

Section A test for Clockwork Universe: Time 30 minutes

1. The graph in Fig. 1b shows the decay curve obtained from the circuit of Fig. 1a

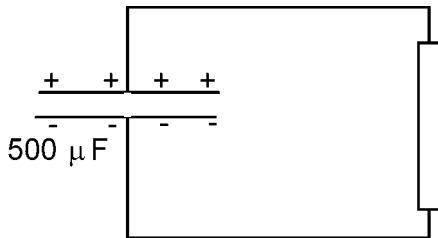


Fig. 1 a

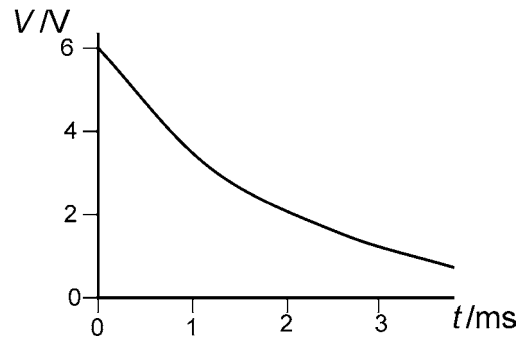


Fig. 1b

- (a) Calculate the charge on the capacitor at the time $t = 0$.

$$C = Q/V \quad \checkmark$$

$$\text{So } Q = CV = 500 \times 10^{-6} \text{ F} \times 6.0 \text{ V} = 3.0 \times 10^{-3} \text{ C} \quad \checkmark \text{ m} \quad \checkmark \text{ e} \quad [3]$$

- (b) Calculate the energy stored in the capacitor at time $t = 0$.

$$E = \frac{1}{2}QV = 0.5 \times 3.0 \times 10^{-3} \text{ C} \times 6.0 \text{ V} = 9.0 \times 10^{-3} \text{ J} \quad \checkmark \text{ m} \quad \checkmark \text{ e} \quad [2]$$

- (c) Show that the resistor has a resistance of about 4Ω .

From the graph, the time constant $RC \approx 2 \text{ ms}$ (time to go to $1/3$ of initial value) \checkmark

$$RC = 2 \times 10^{-3} \text{ s} \Rightarrow R = 2 \times 10^{-3} / 500 \times 10^{-6} \text{ F} = 4.0 \Omega \quad \checkmark \quad [2]$$

- (d) Calculate the current flowing at time $t = 0$.

$$R = V/I \quad \checkmark \Rightarrow I = V/R = 6.0 \text{ V} / 4.0 \Omega = 1.5 \text{ A} \quad \checkmark$$

[2]

2. Fig. 2 shows a satellite orbiting the Earth at a distance of 1.0×10^7 m from the centre of the Earth.

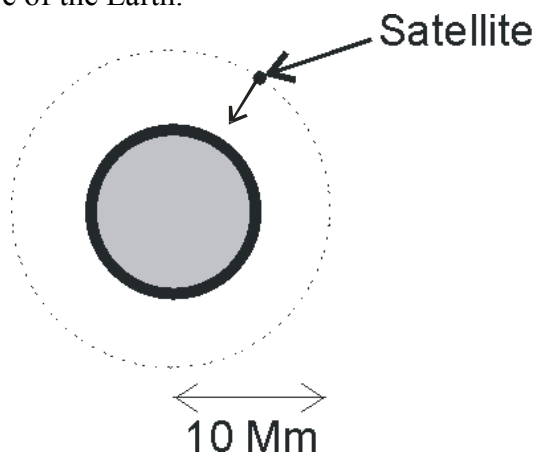


Fig. 2

- (a) Draw an arrow on the satellite in Fig. 2 to indicate the direction of the resultant force acting upon it. [1]
- (b) Show that the gravitational field strength g at the satellite is about 4 N kg^{-1} .
 $G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
 Mass of Earth, $M_E = 6.0 \times 10^{24} \text{ kg}$

$$g = GM/r^2 \quad \checkmark = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 6.0 \times 10^{24} \text{ kg} / (1.0 \times 10^7 \text{ m})^2$$

$$= 4.02 \text{ N kg}^{-1} \approx 4 \text{ N kg}^{-1} \quad \checkmark \text{ m} \quad \checkmark \text{ e}$$

[3]

3. A balloon has a volume of $2.4 \times 10^{-3} \text{ m}^3$ at a pressure of $1.0 \times 10^5 \text{ Pa}$ and a temperature of 300 K .

