2018 Ph H2 Q5
Section: The Expanding Universe
Topic: Hubble's Law and the Big Bang

Summary:
The question explores evidence supporting the Big Bang theory, involves a calculation of the age of the universe from a given value of the Hubble constant, and asks for explanations regarding differences in values and the cause of accelerated expansion.

(a)
State one other piece of evidence that supports the Big Bang theory.
▶️ **Answer:**

- **Cosmic Microwave Background Radiation**,

or

- **Olber's Paradox**,

or

- **Abundance of Hydrogen and Helium in the universe**

✅ **Mark: 1**
(Any one of the above is acceptable. Do not accept "CMBR" on its own.)

(b)(i)
Calculate the age of the universe, in years, obtained when using the student's value for the Hubble constant.

> Given:
> $H_0 = 2.0 \times 10^{-17}\ \text{s}^{-1}$
>
> Age of universe:
> $$\text{Age} = \frac{1}{H_0} = \frac{1}{2.0 \times 10^{-17}} = 5.0 \times 10^{16}\ \text{s}$$
>
> Convert seconds to years:
> $$\frac{5.0 \times 10^{16}}{60 \times 60 \times 24 \times 365.25} \approx 1.58 \times 10^{9}\ \text{years}$$

▶️ **Answer:** $1.6 \times 10^{9}\ \text{years}$

✅ **Marks: 2**

- 1 mark for correct use of formula
- 1 mark for correct final answer in years

(b)(ii)(A)
State why the value obtained in (b)(i) is different from the current estimate for the age of the universe (1.8 × 10⁹ years).

▶️ **Answer:**

- The student's value for H_0 is **too large**, or
- The student **drew an incorrect line of best fit**, or
- **Not enough data** at large distances

✅ **Mark: 1**

(b)(ii)(B)
Suggest a change that the student could make to their graph to obtain a value closer to the current estimate for the age of the universe.

▶️ **Answer:**

- Draw a more **accurate line of best fit**, or
- Use **more data**, or
- Use **current, more accurate data**

✅ **Mark: 1**

(c)
State what physicists think is responsible for the increasing rate of expansion of the universe.

▶️ **Answer:**

- **Dark energy**

✅ **Mark: 1**

✅ Final Answer Summary:

- **(a):** Cosmic microwave background radiation / Olber's paradox / Abundance of hydrogen & helium
- **(b)(i):** $1.6 \times 10^{9}\ \text{years}$
- **(b)(ii)(A):** Hubble constant too large
- **(b)(ii)(B):** Draw better line of best fit / Use more data
- **(c):** Dark energy

🔁 Revision Tips:

- Hubble's Law links recessional velocity and distance: $v = H_0 d$
- The reciprocal of H_0 gives an estimate of the **age of the universe**, assuming constant expansion.
- **CMBR**, **elemental abundances**, and **Olber's Paradox** are key observational supports for the Big Bang.
- An increasing rate of expansion suggests the influence of **dark energy**, a form of negative-pressure energy.