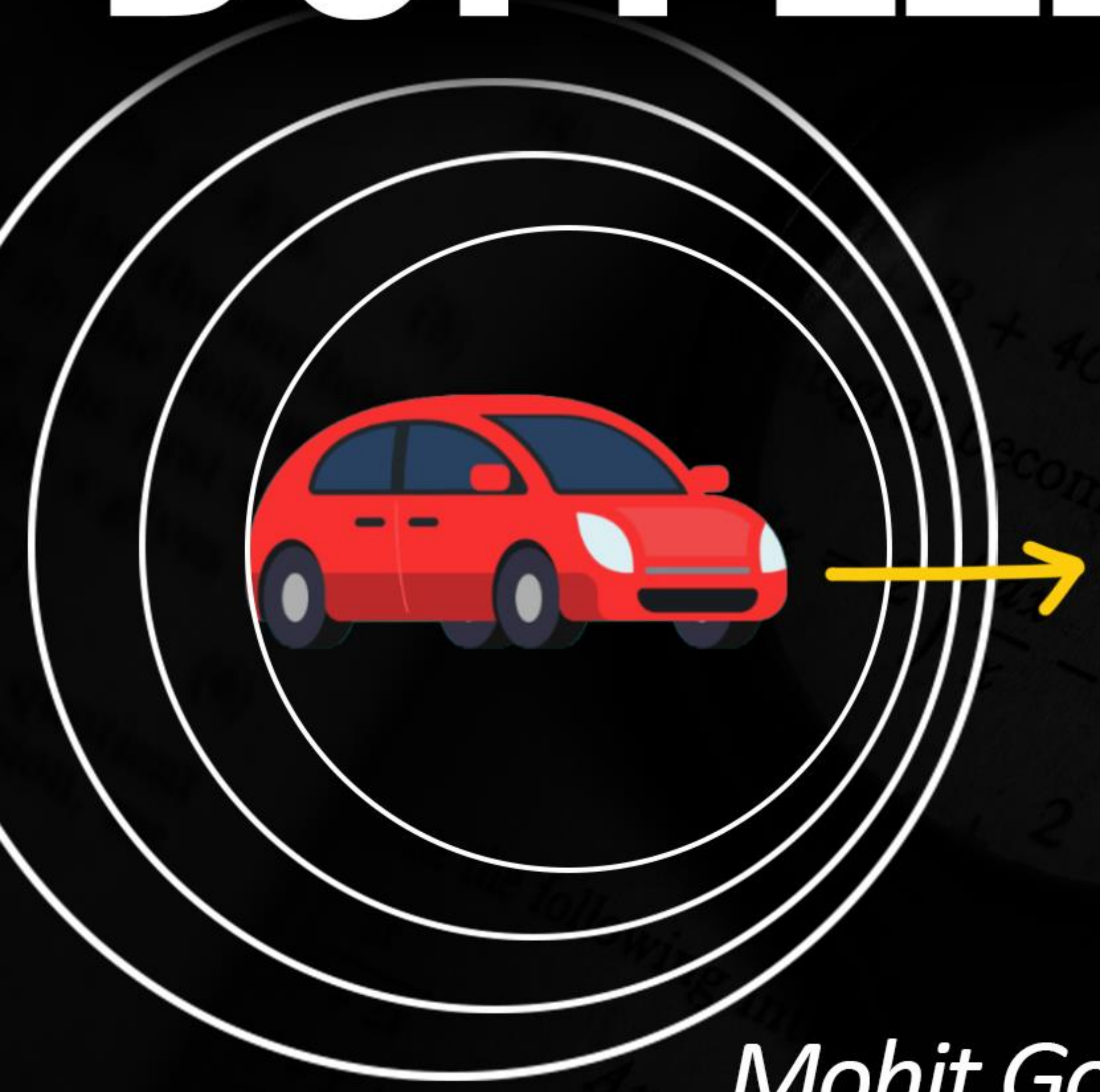
DOPPLER'S EFFECT



JEE Main CONCEPT PYQs

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List of Content on Eduniti YouTube Channel:

1. PYQs Video Solution Topic Wise:
   (a) JEE Main 2018/2020/2021 Feb & March
2. Rank Booster Problems for JEE Main
3. Part Test Series for JEE Main
4. JEE Advanced Problem Solving Series
5. Short Concept Videos
6. Tips and Tricks Videos
7. JEE Advanced PYQs
8. Formulae Revision Series

........and many more to come

TOPICS COVERED

1. Doppler's Effect
2. Different cases (how to write sign)
3. Effect of Wind Speed
4. Sound reflected from fixed wall/object
5. Source and observer not in same line
6. PYQs (Build your understanding)

1. DOPPLER's EFFECT

When a source of sound and a listener are in motion relative to each other, the frequency of the sound heard by the listener is not the same as the source frequency.

MOST GENERAL

$$f_{app} = f_0 \left(\frac{V \pm V_W \pm V_0}{V \pm V_W \pm V_s} \right)$$

V_s : speed of source

V_0 : speed of observer

f_0 : Source sound frequency

f_{app} : Apparent frequency heard by observer

V : speed of sound in still air

2. CASES (V_s and V_o in Same direction)

NOTE:
If any speed tries to decrease separation between source and observer, sign is taken so as to ↑ f_{app} and Vice-Versa.

Source at rest

$$f_{app} = f_o\left(\frac{V - V_o}{V}\right)$$

Observer at rest

$$f_{app} = f_o\left(\frac{V}{V - V_s}\right)$$

Both moves as shown

$$f_{app} = f_o\left(\frac{V - V_o}{V - V_s}\right)$$

2. CASES (V_s and V_o in same direction)

Source at rest

$$f_{app} = f_o\left(\frac{V + V_o}{V}\right)$$

Observer at rest

$$f_{app} = f_o\left(\frac{V}{V + V_s}\right)$$

Both moves as shown

$$f_{app} = f_o\left(\frac{V + V_o}{V + V_s}\right)$$

2. CASES (V_s and V_o in opposite direction)

(a)

$$\Rightarrow f_{app} = f_o\left(\frac{V + V_o}{V - V_s}\right)$$

(b)

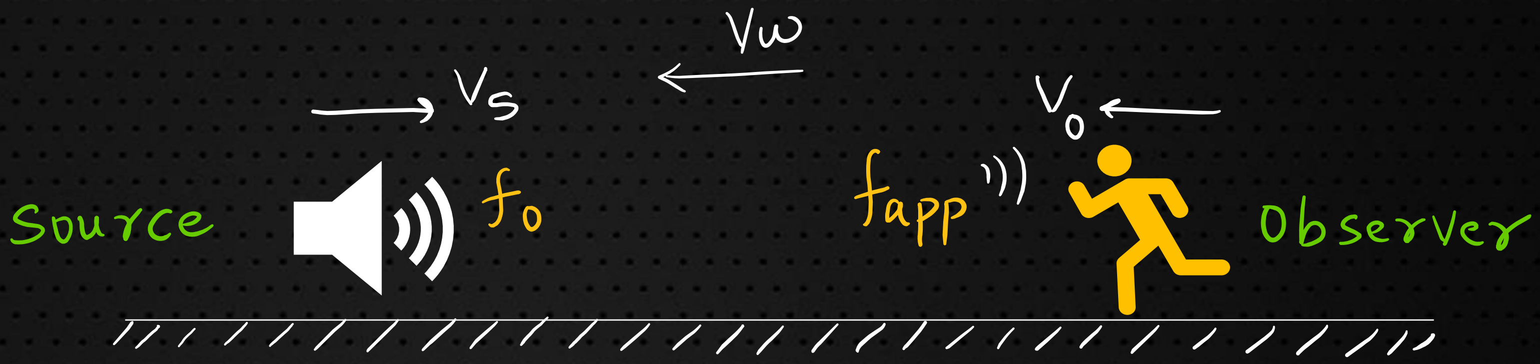
$$\Rightarrow f_{app} = f_o\left(\frac{V - V_o}{V + V_s}\right)$$

