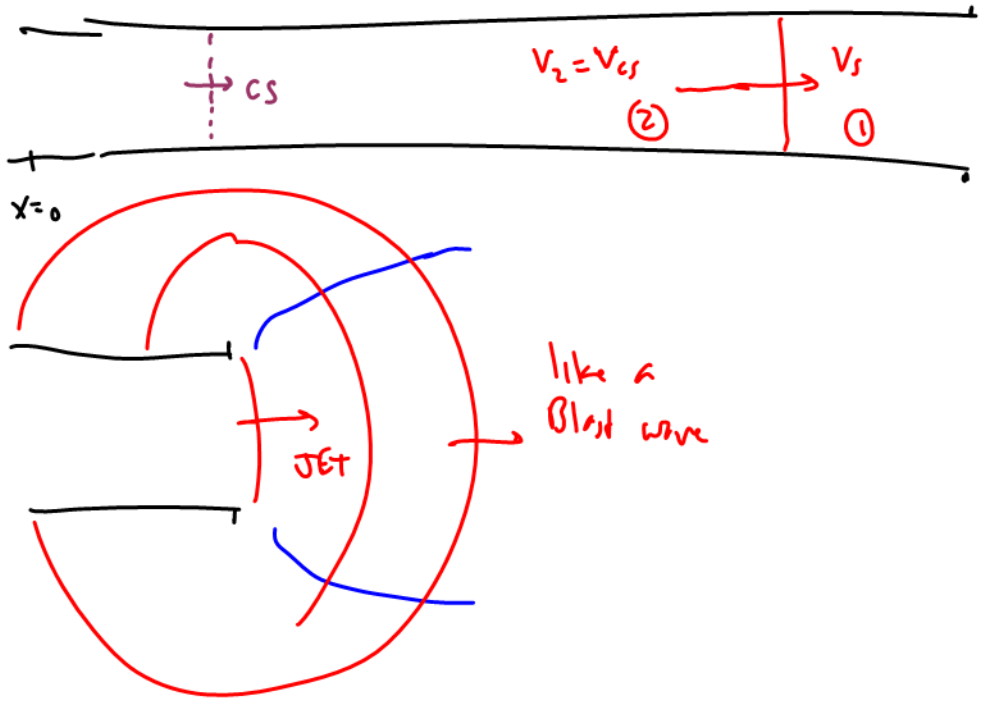
Today, we will:

- Discuss what happens when the shock reaches the end of the shock tube – Two cases: open end and closed end
- Discuss reflecting shocks and reflecting expansion waves in shock tubes

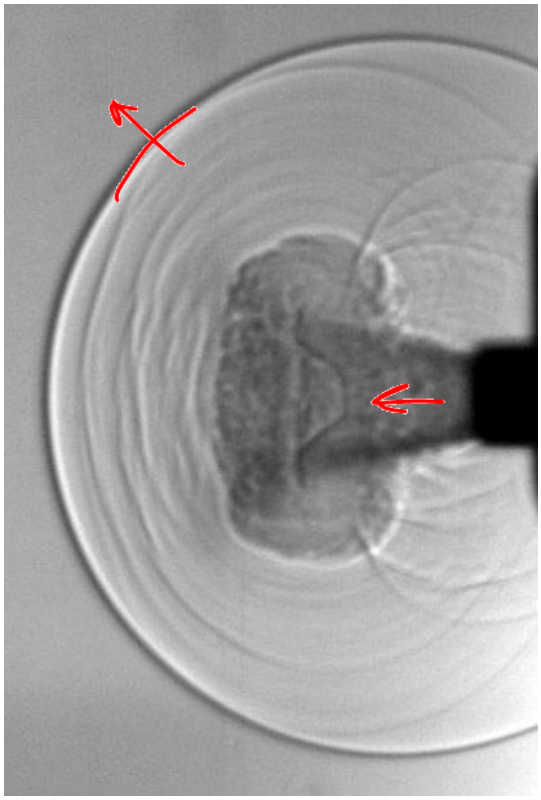
* WHAT HAPPENS WHEN THE SHOCK HITS THE END OF THE SHOCK TUBE?

