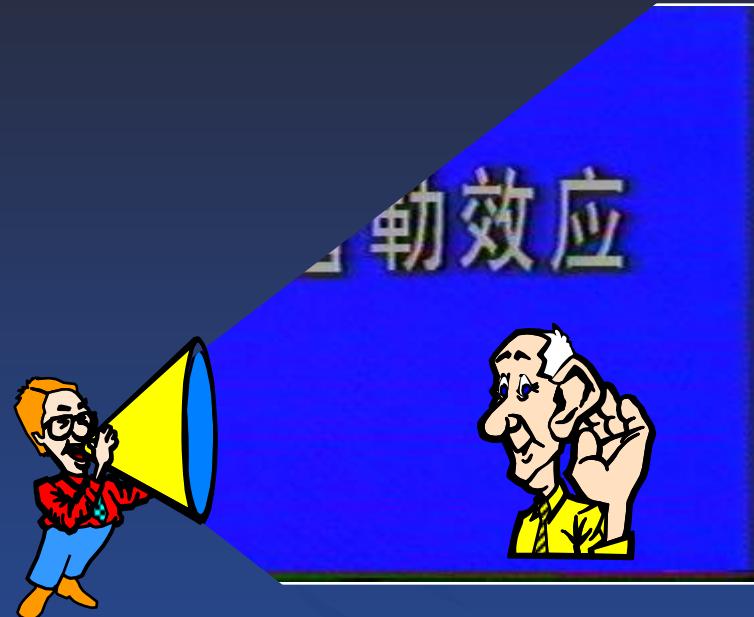


§ 10.7 多普勒效应 冲击波

一、多普勒效应 波的观测频率

观测频率：单位时间内观测者所接受到完整波的波数，即

$$\nu = \frac{\text{每秒波阵面推进的距离}}{\text{相隔一个周期波阵面间距}}$$



写成： $\nu = \frac{l}{d}$ { 相对于观测者波阵面推进的距离 }

两者位置皆不变： $d = \lambda$, $l = u \times 1 \rightarrow \nu = \frac{u \times 1}{\lambda} = \frac{1}{T} = \nu_0$

1. 波源S静止，观测者B运动: $v_S = 0, v_B \neq 0$

写成: $v = \frac{l}{d}$ → 相对于观测者波阵面推进的距离

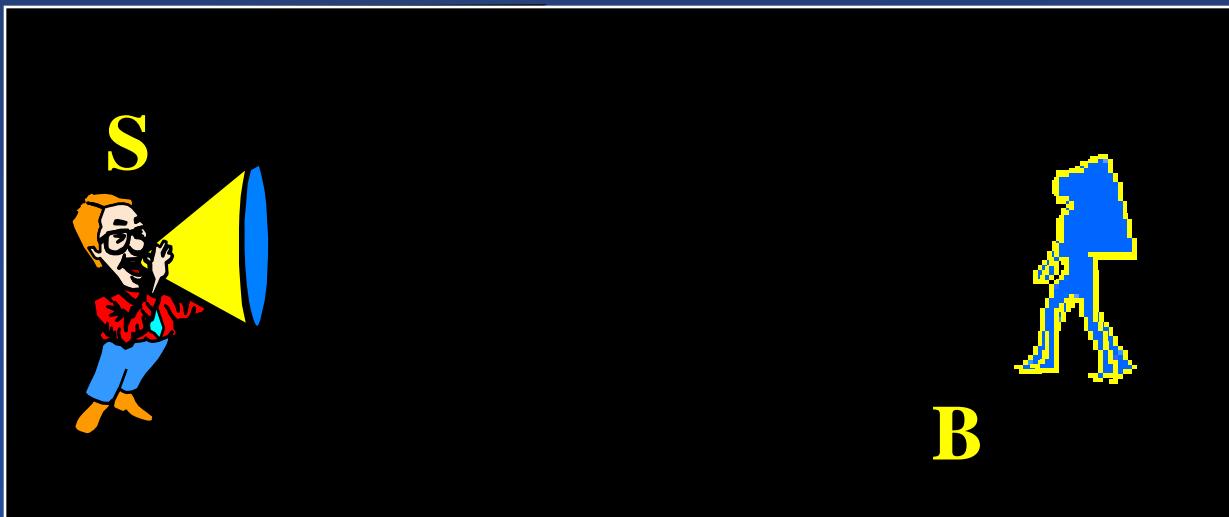
两者位置皆不变: $d = \lambda, l = u \times 1 \rightarrow v = \frac{u \times 1}{\lambda} = \frac{1}{T} = v_0$

