Edexcel Physics Unit 5

Topic Questions from Papers

Astrophysics

13 When nearby stars are observed over a period of a year, their positions are seen to move in tiny ellipses relative to the background of more distant stars.

(a) Explain why relative movement of these nearby stars is observed.

(3)

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(b) By means of a labelled diagram, outline the steps necessary for this effect to be used to find the distance to nearby stars.

(3)

(c) The effect is too small for the distances to more distant stars to be determined. Outline a method which can be used for more distant stars.

(1)

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(Total for Question 13 = 7 marks)

*15 The Sun behaves as an approximate black-body radiator with peak energy radiation occurring at a wavelength of 5.2×10^{-7} m.

(a) (i) Show that the Sun has a surface temperature of about 6000 K.

(2)

(ii) The radiation received from the Sun at the top of the atmosphere is 1.37 kW m^{-2}. Show the Sun's luminosity is about 4×10^{26} W.

Distance from the Sun to the Earth = 1.49×10^{11} m

(2)

(iii) Hence calculate the radius of the Sun.

(2)

Radius = ...

(b) The huge power output of the Sun is due to nuclear fusion reactions taking place within its core. State and explain the conditions necessary for fusion to occur.

(3)

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(Total for Question 15 = 9 marks)

***17** The Hubble Space Telescope (HST) was launched in 1990 into an orbit of radius 6940 km. The satellite makes 15 complete orbits of the Earth every 24 hours and its position high above the Earth's atmosphere has allowed high quality images of extremely distant objects to be produced.

(a) (i) Show that the HST has a centripetal acceleration of about 8 m s^{-2}.

(4)

(ii) The HST is kept in orbit by the gravitational pull of the Earth. Use your answer to (a)(i) to calculate a value for the mass of the Earth.

(3)

Mass = ...

(b) The telescope was named in honour of Edwin Hubble who measured the red shift of light from a number of galaxies and related it to their distance from the Earth.

Explain what is meant by the term *red shift* in this context and state the inference that Hubble made from his measurements.

(2)

(c) The song "Nine Million Bicycles" by Katie Melua includes the lines, "We are 12 billion light years from the edge, that's a guess, no one can ever say it's true".

(i) Explain how the line "12 billion light years from the edge" implies an age of 12 billion years for the universe.

(2)

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(ii) Calculate the value of the Hubble constant consistent with an age of 12 billion years for the universe.

1 billion years = 3.15×10^{16} s

(2)

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Hubble constant = ...

(iii) These lyrics were famously contested by Dr Simon Singh in the Guardian newspaper. He argued that the correct age was 13.7 billion years, and disputed that scientists had guessed the age of the universe. As a result Katie performed the song with revised lyrics.

Discuss the suggestion in the song that values for the age of the universe are only guesses.

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(Total for Question 17 = 16 marks)

12 The planet Mars has a mean distance from the Sun of 2.3×10^{11} m compared with the Earth's mean distance from the Sun of 1.5×10^{11} m.

(a) Calculate the ratio $\dfrac{\text{Sun's radiation flux at distance of Mars}}{\text{Sun's radiation flux at distance of Earth}}$.

(2)

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Ratio = ...

(b) With reference to your answer in (a), comment on the suggestion that Mars could be capable of supporting life.

(2)

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(Total for Question 12 = 4 marks)

13 A Cepheid variable star contracts and expands repeatedly and as it does, so its luminosity varies. By measuring the period of this variation, astronomers can determine the star's average luminosity.

(a) A Cepheid variable star is a type of standard candle. Discuss the use of standard candles in astronomy.

(4)

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(b) As well as the variation in luminosity of the Cepheid, changes in the frequency of the detected radiation are also observed.

Suggest how the Doppler effect may account for these changes.

(2)

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(Total for Question 13 = 6 marks)

15 The Moon takes 27.3 days to make one complete orbit of the Earth.

(a) (i) Show that the orbital angular velocity of the Moon is about 3×10^{-6} rad s^{-1}.

(2)

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(ii) Calculate the radius of the Moon's orbit.

mass of Earth = 6.4×10^{24} kg

(4)

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Radius = ...

(b) The Moon is gradually moving further away from the Earth because of the action of tides.

(i) State and explain how this increasing distance affects the moon's orbital period.

(2)

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(ii) In 200 years the radius of the Moon's orbit is predicted to increase by 8 m.

Calculate the rate of increase of the radius of the orbit in cm per year.

(1)

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Rate of increase = ... cm per year

*(iii) In practice, the rate of increase of the orbital radius due to tidal action will not have been constant. Suggest why this rate of change might have been different in the very distant past.

(3)

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(Total for Question 15 = 12 marks)

18 Records of people walking on fire have existed for thousands of years. Walking across hot coals without getting burned does seem impossible, especially when the coals are at a temperature of 1500 K. However, as long as they do not take too long to walk across the coals, firewalkers won't get burned.

The explanation may have something to do with the relatively small amount of thermal energy involved. Although the coals are hot, the total amount of thermal energy transferred to the soles of the walker's feet is small. This is a little like quenching a red hot metal bar in a trough of cold water. The metal bar cools rapidly, transferring thermal energy to the water, but the rise in temperature of the water is quite small because of the relatively large value for the specific heat capacity of the water.

(a) Describe an experiment you could carry out to measure the specific heat capacity of a metal, assuming that you have a number of metal washers which can be heated to a known temperature in a Bunsen flame and plunged into a container of water. State the measurements that you would need to make and give the theoretical basis of the calculation that you would carry out.

What assumption would you make in calculating the specific heat capacity of the metal?

(4)

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(b) Coals used for firewalking typically glow a dull red, with the peak energy emission taking place at a wavelength of about 2 μm.

(i) To which region of the electromagnetic spectrum does this wavelength belong?

(1)

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(ii) Show that a peak wavelength of 2.00 μm corresponds to a black-body temperature of about 1500 K.

(2)

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(iii) The coals have an average radius of 2.5 cm. Assuming that each coal behaves as a black-body radiator, calculate the rate at which energy is radiated from each coal at a temperature of 1500 K.