CASE A - OPEN END

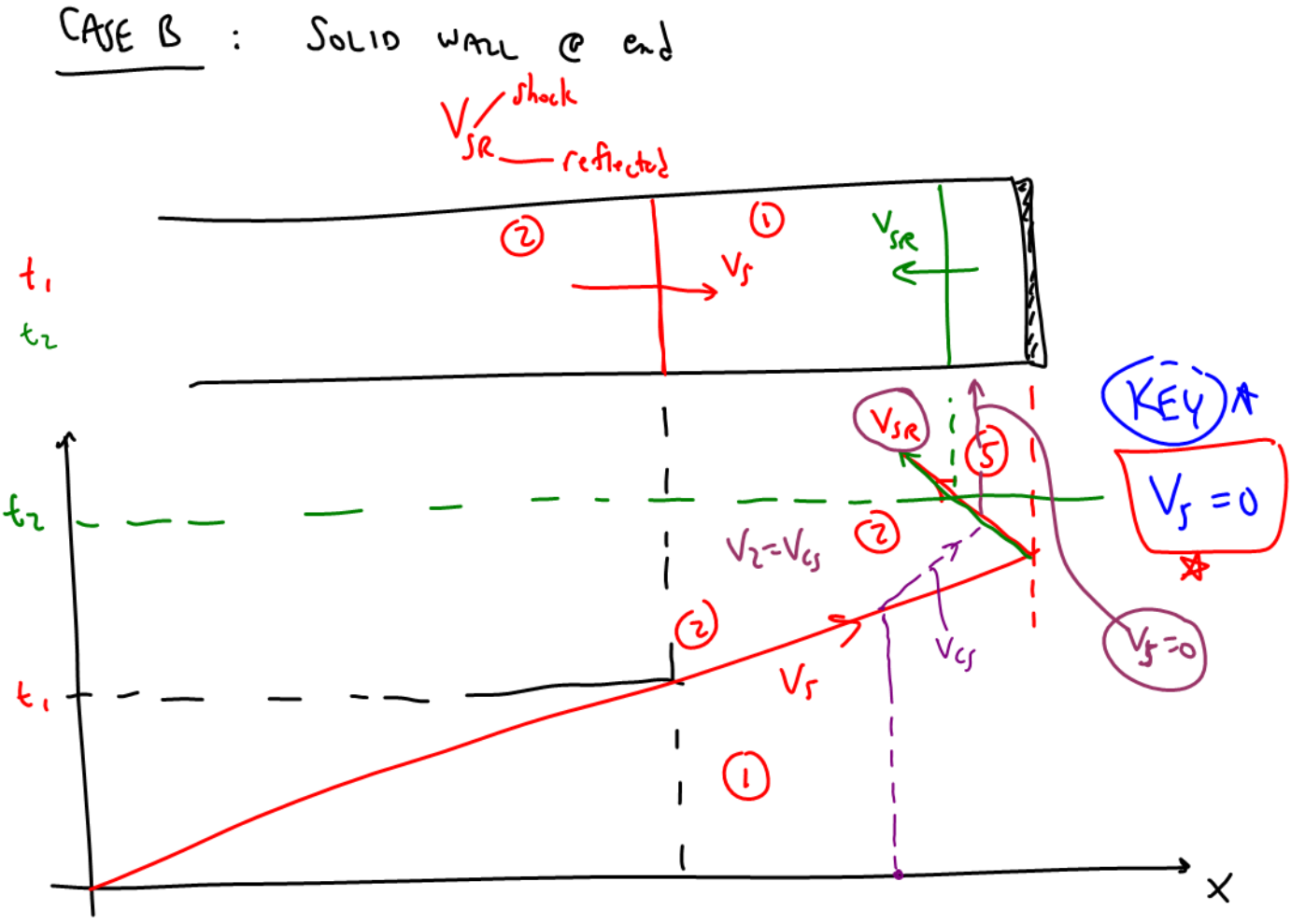
Still air

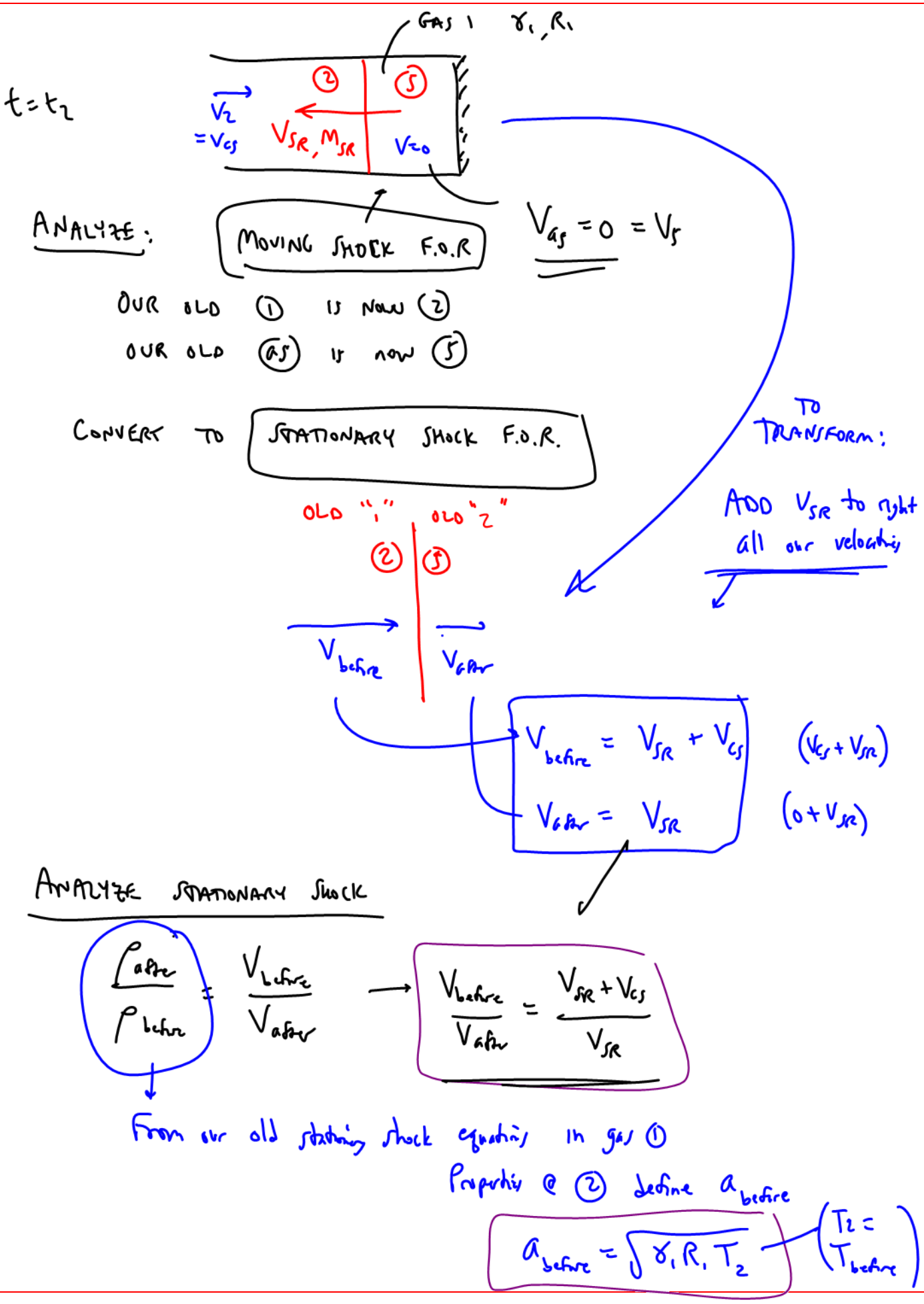


↓ See pic ; video clip on website



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




GAS 1 γ_1, R_1
$t = t_2$
$V_2 = V_{cs}$
V_{SR}, M_{SR}
$V = 0$
ANALYZE:
MOVING SHOCK F.O.R
$V_{gs} = 0 = V_s$
OUR OLD (1) IS NOW (2)
OUR OLD (gs) IS NOW (s)
CONVERT TO
STATIONARY SHOCK F.O.R.
TO TRANSFORM:
ADD V_{SR} to right all our velocities
OLD "1"
OLD "2"
V_{before}
V_{after}
$V_{before} = V_{SR} + V_{cs}$ $(V_{cs} + V_{SR})$
$V_{after} = V_{SR}$ $(0 + V_{SR})$
ANALYZE STATIONARY SHOCK
$\frac{\rho_{after}}{\rho_{before}} = \frac{V_{before}}{V_{after}}$
$\frac{V_{before}}{V_{after}} = \frac{V_{SR} + V_{cs}}{V_{SR}}$
From our old stationary shock equations in gas (1)
