The Doppler Effect.

1. A higher
   B lower
   C doppler
   D effect.

2. a) $f_o = f_s\left(\frac{V}{V - V_s}\right)$

   b) $f_o = f_s\left(\frac{V}{V + V_s}\right)$

3. a) 412 Hz
   b) 389 Hz
   c) 800 Hz
   d) 1035 Hz
   e) $20ms^{-1}$
   f) $60ms^{-1}$

4. As spinning siren approaches observer, they will detect freq > 1200Hz.
   As spinning sire. moves away from observer, they will detect freq < 1200Hz.

5. a) $f_o = f_s\left(\frac{V}{V-V_s}\right)$
   $= 1000\left(\frac{340}{340-20}\right)$
   $= 1063Hz$.

   b) $f_o = f_s\left(\frac{V}{V+V_s}\right)$
   $= 1000\left(\frac{340}{340+20}\right)$
   $= 944Hz$.

6. a) $f_o = f_s\left(\frac{V}{V-V_s}\right)$
   $= 200\left(\frac{340}{340-25}\right)$
   $= 216 Hz$.

   b) $f_o = f_s\left(\frac{V}{V+V_s}\right)$
   $= 200\left(\frac{340}{340+25}\right)$
   $= 186Hz$.

7. $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$470 = 450\left(\frac{340}{340-V_s}\right)$

$V_s = 14.5 ms^{-1}$

8. $f_s = 500Hz$.

$(f_o)_{approaches} = 540Hz$.

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

$540 = 500\left(\frac{340}{340-V_s}\right)$

$\frac{540}{500} = \frac{340}{(340-V_s)}$

$540(340-V_s) = 340 \times 500$

$183600 - 540V_s = 170000$

$V_s = 25.2ms^{-1}$

Then. $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$= 500\left(\frac{340}{340+25.2}\right)$

$= 466Hz$.

9. Lowest $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$= 540\left(\frac{340}{340+10}\right)$

$= 525Hz$

Highest $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$= 540\left(\frac{340}{340-10}\right)$

$= 556Hz$.

10. a) Approaching $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$= 300\left(\frac{340}{340-20}\right)$

$= 319Hz$.

$\lambda = V/f = 340/319 = \underline{1.07m}$

b) Away $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$= 300\left(\frac{340}{340+20}\right)$

$= 283Hz$.

$\lambda = V/f = 340/283 = \underline{1.2m}$

11. $f_s = 1000Hz$.
$v = 10 m s^{-1}$.

a) Away $f_o = f_s \left(\frac{V}{V+V_s}\right)$

$= 1000 \left(\frac{340}{340+10}\right)$

$= 971Hz$.

b) Towards. $f_o = f_s \left(\frac{V}{V-V_s}\right)$

$= 1000 \left(\frac{340}{340-10}\right)$

$= 1030Hz$.

12. $f_o = 10\%$ less than f_s
$\therefore f_o = 0.9 f_s$.

Away $f_o = f_s \left(\frac{V}{V+V_s}\right)$

$0.9(340 + V_s) = 340$.

$306 + 0.9V_s = 340$

$V_s = \frac{340 - 306}{0.9}$

$= 37.8 m s^{-1}$

13. Towards.

a) $f_o = f_s \left(\frac{V}{V-V_s}\right)$

$= 350 \times 10^3 \left(\frac{340}{340-3.6}\right)$

$= 354 kHz$

b) Decrease. V_s decreases $(V - V_s)$ increases
ie denominator increases.
$\therefore f_o$ decreases

c) Away $f_o = f_s \left(\frac{V}{V+V_s}\right)$

= ~~1500~~

$= 350 \left(\frac{340}{340+4.5}\right)$

$= 345 kHz$

14. a) $54 km h^{-1} = \frac{54 \times 1000}{3600} = 15 m s^{-1}$

b). Towards $f_o = f_s \left(\frac{V}{V-V_s}\right)$

$= 1500 \left(\frac{340}{340-15}\right) = 1569 Hz$

14 c) Away $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$= 1500\left(\frac{340}{340+15}\right)$

$= 1437 Hz$.

15. Towards $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$640 = 600\left(\frac{340}{340-V_s}\right)$

$640(340-V_s) = 600 \times 340$

$217600 - 640V_s = 204000$

$V_s = \frac{204000 - 217600}{-640}$

$= 21.3 ms^{-1}$

16. a) $V = \omega r$

$= 2\pi f r$

$= 2\pi \times 3 \times 0.8$

$= 15.1 ms^{-1}$

c) Towards $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$= 2200\left(\frac{340}{340-15.1}\right)$

$= 2302 Hz$.

b) Away $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$= 2200\left(\frac{340}{340+15.1}\right)$

$= 2106 Hz$.