(3)

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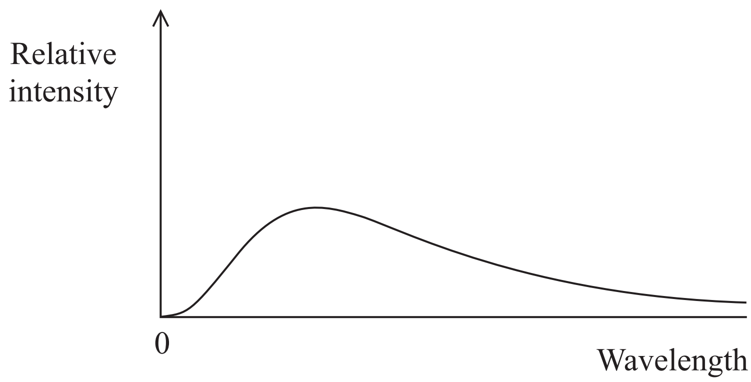
(iv) The graph shows the shape of the spectrum for radiation emitted from a black-body radiator at 1500 K. Add a second curve to show the shape of the spectrum for a temperature of 2000 K.

(2)



(Total for Question 18 = 12 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 (a) State what astronomers mean by a standard candle.

(1)

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(b) The luminosity of Sirius is 8.94×10^{27} W and its distance from the Earth is 8.08×10^{16} m.

Calculate the radiant energy flux of Sirius at the Earth.

(2)

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Radiant energy flux = ...

(Total for Question 11 = 3 marks)

12 (a) Derive an expression for the gravitational field strength g at a distance r from the centre of a mass M. Use the list of equations at the end of this question paper.

(2)

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(b) Use your expression to calculate g at the surface of the Earth.

mass of Earth $M_E = 5.97 \times 10^{24}$ kg
radius of Earth $r_E = 6.38 \times 10^6$ m

(1)

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g = ...

(Total for Question 12 = 3 marks)

16 Polonium-210 is an alpha-emitter with a half-life of 138 days. It emits alpha particles of energy 5.3 MeV as it decays to a stable isotope of lead.

One small pellet of polonium-210 contains 1.3×10^{21} atoms.

(a) (i) Show that the initial activity of this polonium pellet is about 8×10^{13} Bq.

(3)

(ii) Hence show that the rate of energy release by the pellet is more than 60 W.

(3)

(b) The radius of the pellet is 2.25 mm and its equilibrium temperature would be about 1000 K.

(i) Assuming that 5% of the energy released is radiated away, show that this approximate value of temperature is correct.

(3)

(ii) Calculate the wavelength at which peak energy radiation occurs.

(2)

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Wavelength of peak energy radiation = ...

(iii) State the region of the electromagnetic spectrum in which this wavelength of radiation would be found.

(1)

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(c) Explain why very small quantities of polonium-210 are a health hazard only if taken into the body.

(2)

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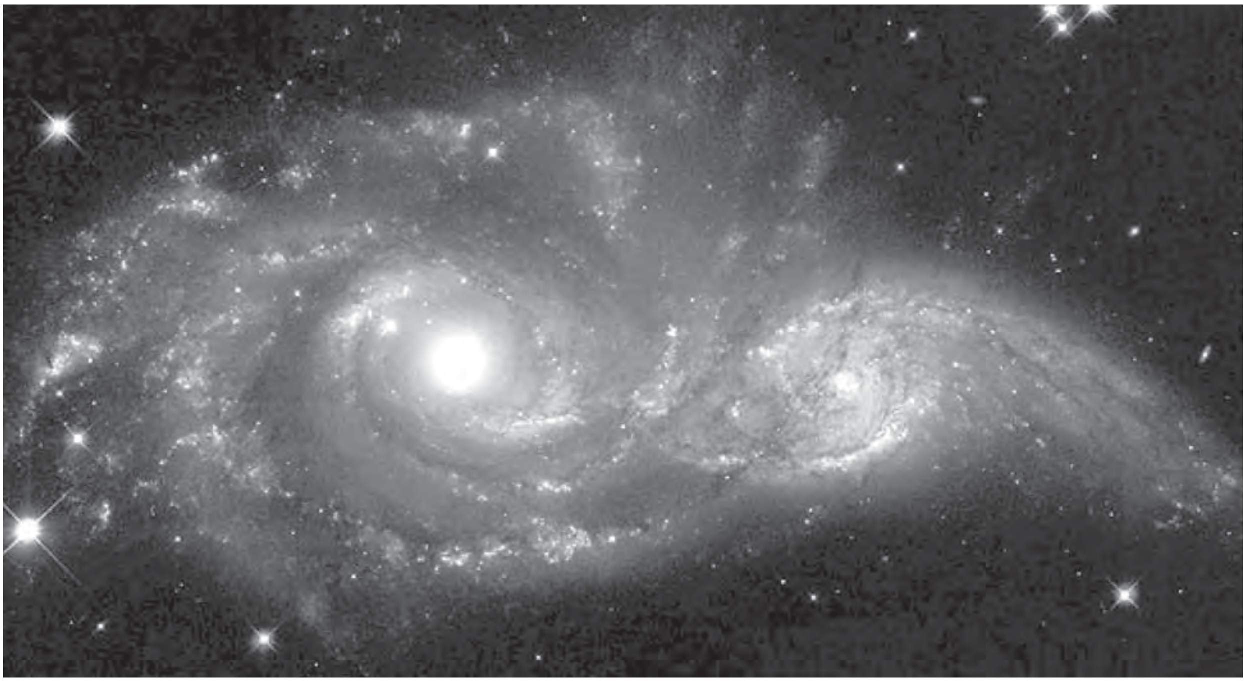
(Total for Question 16 = 14 marks)

18 Current theory predicts that there is a massive black hole at the centre of every galaxy. It is suggested that if galaxies approach, then their central black holes begin to orbit each other until the galaxies merge.



In 2009, astronomers found convincing evidence of two such black holes orbiting as a binary system. From data collected, they estimated that the separation of the black holes was 3.2×10^{15} m and that their masses were 1.6×10^{39} kg and 4.0×10^{37} kg.

(a) (i) State the origin of the force that maintains the black holes in an orbit.

(1)

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(ii) Show that the magnitude of this force is about 4×10^{35} N.

