Higher Universe

Past Paper Questions

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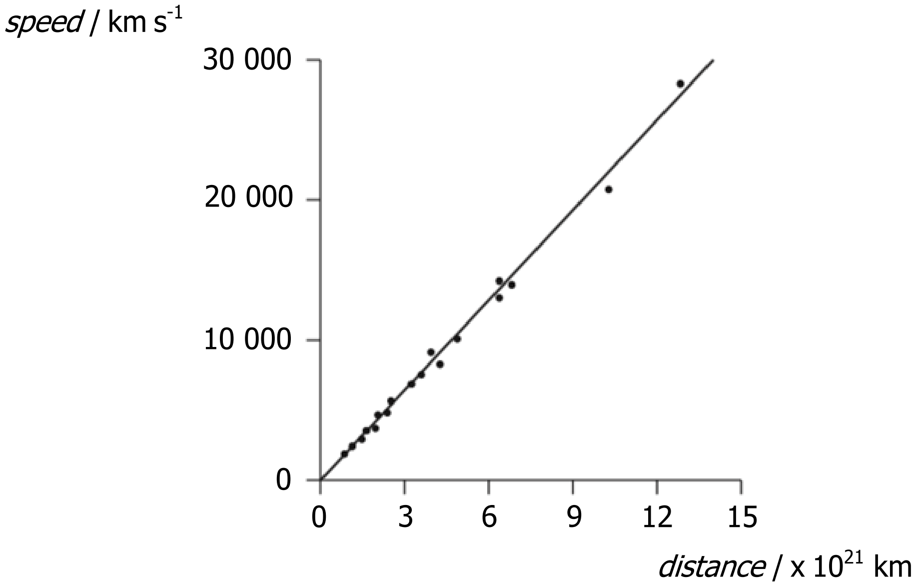
The Big Bang Theory and The Expanding Universe

1. Galaxies at different distances from the Earth have been found to have different speeds.

The graph shows data for some distant galaxies.



A student studies this graph and makes the following statements.

I The speed of distant galaxies varies inversely with their distance from the Earth.

II The gradient of the line gives the value of Hubble's constant.

III The unit for Hubble's constant is s^{-1}.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

2. The cooling of the Universe and cosmic microwave background radiation provide evidence for

A the photoelectric effect

B the Bohr model of the atom

C the theory of special relativity

D the Big Bang theory

E Newton's Universal Law of Gravitation.

3. Measurements of the expansion rate of the Universe lead to the conclusion that the rate of expansion is increasing.

Present theory proposes that this is due to

A redshift

B dark matter

C dark energy

D the gravitational force

E cosmic microwave background radiation.

4. A galaxy has a recessional velocity of $0{\cdot}30c$.

Hubble's Law predicts that the distance between Earth and this galaxy is

A $1{\cdot}3 \times 10^{17}$ m

B $3{\cdot}9 \times 10^{25}$ m

C $1{\cdot}3 \times 10^{26}$ m

D $1{\cdot}4 \times 10^{41}$ m

E $4{\cdot}5 \times 10^{42}$ m.

5. A student makes the following statements about the Universe.

I The force due to gravity acts against the expansion of the Universe.

II Measurements show the rate of expansion of the Universe is increasing.

III The mass of a galaxy can be estimated by the orbital speed of the stars within the galaxy.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

The Big Bang Theory and The Expanding Universe; Open Ended

6. (a) Experimental work at CERN has been described as "*recreating the conditions that occurred just after the Big Bang*".

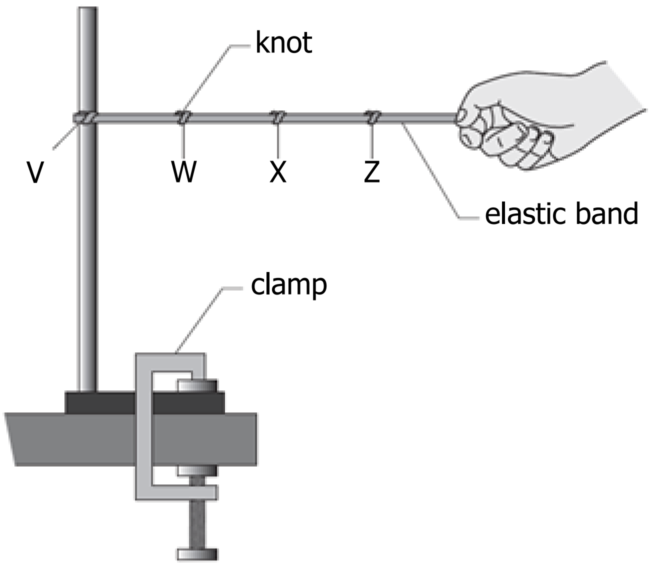
Describe what scientists mean by the *Big Bang theory* and give one piece of evidence which supports this theory. 2

