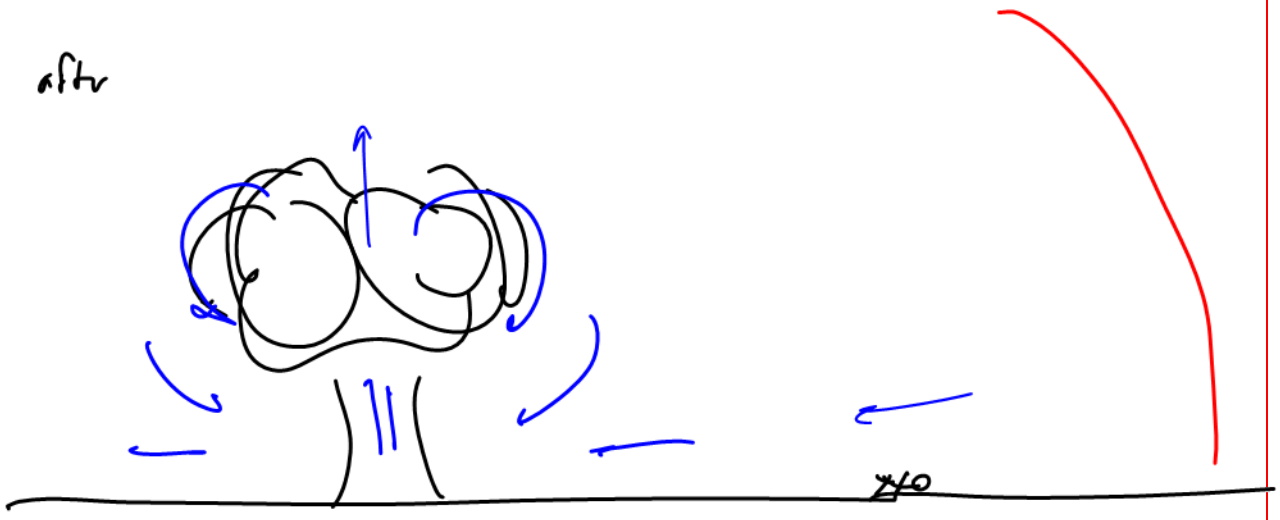
Coolest shock wave picture ever!

Guns shooting from the USS Iowa; shocks seen on water surface!

E.g. nuclear bomb

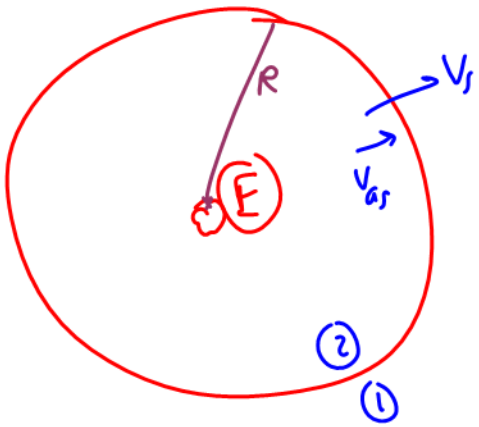


shortly after



BLAST WAVES = spherical shock from an explosion

E = total energy released from the bomb



$P_{atm}, \rho_{atm}, T_{atm}$

R = Radius of shock

$R = f_n(t)$ ↑ with t

M_s ↓ V_s ↓ with t

V_{as} = "after shock" speed

DIMENSIONAL ANALYSIS

E = energy released by the explosion = constant

R = radius of the blast wave

$\rho_{atm} = \rho_1$ = atmospheric density in front of shock (in still air)

$$V_s = \frac{dR}{dt}$$

t = time since explosion

Approx ALL E is released suddenly @ $t=0$

Dim anal.:

$$R = f_{nc}(\rho_{atm}, E, t)$$

$\{L\}$ $\left\{\frac{m}{L^3}\right\}$ $\left\{\frac{mL^2}{t^2}\right\}$ $\{t\}$

$$R = \alpha t^{\Omega}$$

$n=4$, 3 primary dims j → expect 1Π $\quad k = n-j = 4-3 = 1$

$$\Pi_1 = R \rho_{atm}^{a} E^{b} t^{c}$$

$$\{\Pi_1\} = \{m^0 L^0 t^0\} = \{L\}\left\{\frac{m}{L^3}\right\}^{a}\left\{\frac{mL^2}{t^2}\right\}^{b}\{t\}^{c}$$

m: $\quad 0 = a + b \rightarrow a = -b$

L: $\quad 0 = 1 - 3a + 2b = 0$

$\rightarrow a = \frac{1}{5}, \; b = -\frac{1}{5}$

$t:\ 0 = -2b + c \rightarrow c = -\frac{2}{5}$

$$\Pi_1 = R\, \rho_{atm}^{\frac{1}{5}}\, E^{-\frac{1}{5}}\, t^{-\frac{2}{5}} = \text{const}$$

$$R \propto t^{2/5}$$

$R \uparrow$ as $t \uparrow$

$$V_s = \text{const} \cdot t^{-3/5}$$

$V_s \downarrow$ as $t \uparrow$

$M_s \downarrow$ as $t \uparrow$