(2)

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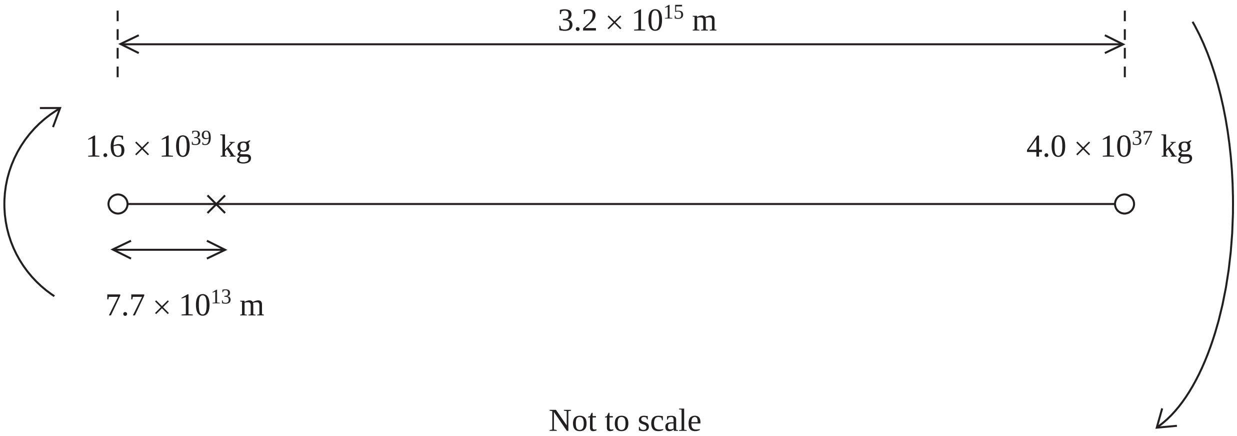
(iii) The black holes orbit about a point 7.7×10^{13} m from the larger mass black hole.



Not to scale

Show that the orbital time of the binary system is about 100 years.

(3)

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(b) As the black holes swallow up matter, radiation is emitted. To observers on Earth this radiation appears to be red shifted.

*(i) State what red shift means and discuss the conclusions that can be drawn from the observation that radiation from all distant galaxies is red shifted.

(3)

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(ii) Suggest why the light from both black holes is red shifted, even though the black holes are orbiting each other and hence moving in opposite directions.

(2)

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(iii) The observed red shift for the two black holes was 0.38.

Calculate the distance of the merging galaxies from the Earth.

$H_o = 1.6 \times 10^{-18}\ s^{-1}$

(3)

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Distance from the Earth = ...

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 In a physics lesson a student learns that the Earth is 81 times more massive than the Moon. Searching the Internet, she is surprised to discover that the gravitational field strength at the surface of the Earth is only 6 times greater than that at the surface of the Moon.

Use the above data to compare the radius of the Earth with that of the Moon.

(3)

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(Total for Question 11 = 3 marks)

12 The Earth can be considered to be a black body radiator at a temperature of 25 °C.

radius of Earth = 6380 km

(a) Calculate the total power radiated from the Earth.

(2)

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Total power radiated = ...

(b) Calculate the wavelength of the peak energy radiation for the Earth.

(2)

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Wavelength of the peak energy radiation = ...

(c) State the region of the electromagnetic spectrum in which this wavelength is found.

(1)

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(Total for Question 12 = 5 marks)

16 (a) The Moon orbits the Earth in a circular path.

Explain why the Moon maintains this circular path and what determines the radius of the path.

(2)

(b) A bucket is swung in a vertical, circular path as shown.

The bucket is half filled with water and swung. The water stays in the bucket, even at the top of the circular path, as long as the speed of the bucket exceeds a certain value.

Explain why.

(3)

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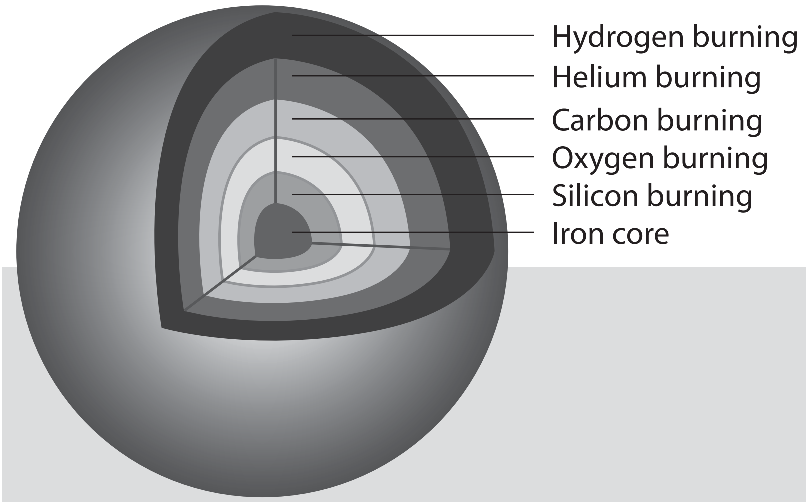
(Total for Question 16 = 5 marks)

19 The following passage is taken from a newspaper article.

Stars exist by fusing hydrogen within their cores. This process generates heat which pushes the star outwards. This outward pressure is matched by the gravitational forces pulling the star inwards. This maintains an equilibrium, allowing the star to radiate away vast amounts of energy for long periods of time. Our Sun has been in this state for about 4.5 billion years.

Eventually the star runs out of hydrogen to fuse, and so changes occur which allow fusion of helium to form heavier elements. Massive stars can produce elements up to iron in their cores by fusion.



Once a star's core has been converted into iron no further fusion can take place and the rapid collapse of the star results in a supernova explosion.

The remnant of the supernova may be a neutron star or black hole, depending upon the remnant's mass.

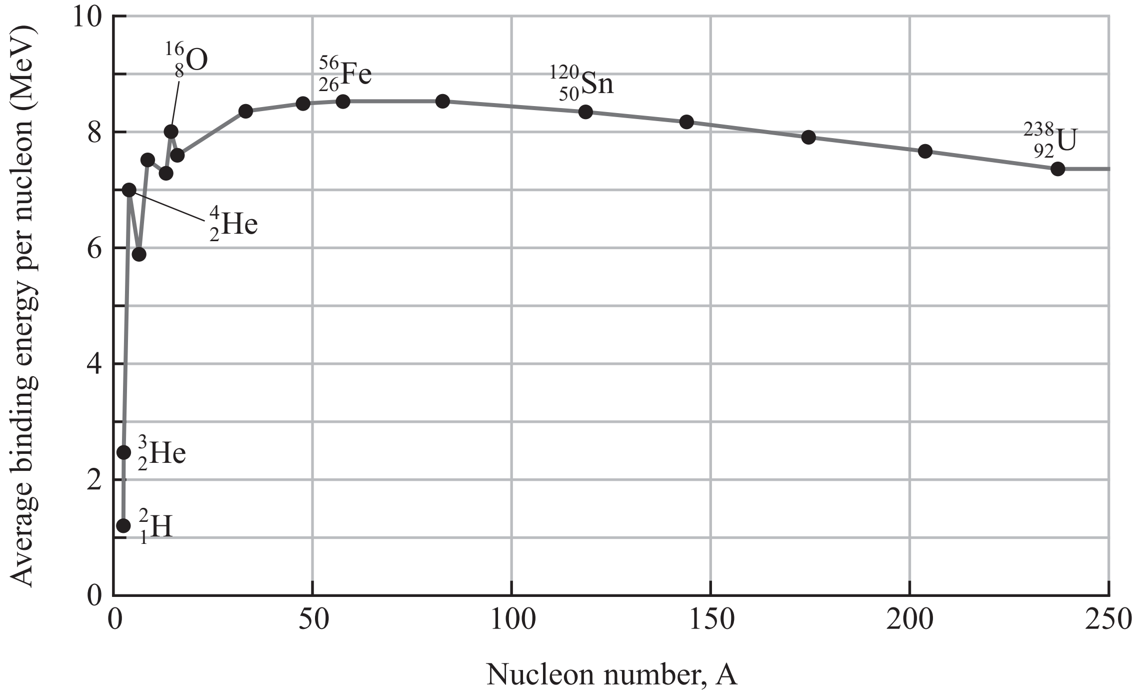
*(a) The conditions needed for fusion to occur make it difficult to replicate outside of a star.