(b) During a television programme the presenter states, "*Looking through a telescope at the night sky is like looking back in time*".

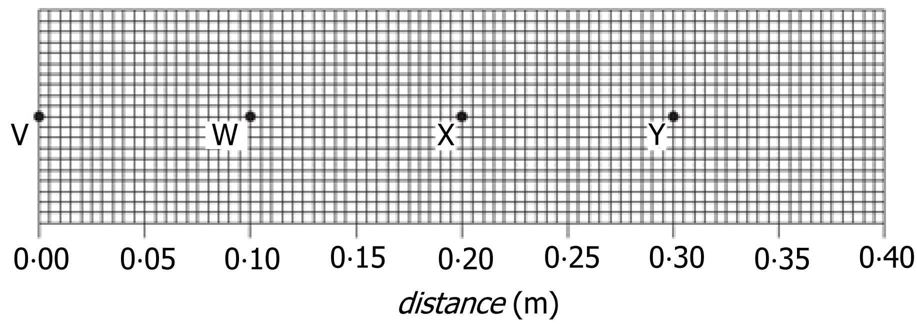
Using your knowledge of Physics, comment on this statement. 3

The Big Bang Theory and The Expanding Universe; Redshift

7. (a) A student is using an elastic band to model the expansion of the Universe.

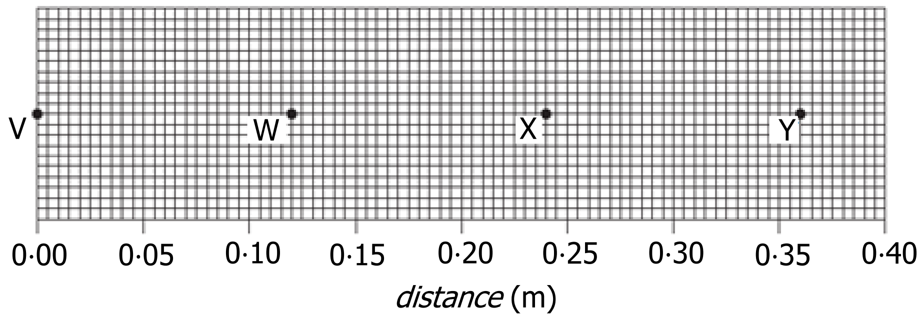


One end of the band is fixed in a clamp stand at V. Knots are tied in the band to represent galaxies. The knots are at regular intervals of 0·10 m, at points W, X and Y as shown.



7. (a) **(continued)**

The elastic band is pulled slowly for 2·5 seconds, so that the band stretches. The knots are now in the positions shown below.



(i) Copy and complete the table to show the average speeds of the knots X and Y. 2

Knot	*Average Speed* (m s^{-1})
W	0·008
X	
Y	

(ii) Explain why this model is a good simulation of the expanision of the Universe. 1

(b) When viewed from the Earth, the continuous emission spectrum from the Sun has a number of dark lines. One of these lines is at a wavelength of 656 nm.

In the spectrum of light from a distant galaxy, the corresponding dark line is observed at 667 nm.