3. EFFECT OF WIND SPEED (V_w)

↳ If "V" is along $V_w \Rightarrow V + V_w$

↳ If "V" is opposite $V_w \Rightarrow V - V_w$

Ex:

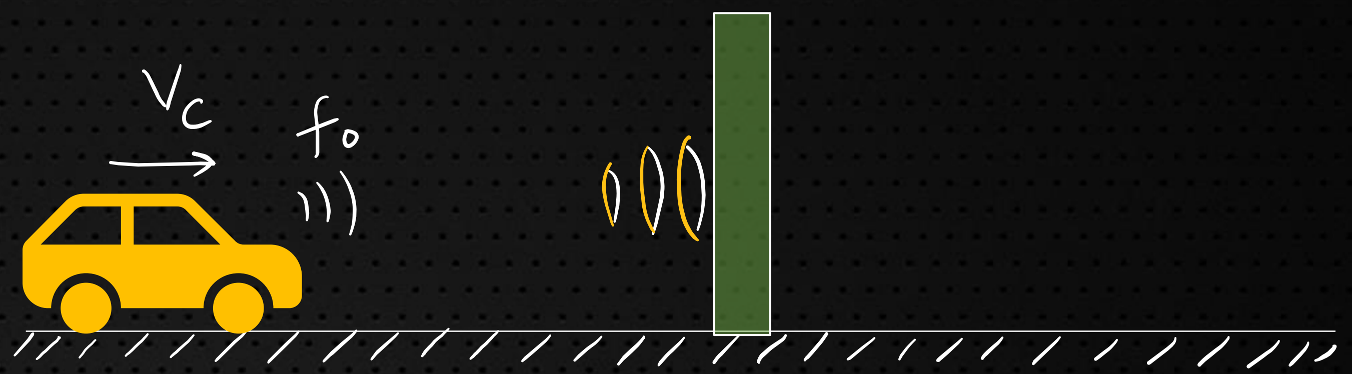


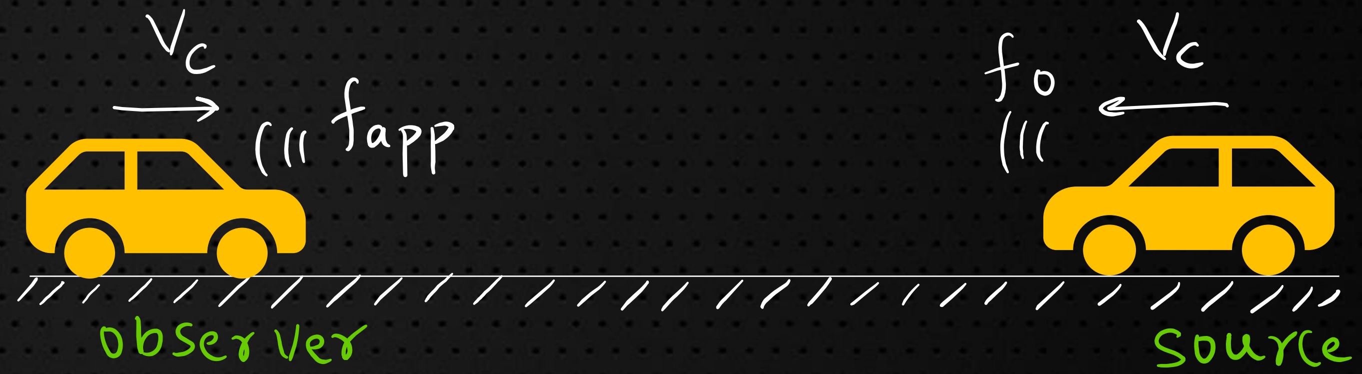
$$f_{app} = f_0 \left(\frac{V - V_w + V_0}{V - V_w - V_s} \right)$$

4. SOUND REFLECTED FROM "FIXED WALL"

Car honk freq = f_0

f_{app} heard by driver after reflection.