State and explain:

- how the process of fusion is able to release energy
- the conditions necessary for fusion to occur
- why the conditions are difficult to replicate outside of a star.

(6)

(b) The graph shows the average binding energy per nucleon for a range of isotopes.



Massive stars can only produce elements up to iron (Fe) in their cores by fusion.
Use information from the graph to explain why.

(3)

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A type 1a supernova occurs when a white dwarf star in a close binary system accumulates matter from its companion star. This eventually leads to a supernova outburst. Type 1a supernovae are used by astronomers as standard candles.

(c) (i) State what is meant by a standard candle.

(1)

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(ii) A type 1a supernova is observed in a distant galaxy. Its flux at the Earth is measured to be 1.84×10^{-15} W m^{-2}. Theory predicts that it has a luminosity of 2.0×10^{36} W.

Show that the distance of the galaxy from the Earth is about 9×10^{24} m.

(2)

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(iii) The light from the galaxy is found to be red-shifted. State what this tells us about the galaxy.

(1)

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(iv) The redshift is measured to be 0.064. Calculate a value for the Hubble constant.

(3)

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Hubble constant = ...

(Total for Question 19 = 16 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 In 1965, two American scientists, Penzias and Wilson, were testing a very sensitive microwave detector. They discovered that the detector was picking up microwave "noise" at a frequency of 160 GHz that appeared to come from all directions equally. Upon investigation they found that the "noise" was the same day and night, throughout the year.

Suggest how this microwave "noise" may show evidence for an expanding universe.

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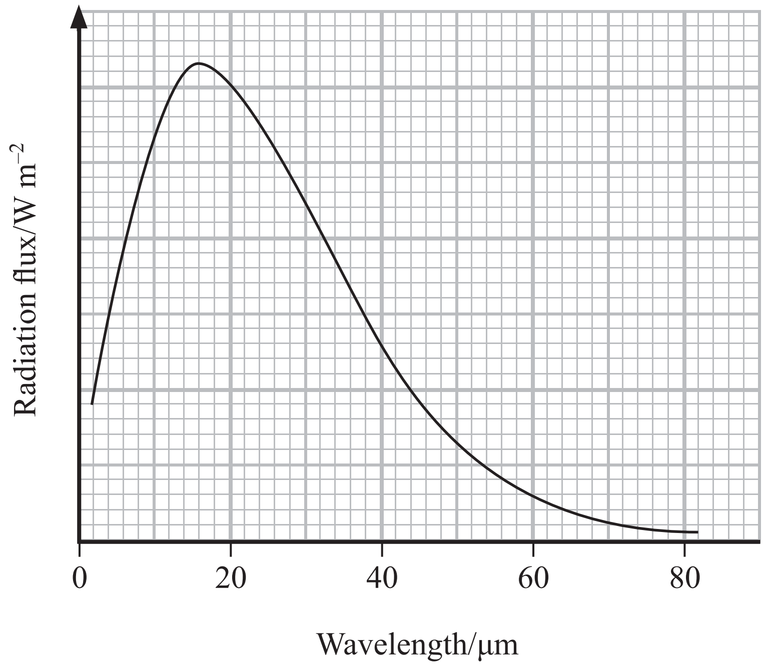
(Total for Question 11 = 3 marks)

13 The radiation emitted from an asteroid is monitored and the following spectrum obtained.



(a) (i) State the wavelength at which the peak radiation flux from the asteroid occurs.

(1)

Wavelength of peak radiation flux = ...

(ii) Use the data to estimate the temperature of the asteroid.

(2)

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Temperature of asteroid = ...

(b) The asteroid is in a circular orbit, of known radius, about the Sun. The average speed of the asteroid cannot be determined directly.

State the two extra data values that you would need in order to calculate the orbital period of the asteroid.

(2)

1 ....

2 ....

(c) This asteroid is about 1.5×10^{11} m from the planet Jupiter.

Calculate the magnitude of the gravitational field strength of Jupiter at this distance.

mass of Jupiter = 1.9×10^{27} kg

(2)

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Gravitational field strength of Jupiter = ...

(Total for Question 13 = 7 marks)

15 (a) Astronomers determine the distance to a nearby star using trigonometric parallax.

Describe the measurements that must be taken to determine this distance.

You may use a diagram to aid your description.

(2)

