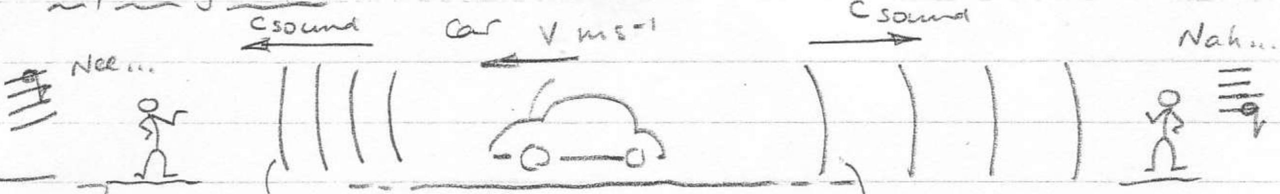
The Doppler effect + Red Shift {1 of 3} [AS Physics]

A. A passing car ....



this is for $v_{car} << c_{sound}$

sound wave fronts are closer → higher f

sound wave fronts are further apart → lower f

difference in frequency, Hz

static frequency Hz

fractional change in frequency

$$\frac{\Delta f}{f} = \frac{v}{c}$$

v – speed of object, m/s

c – speed of wave – sound 330 ms^{-1}

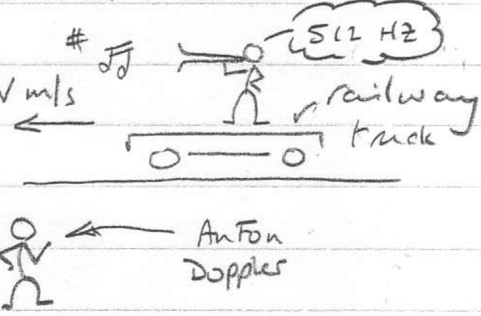
– light 3×10^8 ms^{-1}

[in the data sheet!]

A historical example...

$f_{approaching}$ = 530 Hz $f_{stationary}$ = 512 Hz ("C")

What is the speed of the truck?

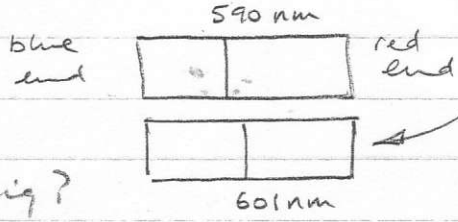


B: Red Shift

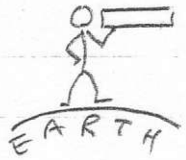
Na spectrum on Earth

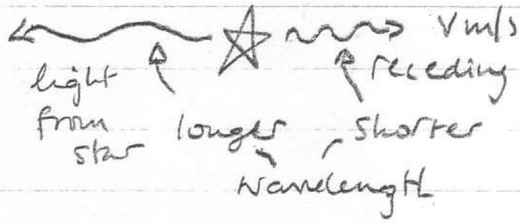
Na spectrum from star

How fast is the star receding?



the Na spectrum line is "red shifted" to longer wavelength because the star is receding.





- f_{Na} on Earth?

- f_{Na} from star?

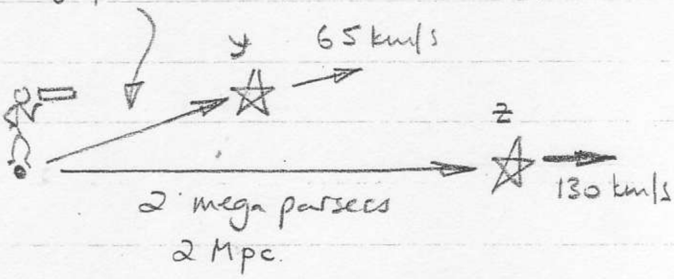
- Δf ?
- V_{star}.

C The Hubble Constant

Edwin Hubble (1920s)

found that....