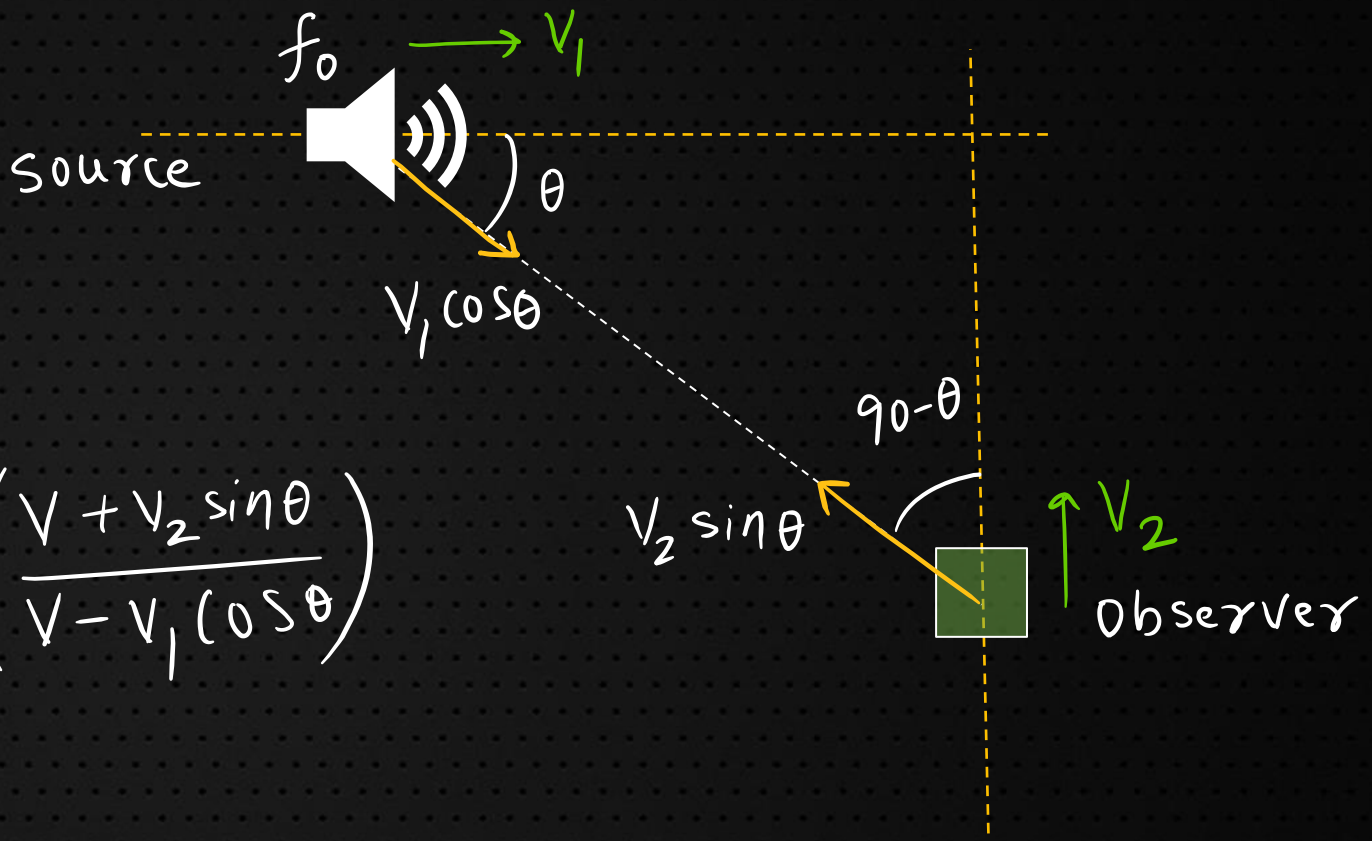


$$f_{app} = f_0\left(\frac{V+V_c}{V-V_c}\right)$$

Beat frequency, $f_b = f_{app} - f_0$

5. SOURCE AND OBSERVER NOT IN SAME LINE

Take components of Velocities along line joining them.