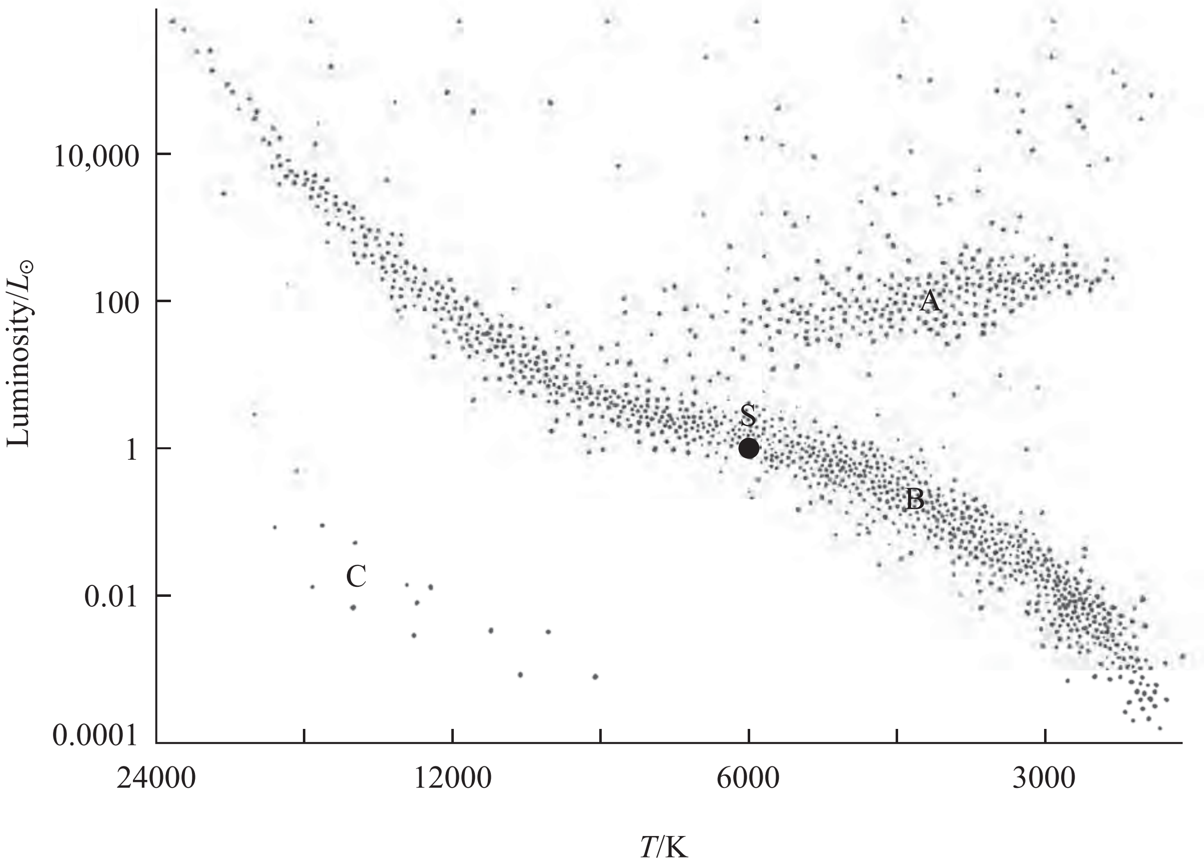
*(b) Radiation received at the Earth from a distant galaxy is redshifted. The distance to the galaxy can be determined from this redshift.

State what is meant by redshift, and explain how it allows the distance to the galaxy to be determined.

(4)

(Total for Question 15 = 6 marks)

16 (a) The position of our Sun, S is shown on the Hertzsprung-Russell (H-R) diagram below.



(i) Identify the three main regions of the H-R diagram.

(3)

Region A = ...

Region B = ...

Region C = ...

(ii) Add lines to the diagram to show the evolutionary path of our Sun from the time when it comes to the end of its hydrogen-burning phase.

(2)

(b) Most stars are too far away from the Earth for astronomers to observe them as anything more than a point source of radiation.

Explain how astronomers calculate the sizes of these stars using information from the H-R diagram.

(3)

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(Total for Question 16 = 8 marks)

19 In 2010 The National Ignition Facility (NIF) in California began experiments to produce viable fusion. They used an extremely powerful laser to fuse hydrogen nuclei.

The following "recipe for a small star" was found on the NIF website:

- Take a hollow, spherical, plastic capsule about 2 mm in diameter.
- Fill it with 150 μg of a mixture of deuterium and tritium, the two heavy isotopes of hydrogen.
- Take a laser that for about 15 ns can generate 500×10^{12} W.
- Focus all this laser power onto the surface of the capsule.
- Wait at least 10 ns.

Result: one miniature star.

(a) Give one similarity and one difference between the nuclei of deuterium and tritium.
(2)

Similarity ....

Difference ....

(b) Show that the energy supplied by the laser in a time period of 15 ns is about 8 MJ.
(2)

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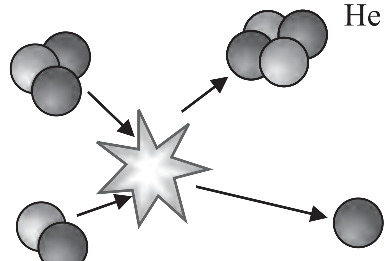
(c) The diagram represents the fusion of deuterium, D, and tritium, T, to form helium, He.



(i) Complete the nuclear equation to represent the fusion of deuterium and tritium to form helium.

(2)

$$\underset{\cdots\cdots}{\overset{\cdots\cdots}{}}\text{D} + \underset{\cdots\cdots}{\overset{\cdots\cdots}{}}\text{T} \rightarrow \underset{\cdots\cdots}{\overset{\cdots\cdots}{}}\text{He} + \underset{\cdots\cdots}{\overset{\cdots\cdots}{}}\text{n}$$

(ii) Use the data in the following table to show that about 20 MeV of energy is released when this fusion reaction takes place.

	Mass / MeV/c^2
Neutron	939.6
Deuterium	1875.6
Tritium	2808.9
Helium	3727.4

(2)

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(iii) Estimate the number of fusions that need to take place in 15 ns if the "miniature star" is to produce the same amount of energy as the laser supplies.

(2)

Number of fusions = ...

(iv) Calculate the kinetic energy, in MeV, of the neutron released by the fusion of deuterium and tritium nuclei. Assume that the net momentum of the nuclei before fusion is zero.

(4)

Neutron kinetic energy = ... MeV

(d) Nuclear power stations currently use the process of fission to release energy. Outline the process of fission.

(3)

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(Total for Question 19 = 17 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

13 Betelgeuse is our nearest red giant. It has a luminosity of 4.49×10^{31} W and emits radiation with a peak energy emission occurring at a wavelength of 850 nm.

Show that Betelgeuse has a surface temperature of about 3000 K. Hence calculate the ratio of the radius of Betelgeuse, r_B to the radius of the Sun, r_S.

$$r_S = 6.95 \times 10^8 \text{ m}$$

(5)

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r_B/r_S = ...