Properties @ (2) define a_{before}
$a_{before} = \sqrt{\gamma_1 R_1 T_2}$ $(T_2 = T_{before})$

$$M_{SR} = \frac{V_{before}}{a_{before}} = \frac{V_{SR} + V_{CS}}{\sqrt{\gamma_1 R_1 T_{before}}} \quad (1)$$

2 unknowns

NEED 2 eqs to solve for M_{SR} & V_{SR} (2 unknowns)

Shock EQ's → $\frac{\rho_2}{\rho_1} = \frac{V_1}{V_2} = \frac{(\gamma_1+1) M_1^2}{2 + (\gamma_1 - 1) M_1^2}$

previous "old" notation ① , ②

HERE

"1" = before

"2" = after

$$\frac{V_{before}}{V_{after}} = \frac{(\gamma_1+1) M_{SR}^2}{2 + (\gamma_1 - 1) M_{SR}^2} = \frac{V_{SR} + V_{CS}}{V_{SR}} \quad (2)$$

I HAVE 2 EQs (1) & (2) FOR M_{SR} & V_{SR}

- SOLVE BY COMBINING (1) & (2) – solve
- OR, SOLVE BY ITERATION → THIS SET OF EQ's IS "STIFF"

Technique = underrelaxation

PROCEDURE:

1) Guess M_{SR}
2) Eq (2) → Solve for V_{SR}
3) Eq (1) — calc a new M_{SR}
4) Avg. M_{SR} from previous guess & the new Guess
5) Use this avg M_{SR} from step (4) as new guess
6) Repeat steps (2) to (5) till convergence

HERE: OUR SHOCK TUBE EXAMPLE

We had $V_{cs} = 393.462$ m/s

$a_2 = 438.088$ m/s

$\gamma_1 = 1.40$

Iterate w/ above procedure → Get ⊗

$M_{SR} = 1.675$

$V_{SR} = 340.3$ m/s

• CALC T_5

Stationary shock F.O.R

(2) | (5)

M_2 → | M_5 →

Replace (1) with (2) in (2) with (5)

$$\frac{T_5}{T_2} = \frac{1 + \frac{\gamma_1 - 1}{2} M_2^2}{1 + \frac{\gamma_1 - 1}{2} M_5^2}$$

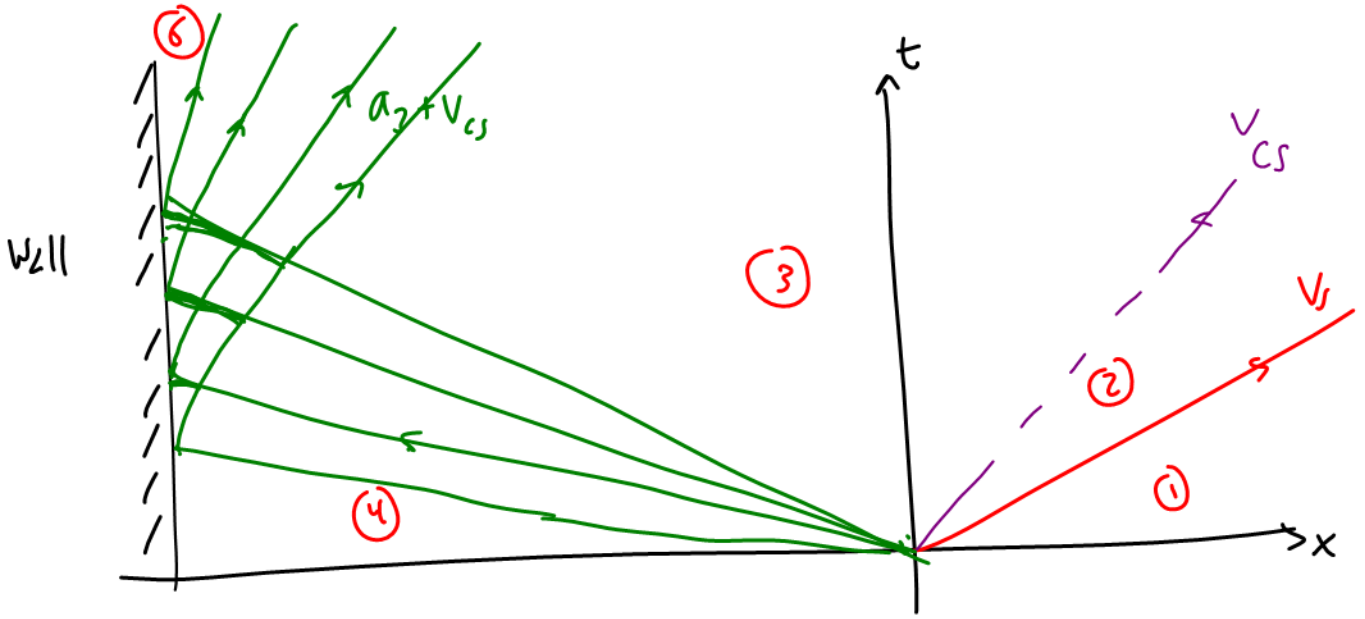
all M_2 | all "1" | all "2"

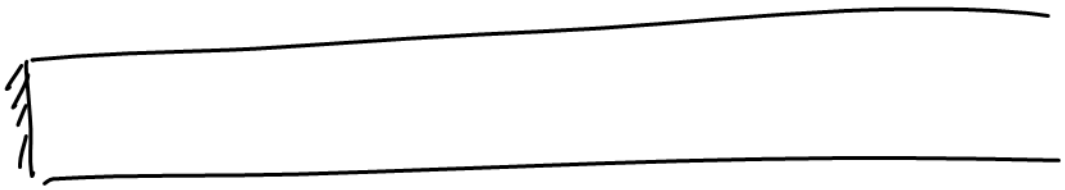
where $M_5^2 = \dfrac{1 + \frac{\gamma_1 - 1}{2} M_{SR}^2}{\gamma_1 M_{SR}^2 - \frac{\gamma_1 - 1}{2}}$

$T_5 = 688.03$ K ⊗

can also calc P_5, ρ_5 ...

REFLECTED EXPANSION FAN (Wall on left side of shock tube)





$T_6 < T_4$

$P_6 < P_4$