- all stars and galaxies are receding (red-shifted)
- their recession speed is proportional to their distance from Earth.... twice as far ⟹ 2x recession speed



Hubble's "Law"

recession speed in km/s !! → —— $V_{object} = H\,d$ — distance in Mpc

1 Mpc = 3.16 light years

Hubble's constant... about 65 km/s/Mpc

1 light year is the distance light travels in 1 year....

- So how many metres is that?

- If a galaxy (not the choc bar!) is 200 light years away, how fast is it receding?

- If a star is receding at 600 km/s, how far away is it?

PAN

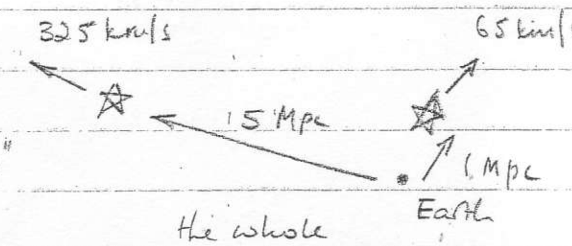
05.03 + 05.04

II Doppler Effect... Red Shift + Big Bang 3/3 (A's Phys)

D Big Bang!

All space objects appear red-shifted...
the whole Universe is expanding from a "Big Bang"
about 12,000 million years (12×10^9 y) ago
Q: at 65 km/s, how long would it take to go 1 Mpc?

TRN 05.03



the whole "fabric" of space is expanding.

E Exam Question...

- Exam problem..... The mercury line spectrum has a blue line at 436 nm. An astronomy student detects this line in a star's spectrum at 453 nm. How far away is the star?
(Hint: think.... f on earth + from star.... Δf .... V_{star} .... d star... got it?)

TRN
May '04

ANSWERS

The Doppler effect + Red Shift

TZN 3

AS Physics

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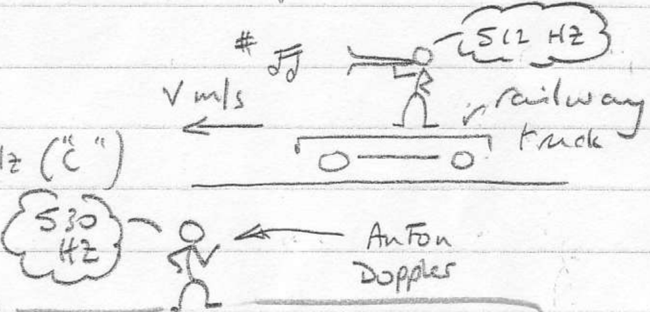
in the data sheet!

A historical example...



$f_{approaching} = 530\ Hz$ $f_{stationary} = 512\ Hz$ ("C")

What is the speed of the truck?

A: $\frac{\Delta f}{f} = \frac{530-512}{512} = \frac{18}{512} = 0.035 = \frac{v}{c}$

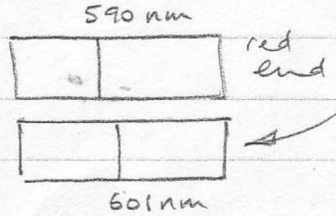
$v_{truck} = 0.035 \times 330 = 11.6\ m/s$ (3 s.f.)

B: Red Shift

Na spectrum on Earth

Na spectrum from star

How fast is the star receding?



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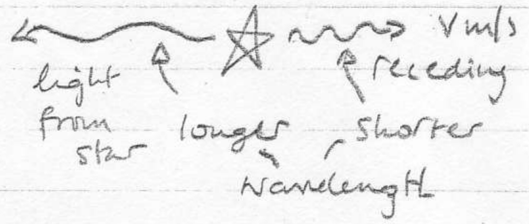

- f_{Na} on Earth?

$f = v/\lambda = \frac{3\times10^8}{590\times10^{-9}} = 5.085\times10^{14}\ Hz$

- f_{Na} from star?