1. 波源S静止，观测者B运动： $v_S = 0$, $v_B \neq 0$

相对于观测者： $l = (u + v_B) \times 1$, $d = \lambda$

观测频率：

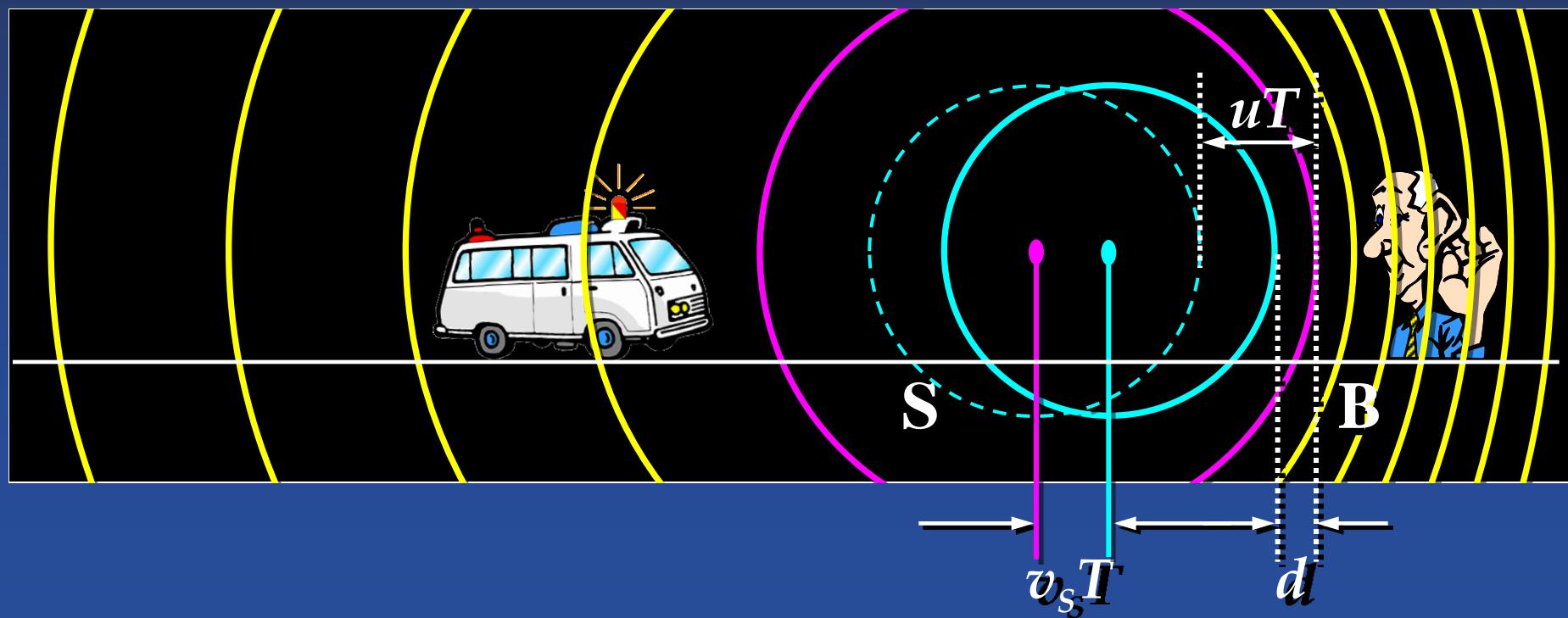
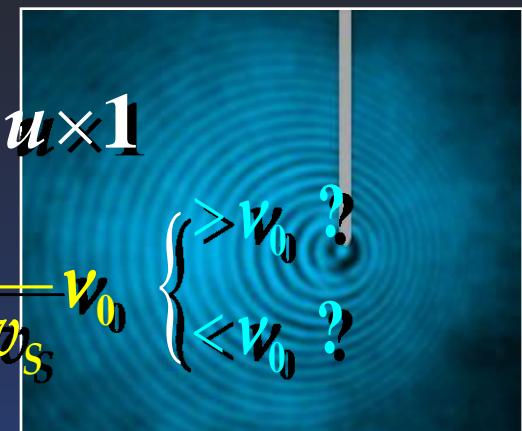
$$\nu = \frac{l}{d} = \frac{u + v_B}{\lambda} = \frac{u}{\lambda} \left(1 + \frac{v_B}{u}\right) = \frac{u + v_B}{u} \nu_0 \quad \left\{ \begin{array}{l} > \nu_0 ? \\ < \nu_0 ? \end{array} \right.$$