$$f_{app} = f_0\left(\frac{V + V_2 \sin\theta}{V - V_1 \cos\theta}\right)$$

5 PYQs For UNDERSTANDING

1. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the speed of the train is reduced to 17 m/s, the frequency registered is f_2. If speed of sound is 340 m/s, then the ratio f_1/f_2 is

(a) 18/17 **(b)** 19/18

(c) 20/19 (c) 21/20

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1. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the speed of the train is reduced to 17 m/s, the frequency registered is f_2. If speed of sound is 340 m/s, then the ratio f_1/f_2 is

(a) 18/17 ✓ **(b)** 19/18
(c) 20/19 (c) 21/20

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$V = 340\,m/s, \quad V_{s_1} = 34\,m/s, \quad V_{s_2} = 17\,m/s$

$$f_1 = f_0\left(\frac{V}{V - V_{s_1}}\right) \quad \text{--- (1)}$$

$$f_2 = f_0\left(\frac{V}{V - V_{s_2}}\right) \quad \text{--- (2)}$$

$$\therefore \frac{f_1}{f_2} = \frac{V - V_{s_2}}{V - V_{s_1}} = \frac{340-17}{340-34} = \boxed{\frac{19}{18}}$$

2. A stationary source emits sound waves of frequency 500 Hz. Two observers moving along a line passing through the source detect sound to be of frequencies 480 Hz and 530 Hz. Their respective speeds are, in ms^{-1}, (Given speed of sound = 300 m/s)

(a) 12, 16
(b) 12, 18
(c) 16, 14
(d) 8, 18

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(a) 12, 16 (b) 12, 18

(c) 16, 14 (d) 8, 18

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$f_0 = 500\,Hz$, $f_1 = 480\,Hz$

$V = 300\,m/s$ $f_2 = 530\,Hz$

$$f_1 = f_0\left(\frac{V - V_1}{V}\right) \Rightarrow 480 = 500\left(\frac{300 - V_1}{300}\right)$$

$$\therefore \boxed{V_1 = 12\,m/s}$$

$$f_2 = f_0\left(\frac{V + V_2}{V}\right)$$

$$\Rightarrow 530 = 500\left(\frac{300 + V_2}{300}\right) \quad \therefore \boxed{V_2 = 18\,m/s}$$

3. A submarine (A) travelling at 18 km/hr is being chased along the line of its velocity by another submarine (B) travelling at 27 km/hr. B sends a sonar signal of 500 Hz to detect A and receives a reflected sound of frequency v. The value of v is close to (Speed of sound in water = 1500 ms^{-1})

(a) 504 Hz (b) 507 Hz
(c) 499 Hz **(d)** 502 Hz

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3. A submarine (A) travelling at 18 km/hr is being chased along the line of its velocity by another submarine (B) travelling at 27 km/hr. B sends a sonar signal of 500 Hz to detect A and receives a reflected sound of frequency ν. The value of ν is close to (Speed of sound in water = 1500 ms^{-1})

(a) 504 Hz (b) 507 Hz
(c) 499 Hz **(d) 502 Hz** ✓

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freq recieved by A, $f_A = f_0\left(\frac{V - V_A}{V - V_B}\right)$

Reflected sound freq recieved by B :

$$f_B = f_A\left(\frac{V+V_B}{V+V_A}\right) = f_0\left(\frac{V-V_A}{V-V_B}\right)\left(\frac{V+V_B}{V+V_A}\right)$$

