Astrophysics and Cosmology

Please revise Topic 11 (Astrophysics and Cosmology) and solve the following questions:

1. (a) What is meant by the Doppler effect (electromagnetic Doppler effect) when applied to light?

.....

.....

.....

(2)

(b) Edwin Hubble reached a number of conclusions as a result of observations and measurements of red-shift. State two of these conclusions.

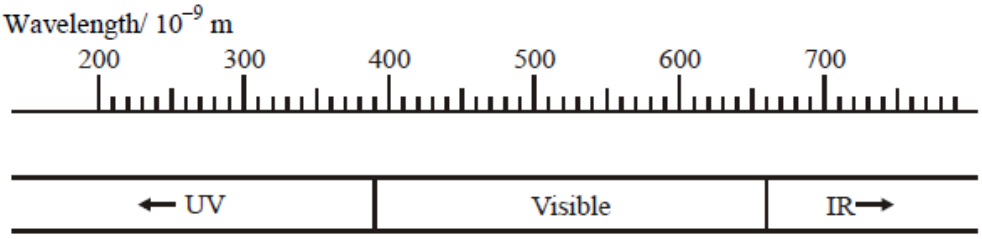
.....

.....

.....

(2)

(c) The diagram gives values of wavelength for part of the electromagnetic spectrum.



A very hot distant galaxy emits violet light just at the edge of the visible spectrum. Estimate the maximum velocity the galaxy could have so that visible light could still be detected as it moves away from the Earth.

.....

.....

.....

.....

(4)

(d) The fate of the Universe is dependent on the average mass-energy density of the Universe. What is meant by the critical density of the Universe?

.....

.....

.....

(2)

2. Hubble's law can be represented by the formula $v = Hd$.

(a) State the unit of the Hubble constant H.

.....

(1)

(b) Show how the age of the Universe can be estimated by using the above formula. State an assumption that has to be made.

.....

.....

.....

.....

.....

.....

.....

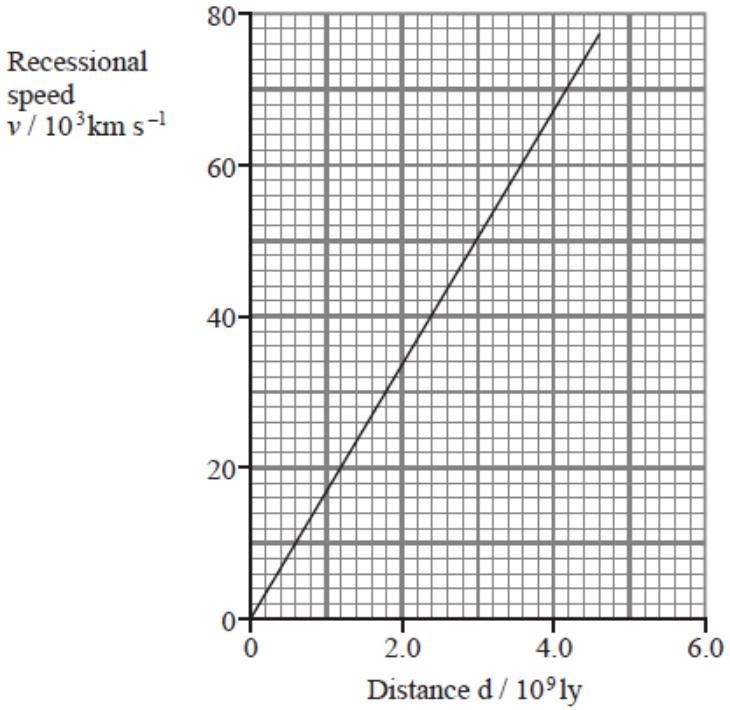
Assumption: .....

.....

.....

(4)

3. (a) Edwin Hubble examined the relationship between the recessional speed of galaxies, v, and their distance, d, from Earth. The graph shows the best-fit line for his results.



(i) Use the graph to determine a value for the Hubble constant, H, in s^{-1}. Show your working.

.....

.....

.....

.....

.....

.....

.....

Hubble constant = ...s^{-1}

(4)

(ii) What is the main source of uncertainty in the value of H?

.....

(1)

(b) Explain how the Hubble constant provides us with an estimate for the age of the Universe, t.

.....

.....

.....

.....

.....

.....

(2)

(c) Ionised calcium has a line spectrum which includes a spectral line of wavelength 393 nm. The observed wavelength of this calcium line in the radiation from a distant galaxy is 469 nm. Calculate the galaxy's recessional speed.

.....

.....

.....

.....

.....

Recessional speed = ...

(3)

(d) Briefly explain how the value of the average mass-energy density of the Universe will determine whether the Universe is open or closed.

.....