(Total for Question 13 = 5 marks)

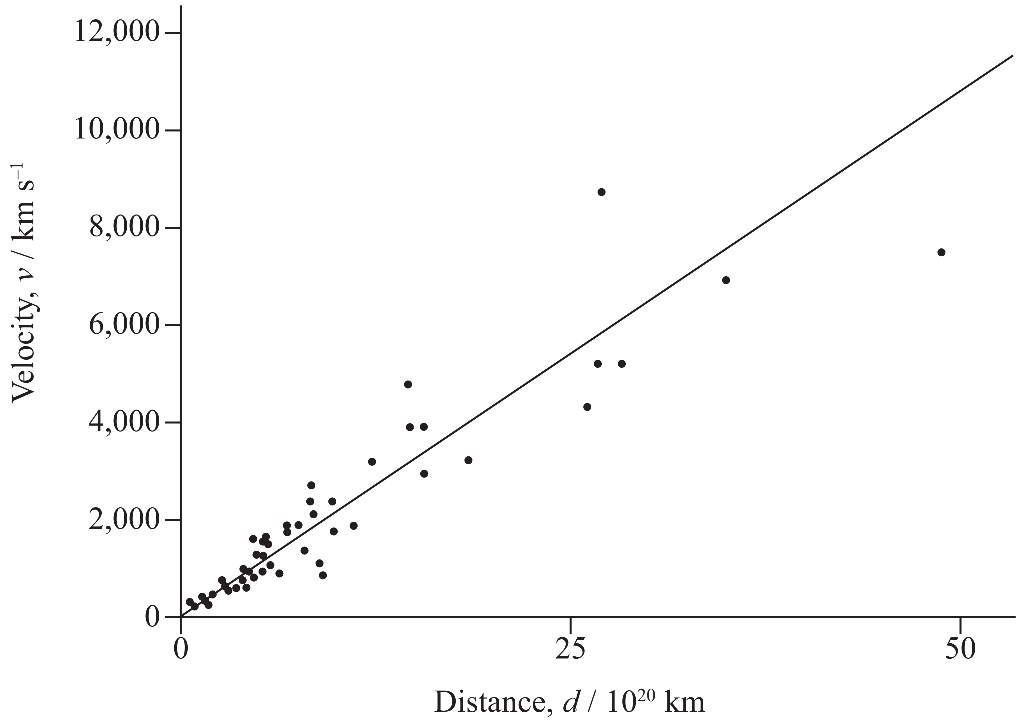
***14** Cepheid variable stars have long been seen as examples of standard candles. Recent measurements have indicated that the movement of the star through interstellar material might result in the formation of a layer of dust around the star. This affects how bright the star appears.

Explain how standard candles are used in astronomy, and suggest how the existence of a layer of dust around a Cepheid variable star might affect the conclusions drawn by astronomers.

(6)

(Total for Question 14 = 6 marks)

16 The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.



(a) Use the graph to estimate an age for the Universe.

(4)

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Age of the Universe = ...

*(b) Describe how astronomers would have determined the velocity of each galaxy.

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*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

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(Total for Question 16 = 12 marks)

17 Communications satellites were first proposed in 1945 by the science fiction author Arthur C. Clarke. In an article published in the magazine Wireless World he asked whether rocket stations could give worldwide radio coverage.

In the article Clarke states:

"There are an infinite number of possible stable orbits, circular and elliptical, in which a rocket would remain if the initial conditions were correct. A velocity of 8 km s^{-1} applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90 minutes. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it."

(a) State what is meant in the article by the phrase "gravity is diminishing", and criticise the statement that "less centrifugal force is needed to balance (the satellite)".

(3)

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(b) (i) By deriving an appropriate equation, show that the orbital speed of the satellite decreases as the radius of orbit increases.

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(ii) By deriving an appropriate equation, show that the orbital period of a satellite increases as the orbital speed decreases.

(2)

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(c) The period T of a satellite in a circular orbit is given by the equation

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

where r is the radius of orbit and M is the mass of the Earth.

Calculate the period of a satellite in an orbit 4.0×10^5 m above the surface of the Earth.

mass of the Earth = 5.98×10^{24} kg

radius of the Earth = 6.36×10^6 m

(2)

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Period of satellite = ...

(d) After a time the radius of the satellite's orbit will start to decrease due to the resistive forces acting on the satellite from the atmosphere. As this happens the satellite speeds up.

Describe the energy changes occurring as the radius of the orbit decreases.

(2)

(Total for Question 17 = 12 marks)

18 Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

© quotationsbook.com (http://quotationsbook.com/quote/12426/)

Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

$$^{14}_{7}\text{N} + ^{4}_{2}\alpha \rightarrow \; ^{\cdots}_{\cdots}\text{O} + ^{1}_{\cdots}\text{p}$$

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

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(b) Uranium-235 is able to undergo fission when it absorbs a neutron to become uranium-236. The equation below shows a possible fission reaction.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 3 \times ^{1}_{0}\text{n}$$

Use the data in the table to show that the energy released by the fission of one uranium nucleus is about 170 MeV.

Isotope	Mass / 10^{-27} kg
^{235}U	390.29989
^{141}Ba	233.99404
^{92}Kr	152.64708
^{1}n	1.67493

(4)

P 4 1 6 3 0 A 0 1 8 2 8

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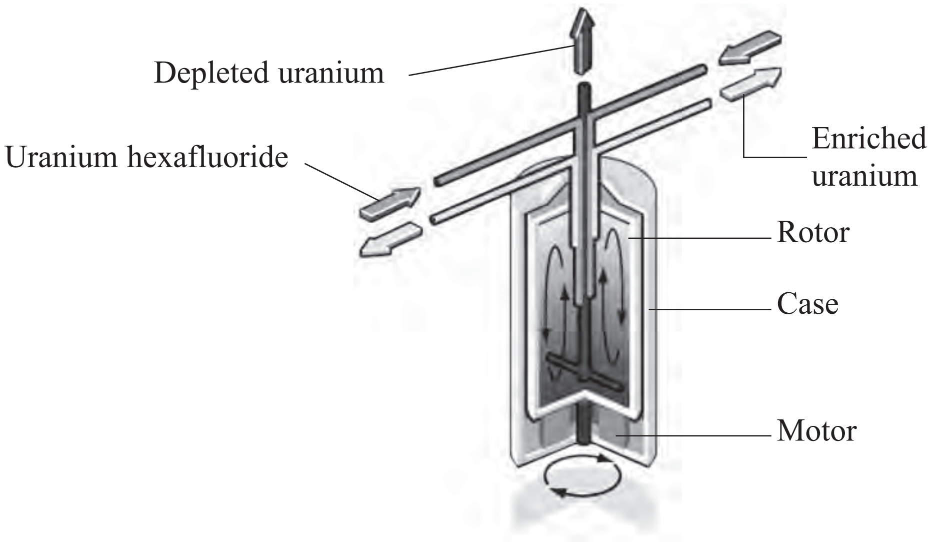
(c) Naturally occurring uranium is more than 99% uranium-238. Fuel for a fission reactor requires at least 3% of the uranium to be uranium-235.

Uranium hexafluoride gas is used during the uranium enrichment process. It is fed into a centrifuge, and a rotating cylinder (rotor) sends the uranium-238 to the outside of the cylinder, where it can be drawn off, while the uranium-235 diffuses to the centre of the cylinder.

Gas centrifuge



(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

(2)

Similarity ....

Difference ....

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute.

Calculate the centripetal acceleration at the rim of the rotor.

(2)

....

....

....

....

Centripetal acceleration = ...