17. Towards $f_o = f_s\left(\frac{V}{V-V_s}\right)$

$460 = f_s\left(\frac{340}{340-V_s}\right)$

$\frac{460(340-V_s)}{340} = f_s$ — (1)

Away $f_o = f_s\left(\frac{V}{V+V_s}\right)$

$410 = f_s\left(\frac{340}{340+V_s}\right)$ — (2)

Sub ① in ②

$$410 = \frac{460(340 - V_s)}{\cancel{340}}\left(\frac{\cancel{340}}{340 + V_s}\right)$$

$$410 = \frac{156400 - 460V_s}{340 + V_s}$$

$$410(340 + V_s) = 156400 - 460V_s$$

$$139400 + 410V_s = 156400 - 460V_s.$$

$$(410 + 460)V_s = 156400 - 139400$$

$$V_s = 19.5 ms^{-1}$$

$d = 3km$

$V_s = 19.5 ms^{-1}$

$t = ?$

$t = d/V = 3000/19.5 = 153.8s.$

18. Towards $f_o = f_s\left(\frac{V}{V - V_s}\right)$

$$1200 = 1100\left(\frac{\cancel{340}V}{\cancel{340}V - 10}\right)$$

$$1200(V - 10) = 1100V.$$

$$1200V - 12000 = 1100V.$$

$$V = 120 ms^{-1}$$

Expanding Universe

19. A longer
B red
C shorter
D blue
E away.

20. $\Delta Z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

a) 1.01×10^{-1}
b) 5.07×10^{-2}
c) 525 nm
d) 682 nm
e) 434 nm
f) 365 nm.

Hubbles Law

21 a) $1 \times 365 \times 24 \times 3600 \times 3 \times 10^8 = 9.46 \times 10^{15}$ m.
b) $50 \times$ " $= 4.73 \times 10^{17}$ m
c) $100\,000 \times$ " $= 9.46 \times 10^{20}$ m.
d) $16,000,000,000 \times$ " $= 1.51 \times 10^{26}$ m.

22. a) $\frac{1.44 \times 10^{11}}{9.46 \times 10^{15}} = 1.52 \times 10^{-5}$ l.years.
b) 4.2 l.years
c) 5.19×10^7 l.years

23. $H_o = \frac{V}{d}$.

a) $V = H_o d$
$= 2.4 \times 10^{-18} \times 7.1 \times 10^{22}$
$= 1.7 \times 10^5$ ms^{-1}.

c) $V = H_o d$
$= 4.54 \times 10^6$ ms^{-1}

b) $Z = \frac{V}{C} = \frac{1.7\times10^5}{3\times10^8} = 5.67\times10^{-4}$

d) $Z = V/_C = 1.51\times10^{-2}$

e) $d = \frac{V}{H_0} = \frac{1.7\times10^6}{2.4\times10^{-18}} = 7.08\times10^{23}$ m.

g) $d = \frac{V}{H_0} = 9.21\times10^{23}$ m

f) $Z = \frac{V}{C} = \frac{1.7\times10^6}{3\times10^8} = 5.67\times10^{-3}$

h) $Z = \frac{V}{C} = 7.37\times10^{-3}$

24. a) $\Delta z = \frac{\lambda_0 - \lambda_r}{\lambda_r}$

$= \frac{466-434}{434}$

$= 7.37\times10^{-2}$

b) $V = ZC$

$= 7.37\times10^{-2} \times 3\times10^8$

$= 2.21\times10^7\ ms^{-1}$

c) Away since $\lambda_0 > \lambda_r$

25. a) $V = ZC$, $\Delta Z = \frac{\lambda_0 - \lambda_r}{\lambda_r}$

$= \frac{530-505}{505}$

$= 0.05$

$V = 0.50\times3\times10^8$

$= 1.49\times10^7\ ms^{-1}$

b) $d = \frac{V}{H_0}$

$= \frac{1.49\times10^7}{2.4\times10^{-18}}$

$= 6.21\times10^{24}$ m.

26. a) $0.074C = 0.074\times3\times10^8$

$= 2.22\times10^7\ ms^{-1}$

b) $d = \frac{V}{H_0} = \frac{2.22\times10^7}{2.4\times10^{-18}} = 9.25\times10^{+24}$ m.