$V_A = 5\,m/s$, $V_B = 7.5\,m/s$

$V = 1500\,m/s$

$$f_B = 500\left(\frac{1500-5}{1500-7.5}\right)\left(\frac{1500+7.5}{1500+5}\right)$$

$$= 500\left(\frac{1-1/300}{1-1/200}\right)\left(\frac{1+1/200}{1+1/300}\right) = 500\left(1-\frac{1}{300}\right)^2\left(1+\frac{1}{200}\right)^2$$

$$= 500\left(1-\frac{2}{300}\right)\left(1+\frac{2}{200}\right) = 500(1-0.0067)(1+0.01)$$

$$= 500(1+0.01-0.0067-\underbrace{0.0067\times0.01}_{\text{neglect}})$$

$$= 500(1+0.0033)$$

$$\approx \boxed{502\,Hz}$$

$$\frac{1}{1-\frac{1}{200}} = \left(1-\frac{1}{200}\right)^{-1} = \left(1+\frac{1}{200}\right)$$

$(1+x)^n \approx (1+nx)$, $x \ll 1$

4. A stationary observer receives sound from two identical tuning forks, one of which approaches and the other one recedes with the same speed (much less than the speed of sound). The observer hears 2 beats/sec. The oscillation frequency of each tuning fork is $\nu_0 = 1400\,\text{Hz}$ and the velocity of sound in air is 350 m/s. The speed of each tuning fork is close to

(a) 1 m/s

(b) $\frac{1}{2}$ m/s

(c) $\frac{1}{8}$ m/s

(d) $\frac{1}{4}$ m/s

JEE Main 2020

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4. A stationary observer receives sound from two identical tuning forks, one of which approaches and the other one recedes with the same speed (much less than the speed of sound). The observer hears 2 beats/sec. The oscillation frequency of each tuning fork is $\nu_0 = 1400\,\text{Hz}$ and the velocity of sound in air is 350 m/s. The speed of each tuning fork is close to

(a) 1 m/s
(b) $\frac{1}{2}$ m/s
(c) $\frac{1}{8}$ m/s
(d) $\frac{1}{4}$ m/s

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$V_1 = V_2 = V_s$

$f_1 - f_2 = f_b$

$\Rightarrow f_0\left(\frac{V}{V-V_s}\right) - f_0\left(\frac{V}{V+V_s}\right) = f_b$

$\Rightarrow f_0 V\left(\frac{\cancel{V}+V_s-\cancel{V}+V_s}{V^2-\cancel{V_s^2}}\right) = f_b$ $\left\{\because V_s << V \text{ neglect } V_s^2\right\}$

$\Rightarrow V_s = \frac{V f_b}{2 f_0} = \frac{350 \times 2}{2 \times 1400} = \boxed{\frac{1}{4}\,\text{m/s}}$

5. The driver of a bus approaching a big wall notices that the frequency of his bus's horn changes from 420 Hz to 490 Hz, when he hears it after it gets reflected from the wall. Find the speed of the bus if speed of the sound is 330 ms^{-1}.

(a) 91 kmh^{-1} (b) 71 kmh^{-1}

(c) 81 kmh^{-1} (d) 61 kmh^{-1}

JEE Main 2020

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5. The driver of a bus approaching a big wall notices that the frequency of his bus's horn changes from 420 Hz to 490 Hz, when he hears it after it gets reflected from the wall. Find the speed of the bus if speed of the sound is 330 ms^{-1}.

(a) 91 kmh^{-1} (b) 71 kmh^{-1}

(c) 81 kmh^{-1} (d) 61 kmh^{-1}

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$f_0 = 420\,Hz$, $V = 330\,m/s$

$f_{app} = 490\,Hz$ V_b = bus speed

$$f_{app} = f_0\left(\frac{V+V_b}{V-V_b}\right)$$

$$\Rightarrow 490 = 420\left(\frac{330+V_b}{330-V_b}\right)$$

$$\therefore V_b = \frac{330}{13}\,m/s = \frac{330}{13}\times\frac{18}{5}\,kmh^{-1}$$

$$\approx \boxed{91\,kmh^{-1}}$$