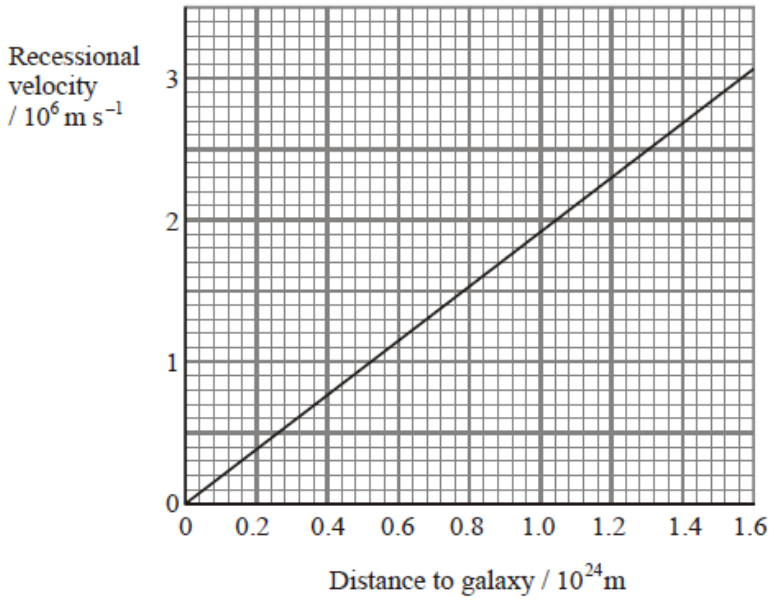
.....

.....

.....

(2)

4. (a) The graph shows the best-fit line obtained when recessional velocity is plotted against distance from Earth for a large number of galaxies.



Use this graph to calculate a value for the Hubble constant.

.....

.....

.....

Hubble constant = ...

A spectral line measured using a laboratory source has a wavelength of 372.7 nm. The same line, measured in light from a distant galaxy, has an apparent wavelength of 410.0 nm. Estimate the distance of this galaxy from Earth.

.....

.....

.....

.....

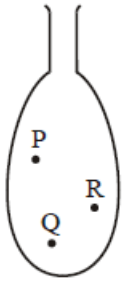
.....

.....

Distance = ...

(4)

(b) The diagram shows a deflated balloon. It has three dots on its surface, labelled P, Q and R. In the space next to the diagram, draw the balloon as it would appear when fully inflated. Mark the new positions of the three dots.



(2)

Explain how the inflation of the balloon can be used to model the expansion of the Universe. You may be awarded a mark for the clarity of your answer.

.....

.....

.....

.....

.....

.....

.....

(4)

5. Discuss the ultimate fate of the Universe. Your answer should include reference to dark matter and the reason why the fate of the Universe is uncertain.

.....

.....

.....

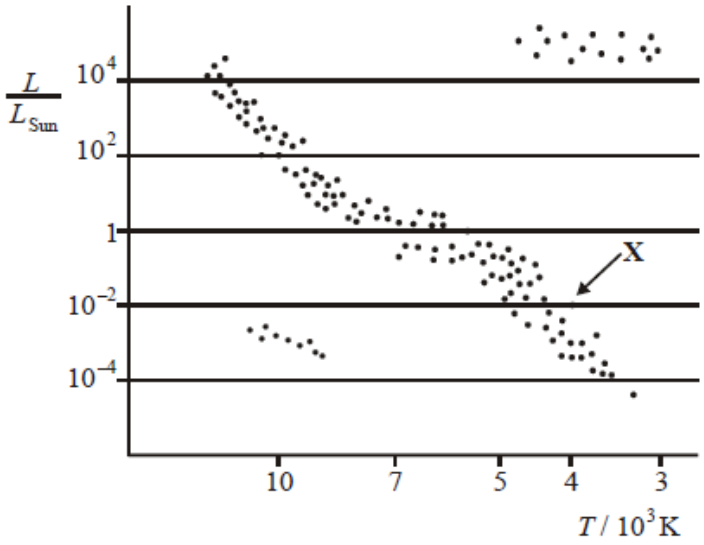
.....

.....

.....

.....

6. In the Hertzsprung-Russell (HR) diagram below, the dots represent stars.



What does T, on the horizontal axis, represent?

.....

.....

(1)

Circle the dot on the diagram which represents our Sun.

(1)

Calculate the flux reaching the Earth from the star marked **X** on the HR diagram.

Distance from **X** to the Earth = 500 parsec
1 parsec = 3.09×10^{16} m
$L_{sun} = 3.9 \times 10^{26}$ W

.....

.....

.....

.....

.....

.....

(3)

What force holds our Sun together?

.....

(1)

Explain how the nuclear processes within the Sun are able to release energy.

.....

.....

.....

.....

.....

.....

.....