2. 波源S运动，观测者B静止： $v_s \neq 0, v_B = 0$

波前间距： $d = uT - v_s T$ 1秒内： $l = u \times 1$

$$\text{B 的观测频率} : \nu = \frac{l}{d} = \frac{u}{(u - v_s)T} = \frac{u}{u - v_s} \nu_0 \quad \left\{ \begin{array}{l} > \nu_0 ? \\ < \nu_0 ? \end{array} \right.$$

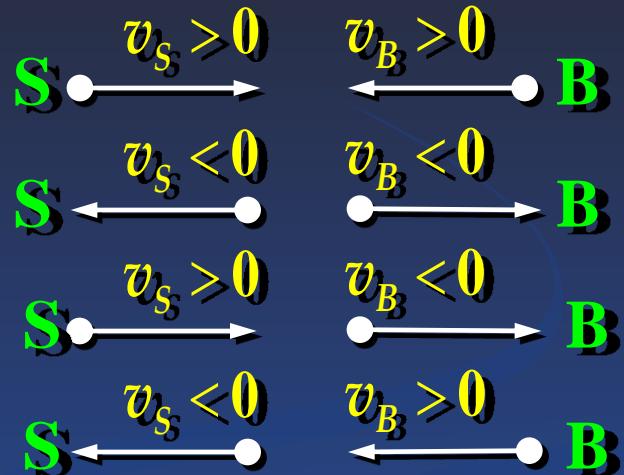


3. 波源S、观测者B皆运动: $v_S \neq 0, v_B \neq 0$

$$l = (u + v_B) \times 1, \quad d = uT - v_S T$$

观测频率:

$$\nu = \frac{u + v_B}{u - v_S} \nu_0$$



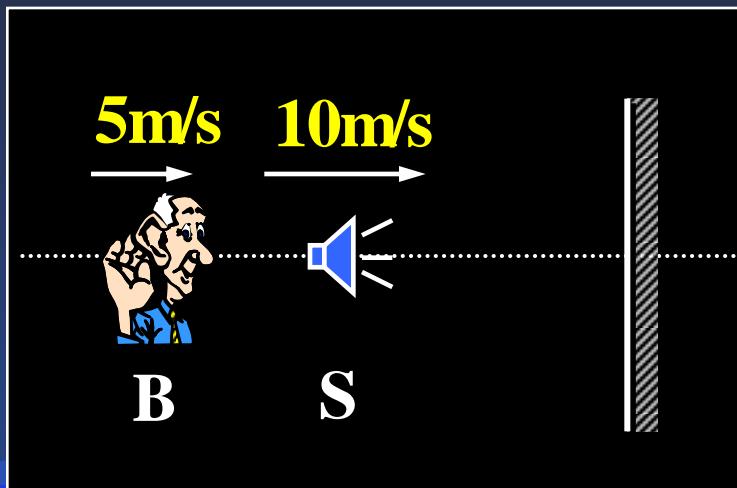
注: 以上测得的观测频率 ν 皆发生在两者连线上, 且 $v_S < u$!

例如图, 已知 $v_0 = 1000 \text{ Hz}$, 空气中 $u = 340 \text{ m/s}$, 求:
B直接接收 S 的频率、反射波频率及拍频。

解 B直接接收S 的频率:

$$v_B = 5 \text{ m/s}$$

$$v_S = -10 \text{ m/s}$$



注: 以上测得的观测频率 v 皆发生在两
者连线上, 且 $v_S < u$!

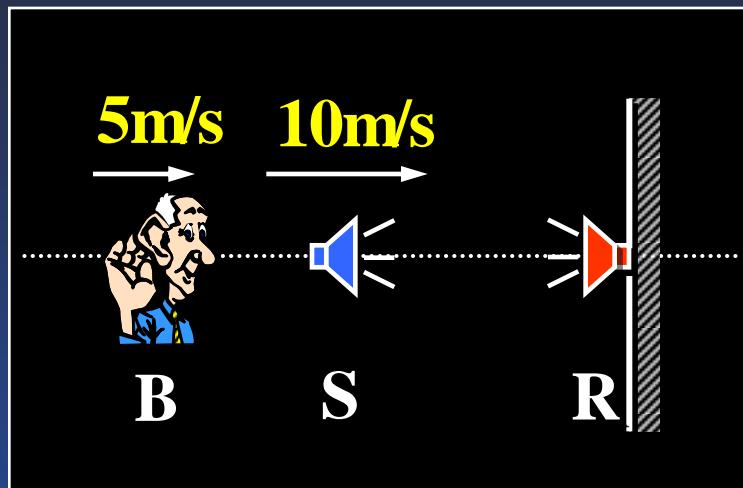
例如图, 已知 $v_0 = 1000 \text{ Hz}$, 空气中 $u = 340 \text{ m/s}$, 求:
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解 B直接接收S 的频率:

$$v_B = 5 \text{ m/s}$$

$$v_S = -10 \text{ m/s}$$

$$\nu = \frac{u + v_B}{u - v_S} v_0 \approx 986 \text{ Hz}$$



R直接接收S 的频率: $v_R = 0$, $v_S = 10 \text{ m/s}$

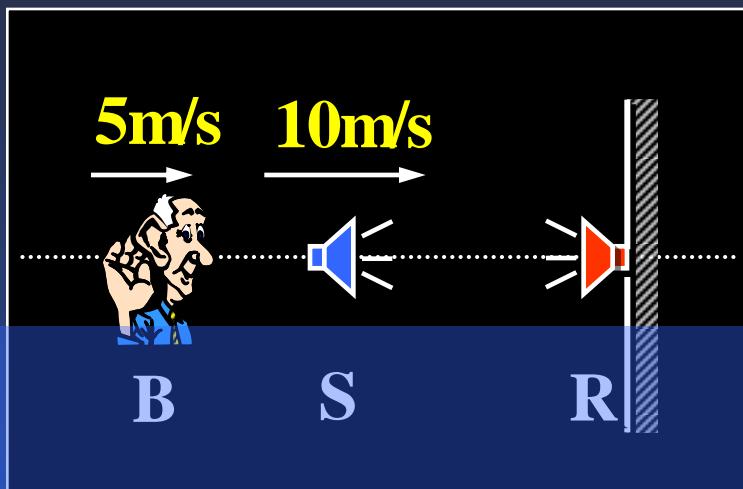
$$\nu_R = 1000 \times (340 + 0) / (340 - 10) \approx 1030 \text{ Hz}$$

B 直接接收 R 的频率： $v_R = 0, v_B = 5 \text{ m/s}, v_0 = 1030 \text{ Hz}$

$$\nu = \frac{u + v_B}{u - v_S} \nu_0$$

$$\nu' = \frac{340 + 5}{340 - 0} \times 1030$$

$$\nu = \frac{u + v_B}{u - v_S} \nu_0 \approx 986 \text{ Hz}$$



R直接接收S 的频率： $v_R = 0, v_S = 10 \text{ m/s}$

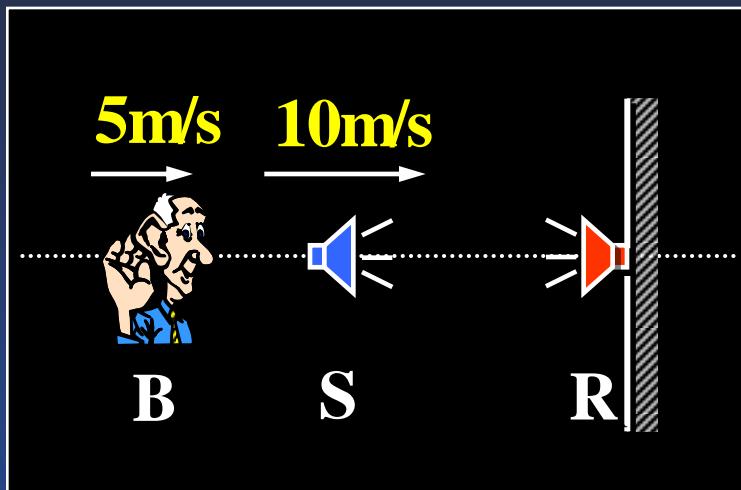
$$\nu_R = 1000 \times (340 + 0) / (340 - 10) \approx 1030 \text{ Hz}$$

B 直接接收 R 的频率： $v_R = 0, v_B = 5 \text{ m/s}, v_0 = 1030 \text{ Hz}$

$$\nu = \frac{u + v_B}{u - v_S} \nu_0$$

$$\nu' = \frac{340 + 5}{340 - 0} \times 1030$$

$$\approx 1045 \text{ Hz}$$



B 接收到的拍频：

$$\Delta\nu = \nu' - \nu = 1045 - 986 = 59 \text{ (Hz)}$$

(the end)

二、冲击波 (shock wave)

若 $v_s > u$, 将出现锥面波, 即马赫波或冲击波!