27. a) $z = \frac{v}{c}$

$= \frac{2.4 \times 10^7}{3 \times 10^8}$

$= 0.08$

b) $\Delta z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

$0.08 = \frac{443 - \lambda_r}{\lambda_r}$

$0.08 \lambda_r = 443 - \lambda_r$

$(0.08 + 1) \lambda_r = 443$

$\lambda_r = 410 nm$

28 a) $\Delta z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

$= \frac{538 - 489}{489}$

$= 0.10$

$v = zc$

$= 0.1 \times 3 \times 10^8$

$= 3 \times 10^7 ms^{-1}$

b) $d = \frac{v}{H_o} = \frac{3 \times 10^7}{2.4 \times 10^{-18}} = 1.25 \times 10^{25} m$

$= \frac{1.25 \times 10^{25}}{9.46 \times 10^{15}}$

$= 1.32 \times 10^9$ light years

29. 1 000 million light years $= 1000 \times 10^6 \times 9.46 \times 10^{15}$

$= 9.46 \times 10^{24} m$

$v = d H_o$

$= 9.46 \times 10^{24} \times 2.4 \times 10^{-18}$

$= 2.27 \times 10^7 ms^{-1}$

30. a) $\lambda = \frac{v}{f}$

$= \frac{3\times10^8}{5\times10^{14}}$

$= 6\times10^{-7}$ m.

b) $z = \frac{v}{c} = \frac{3\times10^7}{3\times10^8} = 0.1$

$\Delta z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

$0.1 = \frac{\lambda_o - 600}{600}$

$\lambda_o = 660$ nm.

$f = v/\lambda = \frac{3\times10^8}{660\times10^{-9}} = 4.55\times10^{14}$ Hz.

31. a) $\Delta z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

$= \frac{506-486}{486}$

$= 0.04$

$v = zc$

$= 0.04 \times 3\times10^8$

$= 1.23\times10^7$ ms^{-1}.

b) $d = \frac{v}{H_0} = \frac{1.23\times10^7}{2.4\times10^{-18}} = 5.14\times10^{24}$ m.

$= \frac{5.14\times10^{24}}{9.46\times10^{15}}$

$= 544$ light years.

32. $\Delta z = \frac{\lambda_o - \lambda_r}{\lambda_r}$

$= \frac{660-656}{656}$

$= 0.0061$

$v = zc$

$= 0.0061\times3\times10^8$

$= 1.83\times10^6$ ms^{-1}.

33.

$$z = \frac{v}{c}$$

$$= \frac{2000}{3 \times 10^{8}}$$

$$= 6.67 \times 10^{-6}$$

$$z = \frac{\lambda_o - \lambda_r}{\lambda_r}$$

$$6.67 \times 10^{-6} = \frac{\lambda_o - 486.1 \times 10^{-9}}{486.1 \times 10^{-9}}$$

$$6.67 \times 10^{-6} \times 486.1 \times 10^{-9} = \Delta\lambda$$

$$\Delta\lambda = 3.24 \times 10^{-12}\,m$$

Big Bang Theory.

34.

a) CMBR
Abundance of light elements.
Expanding Universe (Hubbles Law).

35. CMBR.

36 a) UV $\lambda <$ Ultraviolet $\therefore$ P.

b) Amount of energy emitted increases.

c) Increases.

d) i)

ii)

Temp (K)	λ_{max}	$\lambda_{max} T$
6000	4.8×10^{-7}	2.88×10^{-3}.
5000	5.8 "	2.9×10^{-3}
4000	7.3 "	2.92×10^{-3}
3000	9.7 "	2.91×10^{-3}.

$Av.(\lambda_{max} T) = 2.9 \times 10^{-3}$.

$\therefore (\lambda_{max} T) = 2.9 \times 10^{-3}$.

e) i) $T = \dfrac{2.9 \times 10^{-3}}{2.7 \times 10^{-7}}$

$= 10740 K$

$= 11000 K$ (2 sig figs)

36. e) ii) $\lambda_{max} = \frac{2.9 \times 10^{-3}}{23000}$

$= 1.26 \times 10^{-7}$

$= 1.3 \times 10^{-7}$ m (2 sig figs)

iii) $T = \frac{2.9 \times 10^{-3}}{1.1 \times 10^{-3}}$

$= 2.6$ K.

iv) $\lambda_{max} = \frac{2.9 \times 10^{-3}}{310}$

$= 9.35 \times 10^{-6}$ m.

Temp of skin = 37°C

= 37 + 273

= 310 K.