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1 ....

Property 2 ....

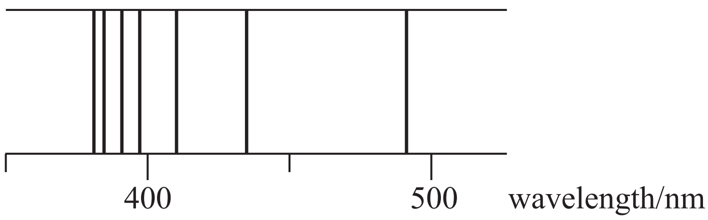
(d) The waste heat from some power stations is transferred to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of 7.0×10^4 kg s^{-1}. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.

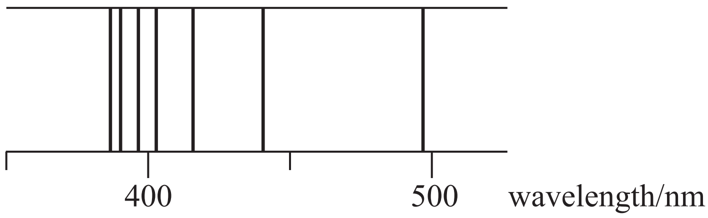
SECTION B

Answer ALL questions in the spaces provided.

11 The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



Laboratory Spectrum



Distant Galaxy Spectrum

The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

(2)

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(Total for Question 11 = 2 marks)

*14 Parallax measurements are used to determine the distance to nearby stars, but this method is unsuitable for more distant objects.

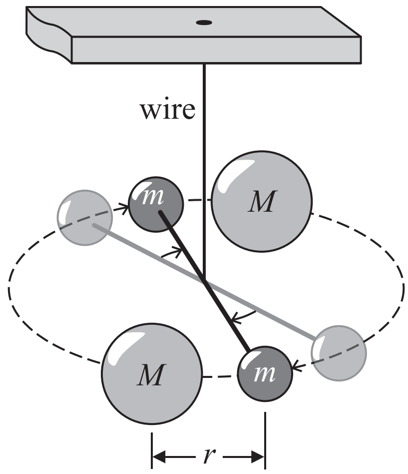
Outline how parallax measurements are used to determine the distance to nearby stars and explain how the use of a standard candle enables the distance to more distant objects to be determined.

(6)

(Total for Question 14 = 6 marks)

15 In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant *G*.

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere $M = 160$ kg

mass of small sphere $m = 0.75$ kg

distance $r = 0.23$ m

gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for *G*.

(2)

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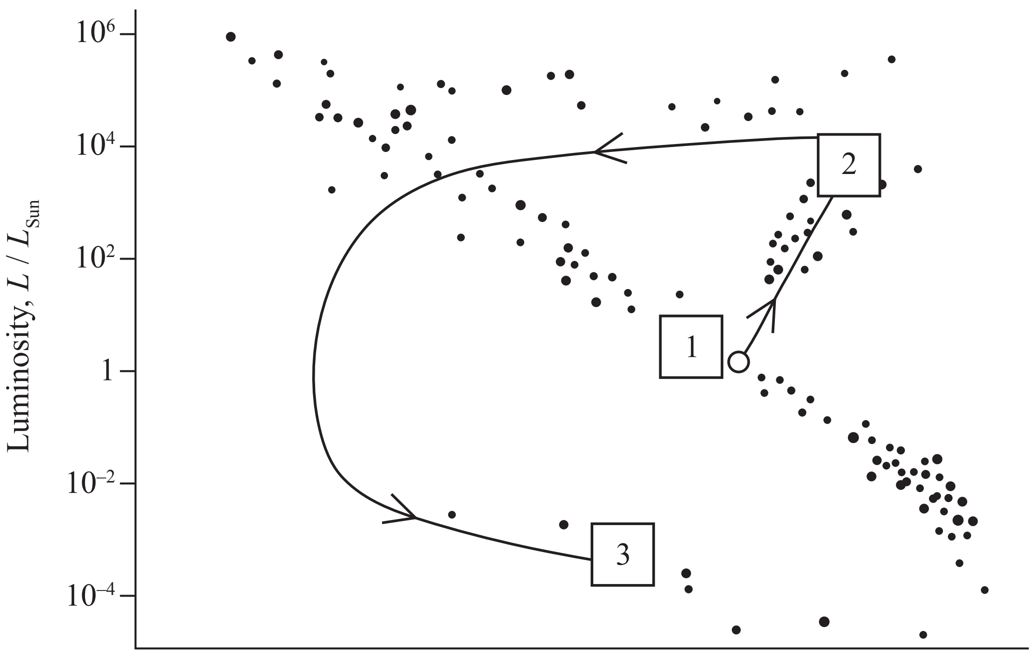
....

G = ... Nm^2 kg^{-2}

17 The Sun has a surface temperature of 5800 K and is approximately 4.5 billion years old.

The Hertzsprung-Russell diagram maps the future evolution of the Sun, from its current position in area 1 of the diagram, through to its final position in area 3 of the diagram.



(a) (i) Complete a suitable temperature scale on the x-axis.

(2)

*(ii) Use the diagram to describe the lifecycle of the Sun starting from its present position in area 1 and concluding in area 3.

(6)

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P 4 1 6 3 6 A 0 1 8 2 8

(b) The energy source for the Sun is the fusion of light nuclei to heavy nuclei. In its present stage of evolution hydrogen is being converted into helium in the core of the Sun.

(i) State and explain the conditions necessary for fusion to occur in a star.

(3)

(ii) In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is:

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2 \times ^{1}_{1}H$$

Calculate the energy released in MeV when one nucleus of the normal isotope of helium is produced.

(4)

Isotope	**Mass / 10^{-27} kg**
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

Energy released = ... MeV

(Total for Question 17 = 15 marks)

SECTION B

Answer ALL questions in the spaces provided.

11 Light from all distant galaxies is found to be shifted towards longer wavelengths. The more distant the galaxy, the greater the shift in wavelength.

State the conclusions that we can draw from this.

(3)

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(Total for Question 11 = 3 marks)

12 A student is constructing a spreadsheet to calculate the radius R of some stars. To obtain the radius, the surface temperature T of the star must first be calculated. She is given values for the stars' luminosities L and the wavelengths λ_{max} at which peak energy emission occurs. Part of the spreadsheet is shown, A is the surface area of the star.

	A	B	C	D	E
1	**λ_{max} / 10^{-7} m**	**T / 10^3 K**	**L / 10^{27} W**	**A / 10^{19} m^2**	**R / 10^9 m**
2	6.85	4.23	0.039		0.41
3	5.74	5.05	0.384	1.04	0.91
4	3.56	8.14	3.385	1.36	1.04
5					

(a) Write an equation to show how the value in B2 is calculated.