B 接收到的拍频:

$$\Delta\nu = \nu' - \nu = 1045 - 986 = 59 \text{ (Hz)}$$

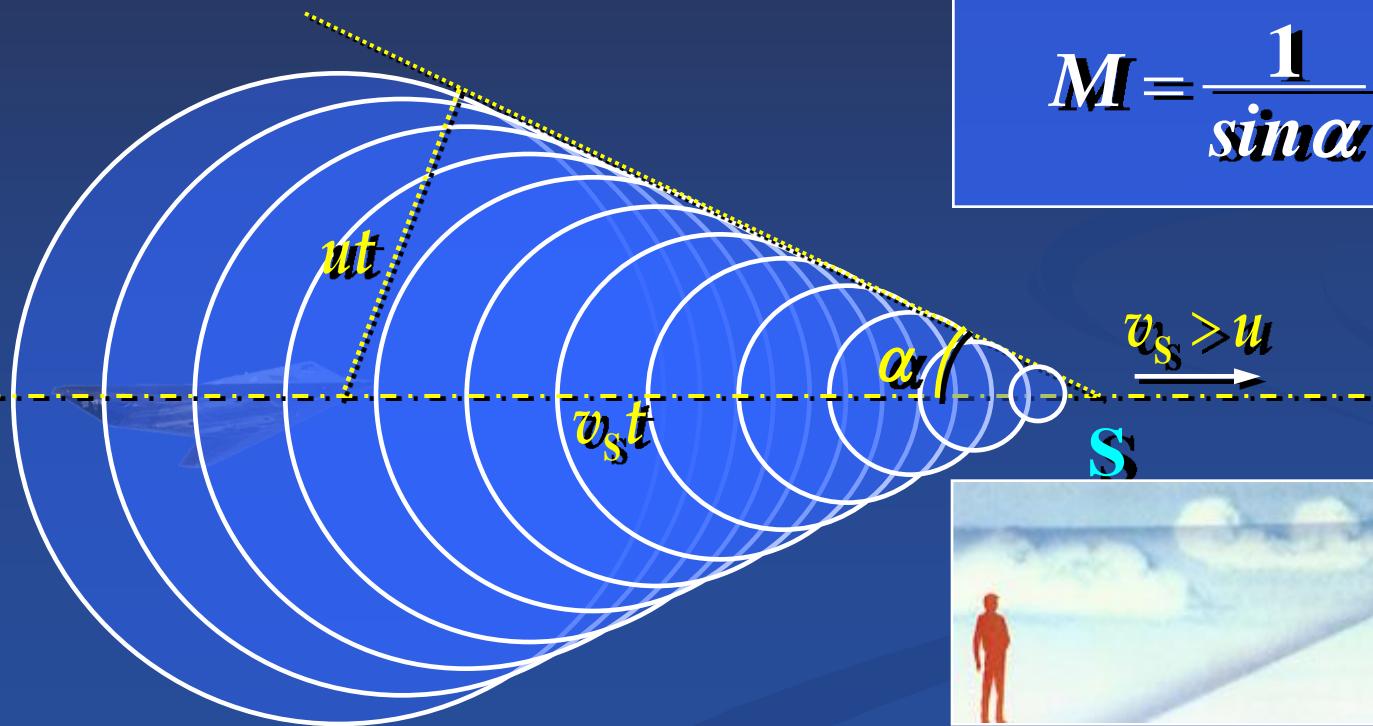
(the end)

二、冲击波 (shock wave)

若 $v_s > u$, 将出现锥面波, 即马赫波或冲击波!

马赫数 (Mach number):

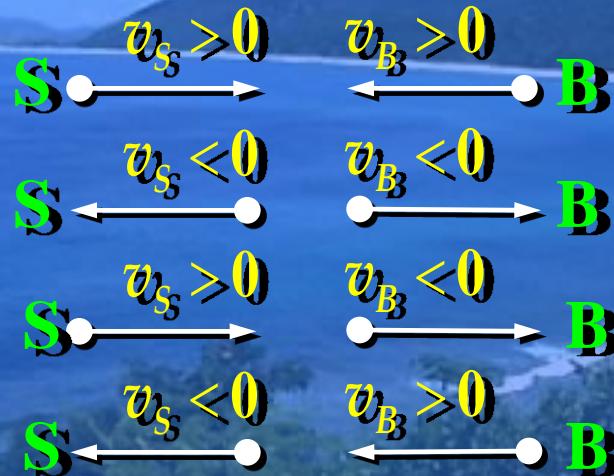
$$M = \frac{1}{\sin \alpha} = \frac{v_s}{u} > 1$$



归纳:

1. 观测者接收的频率:

$$\nu = \frac{u + v_B}{u - v_S} \nu_0$$



*2. 冲击波: $M = \frac{1}{\sin \alpha} = \frac{v_S}{u} > 1$

(请看录像)