(3)

At the end of the Sun's life, when energy can no longer be released in this manner, theory predicts that the Sun will become a larger star, of about the same mass, called a red giant.

(i) How will this change affect the Sun's gravitational pull on an outer planet? Explain your reasoning.

.....

.....

.....

.....

(ii) On the HR diagram above, draw an arrow to represent the change in position of the Sun.

(3)

7. Using the usual symbols write down an equation for

(i) Newton's law of gravitation

.....

(ii) Coulomb's law

.....

(2)

State one difference and one similarity between gravitational and electric fields.

Difference .....

.....

Similarity .....

(2)

A speck of dust has a mass of 1.0×10^{-18} kg and carries a charge equal to that of one electron. Near to the Earth's surface it experiences a uniform downward electric field of strength 100 N C^{-1} and a uniform gravitational field of strength 9.8 N kg^{-1}.

Draw a free-body force diagram for the speck of dust. Label the forces clearly.

Calculate the magnitude and direction of the resultant force on the speck of dust.

.....

.....

.....

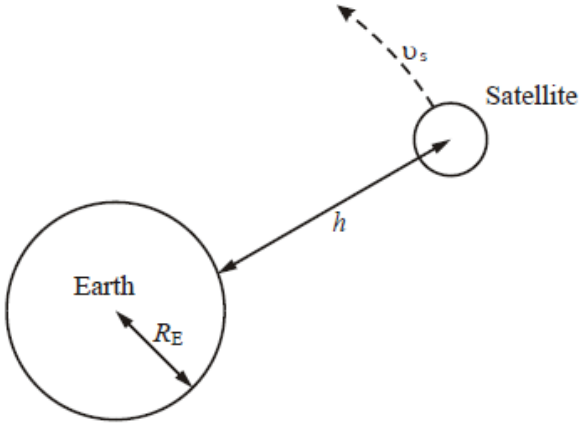
.....

.....

Force = ...

(6)

8. The diagram (not to scale) shows a satellite of mass m_s in circular orbit at speed υ_s around the Earth, mass M_E. The satellite is at a height h above the Earth's surface and the radius of the Earth is R_E.



Using the symbols above write down an expression for the centripetal force needed to maintain the satellite in this orbit.

.....

.....

.....

(2)

Write down an expression for the gravitational field strength in the region of the satellite.

.....

.....

.....

State an appropriate unit for this quantity.

.....

(3)

Use your two expressions to show that the greater the height of the satellite above the Earth, the smaller will be its orbital speed.

.....

.....

.....

.....

.....

(3)

Explain why, if a satellite slows down in its orbit, it nevertheless gradually spirals in towards the Earth's surface.

.....

.....

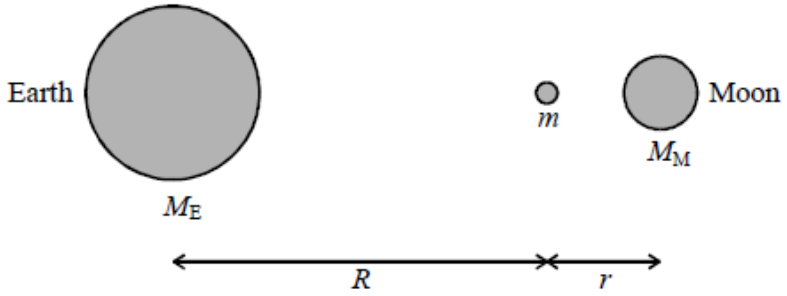
.....

.....

.....

(2)

9. The diagram shows a body of mass m situated at a point which is a distance R from the centre of the Earth and r from the centre of the Moon.



The masses of the Earth and Moon are M_E and M_M respectively. The gravitational constant is G.

Using the symbols given, write down an expression for

(i) the gravitational force of attraction between the body and the Earth,

.....

(ii) the gravitational force of attraction between the body and the Moon.

.....

(2)

The resultant gravitational force exerted upon the body at this point is zero. Calculate the distance R of the body from the centre of the Earth given that

$$r = 3.9 \times 10^7 \text{ m} \text{ and } M_E = 81\, M_M$$

.....

.....

.....

.....

.....

$R =$ .....

(3)

10. The orbit of the Moon, which has a mass m, is a circle of approximate radius $60R$, where R is the radius of the Earth. Show that the gravitational attraction between the Earth, mass M, and the Moon is given by

$$\frac{GMm}{3600R^2}$$

.....

.....

(1)

The mass of the Earth is 6.0×10^{24} kg and its radius is 6.4×10^6 m. Show that the orbital speed of the Moon around the Earth is approximately 1 km s^{-1}.

.....

.....

.....

.....

.....

.....

.....

(4)

Hence confirm that it takes the Moon about 30 days to orbit the Earth.

……

……

……

……

……

……

……

(4)