$f = v/\lambda = \frac{3\times10^8}{601\times10^{-9}} = 4.992\times10^{14}\ Hz$

- Δf? $5.085\times10^{14} - 4.992\times10^{14} = 9.307\times10^{12}\ Hz$

- v_{star}.

$$\frac{\Delta f}{f} = \frac{9.307\times10^{12}}{5.085\times10^{14}} = 0.01830 = \frac{v_{star}}{c}$$

$v_{star} = 0.01830 \times 3\times10^8 = 5.49\times10^6$ m/s away from Earth

ANSWERS

Dopplər ... Red Shift ... and Big Bang! 2/of 2

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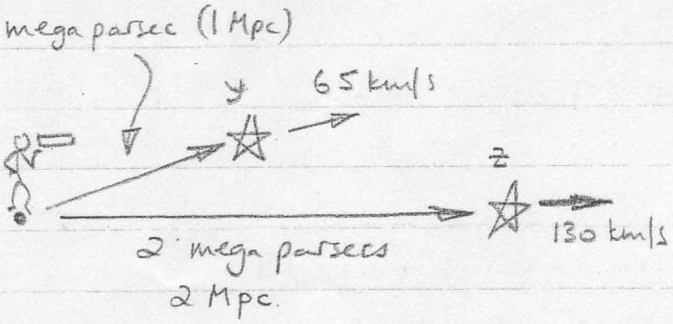


Hubble's "Law"

$$V_{object} = H\,d$$

recession speed in km/s !!

d — distance in Mpc; 1 Mpc = 3.16 light years

H — Hubble's constant ... about 65 km/s/Mpc

1 light year is the distance light travels in 1 year ....

- So how many metres is that?

A: $d = v \times t = 3 \times 10^8 \times (365 \times 24 \times 60 \times 60) = 9.46 \times 10^{15}$ m

- If a galaxy (not the choc bar!) is 200 light years away, how fast is it receding?

A: 200 light years / 3.16 = 63.3 Mpc so $V = 65 \times 63.3 = 4113$ km/s

- If a star is receding at 600 km/s, how far away is it?

A: $V = Hd \Rightarrow d = V/H = 600/65 = 9.23$ Mpc

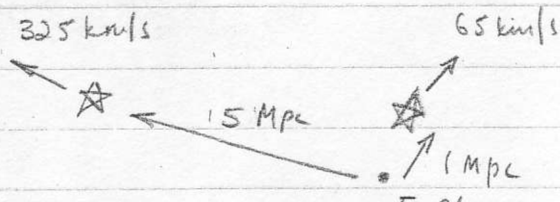
TRN

05.03 + 05.04 + 08.13

(ANSWERS)

II Doppler Effect... Red Shift + Big Bang 3/3 (AS Phys)

D Big Bang!



the whole "fabric" of space is expanding.

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about 12,000 million years (12×10^9 y) ago

Q: at 65 km/s, how long would it take to go 1 Mpc?

TJN 05.03

A:

1 light year = 9.46×10^{15} m

1 Mpc = 3.16 l.y = 2.99×10^{16} m

$$\frac{2.99 \times 10^{16} \text{ m}}{65\,000 \text{ m/s}} = 4.6 \times 10^{13} \text{ year}$$

E Exam Question...

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(Hint: think.... f on earth + from star.... Δf .... V_{star} .... d star... got it?)

A:

f_{Hg} on earth = V/λ = $3 \times 10^8 / 436 \times 10^{-9}$ = 6.881×10^{14} Hz

f_{Hg} star = V/λ = $3 \times 10^8 / 453 \times 10^{-9}$ = 6.623×10^{14} Hz

Δf = 2.582×10^{13} Hz

$$\frac{\Delta f}{f} = \frac{2.582 \times 10^3}{6.881 \times 10^{14}} = 0.0375 = \frac{V_{star}}{c} \Rightarrow V_{star} = 0.0375 \times 3 \times 10^8 = \underline{1.126 \times 10^7 \text{ m/s}}$$

V_{star} = 1.13×10^7 m/s = 1.13×10^4 km/s

$V_{star} = Hd \Rightarrow d_{star} = V/H = \dfrac{1.13 \times 10^4 \text{ km/s}}{65 \text{ km/s/Mpc}}$

= 173. Mpc

TJN
May '04 + 08.13