- (a) Show that the balloon contains about 0.1 mol of gas.
 $R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$

$$pV = nRT \Rightarrow n = pV/RT$$

$$= 1.0 \times 10^5 \text{ Pa} \times 2.4 \times 10^{-3} \text{ m}^3 / (8.3 \text{ J mol}^{-1} \text{ K}^{-1} \times 300 \text{ K})$$

$$= 0.096 \text{ mol} \approx 0.1 \text{ mol} \quad \checkmark \text{ m} \quad \checkmark \text{ e}$$

[2]

- (b) Calculate the volume of the balloon if it is left in a freezer at 260 K , the pressure remaining constant at $1.0 \times 10^5 \text{ Pa}$.

You can use $pV = nRT$ again, but it's easier to use direct proportion
 Giving $V = 2.4 \times 10^{-3} \text{ m}^3 \times (260 \text{ K}/300 \text{ K}) = 2.1 \times 10^{-3} \text{ m}^3 \quad \checkmark \text{ m} \quad \checkmark \text{ e}$

[2]

4. A mole of helium is at a pressure of $5.0 \times 10^6 \text{ Pa}$ and occupies a volume of 0.02 m^3 . Calculate the r.m.s. speed of the molecules.

$$m_{\text{He}} = 6.7 \times 10^{-27} \text{ kg}$$

$$pV = \frac{1}{3} Nmc^2 \Rightarrow c^2 = \frac{3pV}{Nm} = \frac{3 \times 5.0 \times 10^6 \text{ Pa} \times 0.02 \text{ m}^3}{6 \times 10^{23} \text{ mol}^{-1} \times 6.7 \times 10^{-27} \text{ kg}} = 7.5 \times 10^7 \text{ m}^2 \text{ s}^{-2} \quad \checkmark \text{ m} \quad \checkmark \text{ e}$$

so the r.m.s. speed $\sqrt{c^2} = \sqrt{7.5 \times 10^7} \text{ m s}^{-1} = 8600 \text{ m s}^{-1} \checkmark$

5. A ball of mass 0.020 kg hangs on a rubber cord of spring constant 3.0 N m⁻¹. Calculate the period of oscillation when the ball is pulled down and released. [3]

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.020}{3.0}} \text{ s} = 0.51 \text{ s} \quad \checkmark \text{ m} \quad \checkmark \text{ e}$$

[2]

6. Here is a list of different energies (measured in J).

10⁻¹⁸ 10⁻¹⁹ 10⁻²⁰ 10⁻²¹

Which of the energies is closest to:

- (a) the average energy of a gas molecule at room temperature (300 K)?
.....10⁻²¹ J \checkmark [1]
- (b) the average energy of a gas molecule in the Sun's photosphere (at a temperature of 6000 K).?
.....10⁻¹⁹ J \checkmark [1]

$$k = 1.4 \times 10^{-23} \text{ J K}^{-1}$$

7. Here are four different (correct) pieces of astronomical evidence.

- A Distant galaxies are receding at higher speeds than closer ones
- B The entire sky is full of microwave radiation at a temperature of about 3 K
- C The ratio of hydrogen to helium in the universe is about 3:1 by mass
- D The mass of the universe, from gravitational observations, is much greater than the mass predicted from visible stars and galaxies.

Which **one** of these is **not** evidence for the Hot Big Bang theory?

AnswerD... \checkmark [1]