(1)

....

....

(b) Show that the value in D2 is about 0.2

(2)

....

....

....

....

(c) The student was given the luminosity values to enter into column C.

Describe how astronomers could determine the luminosity of a star.

(2)

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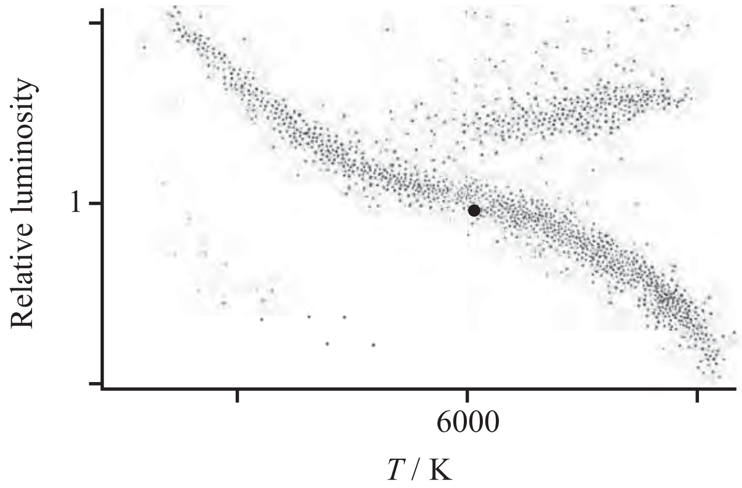
(Total for Question 12 = 5 marks)

13 This Hertzsprung-Russell diagram is a plot of relative luminosity against temperature for a large number of stars.



The position of the Sun, at a surface temperature of about 6000 K and a relative luminosity of 1, is marked on the diagram.

(a) Complete the temperature and relative luminosity scales by adding values at the positions shown.

(2)

(b) The Sun is an example of a main sequence star.

(i) State the fusion process taking place in the core of all main sequence stars.

(1)

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(ii) Draw a circle where the most massive main sequence stars are located on the diagram and explain why they are found in this position.

(3)

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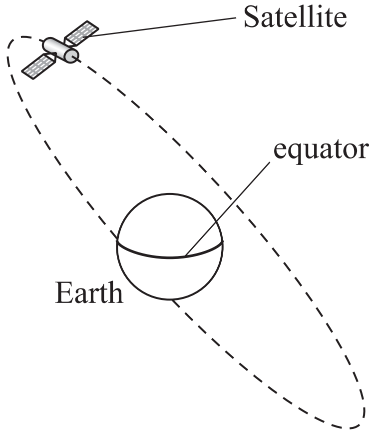
(Total for Question 13 = 6 marks)

14 The Global Positioning System (GPS) is a network of satellites orbiting the Earth. The satellites are arranged in six different orbital planes at a height of 20 200 km above the Earth's surface. Wherever you are, at least four GPS satellites are 'visible' at any time. The diagram shows a single satellite.



(a) Show that the GPS satellites take about 40 000 s (12 hours) to complete one orbit about the Earth.

mass of the Earth $M_E = 6.0 \times 10^{24}$ kg

radius of the Earth $R_E = 6400$ km

(4)

(b) Communications satellites are placed in orbit with an orbital time of 24 hours.

Explain why it is essential for communications satellites to be in such an orbit.

(2)

(c) State how the orbit of a GPS satellite differs from that of a communications satellite.

(2)

(Total for Question 14 = 8 marks)

16 According to astronomers in Denmark and Australia a common type of active galactic nucleus (AGN) could be used as an accurate "standard candle" for measuring cosmic distances. The technique has been used to measure distances corresponding to redshifts significantly larger than was previously possible.

(a) (i) State what is meant by a standard candle.

(1)

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(ii) Explain how a standard candle is used to measure cosmic distances.

(2)

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(b) (i) State what is meant by redshift.

(1)

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(ii) Calculate the distance to a galaxy with a redshift $z = 0.12$

$H_0 = 2.1 \times 10^{-18}\ s^{-1}$

(2)

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Distance to galaxy = ...

*(c) Discuss how astronomers were led to propose the existence of dark matter and the consequences of its existence for the ultimate fate of the universe.

(3)

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(d) Explain why the observable universe has a finite size.

(2)

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(Total for Question 16 = 11 marks)

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Unit 1

Mechanics

Kinematic equations of motion	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
Forces	$\Sigma F = ma$ $g = F/m$ $W = mg$
Work and energy	$\Delta W = F\Delta s$ $E_k = \frac{1}{2}mv^2$ $\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law	$F = 6\pi\eta rv$
Hooke's law	$F = k\Delta x$
Density	$\rho = m/V$
Pressure	$p = F/A$
Young modulus	$E = \sigma/\varepsilon$ where Stress $\sigma = F/A$ Strain $\varepsilon = \Delta x/x$
Elastic strain energy	$E_{el} = \frac{1}{2}F\Delta x$

Unit 2

Waves

Wave speed	$v = f\lambda$
Refractive index	${}_1\mu_2 = \sin i / \sin r = v_1 / v_2$

Electricity

Potential difference	$V = W/Q$
Resistance	$R = V/I$
Electrical power, energy and efficiency	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
Resistivity	$R = \rho l/A$
Current	$I = \Delta Q/\Delta t$ $I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2}QV$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's Laws	$\varepsilon = -d(N\phi)/dt$

Particle physics

Mass-energy	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

Unit 5

Energy and matter

Heating	$\Delta E = mc\Delta\theta$
Molecular kinetic theory	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Ideal gas equation	$pV = NkT$

Nuclear Physics

Radioactive decay	$dN/dt = -\lambda N$
	$\lambda = \ln 2/t_{½}$
	$N = N_0 e^{-\lambda t}$

Mechanics

Simple harmonic motion	$a = -\omega^2 x$ $a = -A\omega^2 \cos \omega t$ $v = -A\omega \sin \omega t$ $x = A \cos \omega t$ $T = 1/f = 2\pi/\omega$
Gravitational force	$F = Gm_1m_2/r^2$

Observing the universe

Radiant energy flux	$F = L/4\pi d^2$
Stefan-Boltzmann law	$L = \sigma T^4 A$ $L = 4\pi r^2 \sigma T^4$
Wien's Law	$\lambda_{max}T = 2.898 \times 10^{-3}$ m K
Redshift of electromagnetic radiation	$z = \Delta\lambda/\lambda \approx \Delta f/f \approx v/c$
Cosmological expansion	$v = H_0 d$