## The Scale of Astrophysics

IB PHYSICS | ASTROPHYSICS

## IB Physics Data Booklet

| Sub-topic D. 1 - Stellar quantities | Sub-topic D. 2 - Stellar characteristics and stellar evolution |
| :---: | :---: |
| $d(\text { parsec })=\frac{1}{p(\text { arc-second })}$ | $\lambda_{\max } T=2.9 \times 10^{-3} \mathrm{~m} \mathrm{~K}$ |
| $\begin{array}{cc}  & p(\text { arc-second }) \\ & P=\sigma T^{4} \end{array}$ | $L \propto M^{3.5} \quad \lambda_{\max }(\text { metres })=\frac{2.90 \times 10^{-3}}{\mathrm{~T}(\text { kelvin })}$ |
| $b=\frac{L}{4 \pi d^{2}} \quad I=\frac{P}{A}=\frac{P}{4 \pi r^{2}}$ |  |
| Sub-topic D. 3 - Cosmology | Sub-topic D. 5 - Further cosmology (HL only) |
| $\begin{aligned} & z=\frac{\Delta \lambda}{\lambda_{0}} \approx \frac{v}{c} \\ & z=\frac{R}{R_{0}}-1 \\ & v=H_{0} d \\ & T \approx \frac{1}{H_{0}} \end{aligned}$ | $\begin{aligned} & v=\sqrt{\frac{4 \pi G \rho}{3}} r \\ & \rho_{\mathrm{c}}=\frac{3 H^{2}}{8 \pi G} \end{aligned}$ |

## Anything look familiar?

## It's a Great Big Universe...



Animaniacs - Yakko's Universe

## The Solar System

|  | Mercury | Venus | Earth | Mars | Jupiter | Saturn | Uranus | Neptune |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Diameter <br> $[\mathrm{km}]$ | 4,880 | 12,104 | 12,756 | 6,787 | 142,800 | 120,000 | 51,800 | 49,500 |
| Distance | to Sun |  |  |  |  |  |  |  |
| to $\left[\times 10^{8} \mathrm{~m}\right]$ | 58 | 107.5 | 149.6 | 228 | 778 | 1,427 | 2,870 | 4,497 |



## Poor Pluto... :'(

## Definition of a Planet (as of 2006)

A celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its selfgravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.


## Measuring Distances

## Speed of Light: <br> $\mathrm{c}=3.00 \times 10^{8} \mathrm{~m} \mathrm{~s}^{-1}$

How far is one light year (ly)

$$
\begin{array}{r}
\frac{3.00 \times 10^{8} \mathrm{~m}}{1 \mathrm{~s}} \times \frac{60 \mathrm{~s}}{1 \min } \times \frac{60 \mathrm{~min}}{1 \mathrm{hr}} \times \frac{24 \mathrm{hr}}{1 \text { day }} \times \frac{365 \text { days }}{1 y r} \\
=9.46 \times 10^{15} \mathrm{myr}^{-1}
\end{array}
$$

## Measuring Distances

Average Distance between the Earth and the Sun
Astronomical $1.5 \times 10^{11} \mathrm{~m}$

$$
\begin{gathered}
\text { Unit } \\
{[\mathrm{AU}]}
\end{gathered}
$$



## Measuring Distances

1 light year $(\mathrm{ly})=9.46 \times 10^{15} \mathrm{~m}$
The distance that light travels in an earth year

## 1 astronomical unit $(\mathrm{AU})=1.50 \times 10^{11} \mathrm{~m}$

The average distance between the earth and the sun

## Measuring Angles



## Parsecs

## 1 parsec $(p c)=3.26$ ly

distance at which the mean radius of the earth's orbit subtends an angle of one second of arc.
parsec stands for parallax angle of one second


## Parsecs

Why is this claim a little odd?

"It's the ship that made the Kessel run in less than 12 Parsecs."

distance

## IB Physics Data Booklet

## Unit conversions

1 radian $(\mathrm{rad}) \equiv \frac{180^{\circ}}{\pi}$
Temperature $(\mathrm{K})=$ temperature $\left({ }^{\circ} \mathrm{C}\right)+273$

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1 \text { light year (ly) = 9.46 < 1015 m}
1 parsec (pc) = 3.26 ly
1 astronomical unit (AU) = 1.50 }\times1\mp@subsup{0}{}{11}\textrm{m
```

1 kilowatt-hour $(\mathrm{kWh})=3.60 \times 10^{6} \mathrm{~J}$
$h c=1.99 \times 10^{-25} \mathrm{~J} \mathrm{~m}=1.24 \times 10^{-6} \mathrm{eV} \mathrm{m}$

| Stefan-Boltzmann constant | $\sigma$ | $5.67 \times 10^{-8} \mathrm{Wm}^{-2} \mathrm{~K}^{-4}$ |
| :--- | :--- | :--- |
| Coulomb constant | $k$ | $8.99 \times 10^{9} \mathrm{~N} \mathrm{~m}^{2} \mathrm{C}^{-2}$ |
| Permittivity of free space | $\varepsilon_{0}$ | $8.85 \times 10^{-12} \mathrm{C}^{2} \mathrm{~N}^{-1} \mathrm{~m}^{-2}$ |
| Permeability of free space | $\mu_{0}$ | $4 \pi \times 10^{-7} \mathrm{Tm} \mathrm{A}^{-1}$ |
| Speed of light in vacuum | $c$ | $3.00 \times 10^{8} \mathrm{~m} \mathrm{~s}^{-1}$ |
| Planck's constant | $h$ | $6.63 \times 10^{-34} \mathrm{~J} \mathrm{~s}$ |
| Elementary charge | $e$ | $1.60 \times 10^{-19} \mathrm{C}$ |

## The Black Hole - by the numbers

SIZE COMPARISON: THE M87 BLACK HOLE
OUR SOLAR SYSTEM

## EHT BCACK HOLE MACE SOURCE NSF <br> OURGE NSF

Just bigger than our solar system
6.5 billion times the mass of the Sun

55 million light years from Earth

Michael Moyer @mmoyr.
What a science journalist's Tweetdeck looks like right now


[^0]
## The Science Behind the Picture

## $5.18 \times 10^{23} \mathrm{~m}$

Remember: $1^{\circ}=3600$ arcseconds
1 arcsecond = 1,000,000 $\mu \mathrm{as}$
*60 uas is about the same as resolving a picture of an orange sitting on the surface of the moon

## The Science Behind the Picture

Each observation day, a telescope site tied to the EHT captures roughly 350 terabytes of data. That's around 10 times the amount of data collected daily at the Large Hadron Collider.

MIT Haystack Observatory



Each telescope of the EHT produced huge amounts of data, which were stored on high-performance helium-filled hard drives and flown to specialized supercomputers at the Max Planck Institute for Radio Astronomy and MIT Haystack Observatory to be combined into an image.


Measurements




[^0]:    Q 49
    〔】 1.7 K
    O 3.9 K
    ث