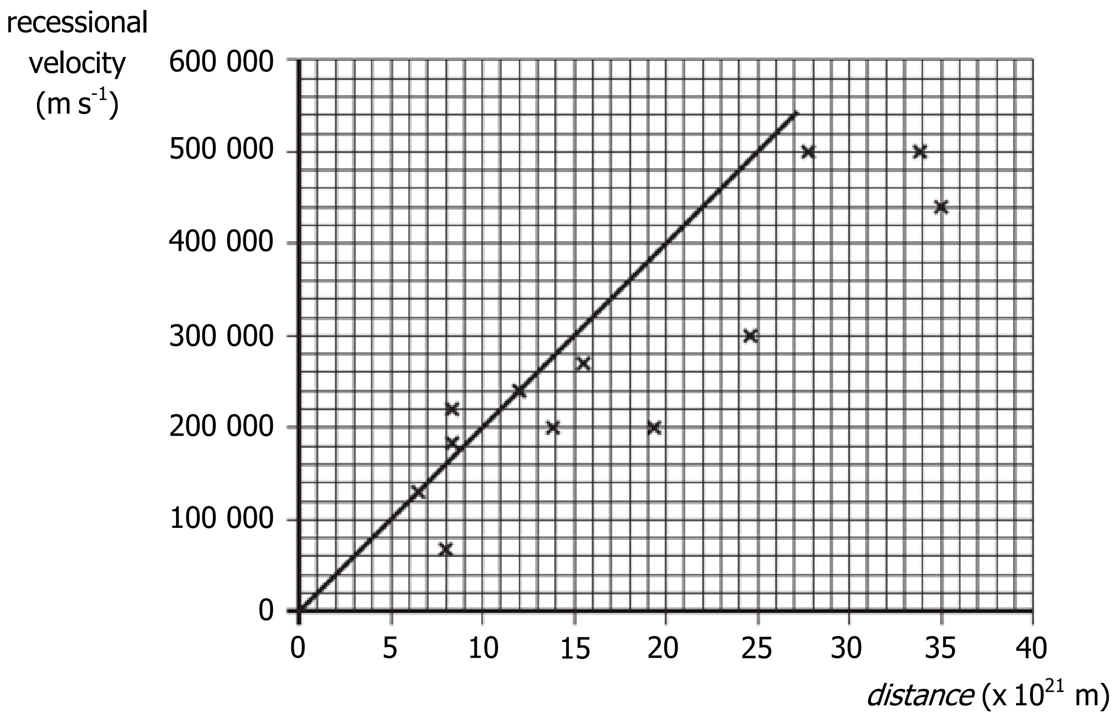
Calculate the redshift of the light from the distant galaxy. 3

<u>The Big Bang and The Expanding Universe; Problem Solver</u>

8. Hubble's Law states that the universe is expanding. The expanding universe is one piece of evidence that supports the Big Bang theory.

(a) State one other piece of evidence that supports the Big Bang theory. 1

(b) A student plots some of the original data from the 1929 paper by Edwin Hubble and adds the line shown in order to determine a value for the Hubble constant H_0.



The student calculates the gradient of their line and obtains a value for the Hubble constant of $2{\cdot}0 \times 10^{-17}$ s^{-1}.

The age of the universe can be calculated using the relationship

$$\text{age of universe} = \frac{1}{H_0}$$

(b) (i) Calculate the age of the universe, in years, obtained when using the student's value for the Hubble constant. 2

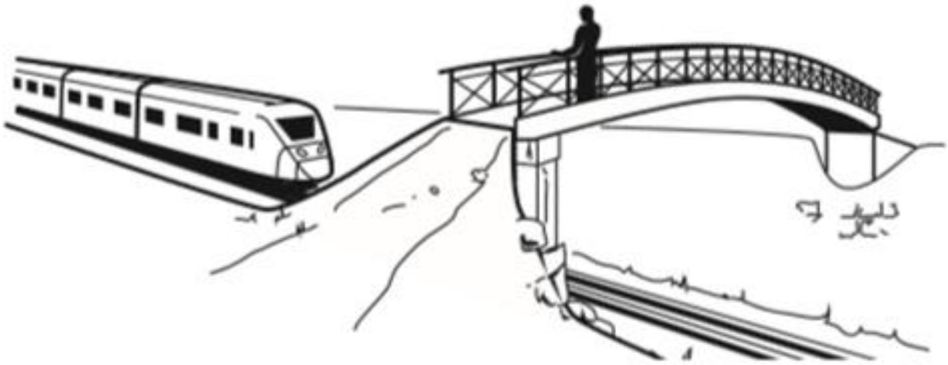
(ii) The current estimate for the age of the universe is $13{\cdot}8 \times 10^9$ years.

(A) State why the value obtained in (b)(i) is different from the current estimate for the age of the universe. 1

(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. 1

Doppler Effect

1. A train is travelling at a constant speed of 16·0 m s^{-1} as it approaches a bridge.



A horn on the train emits sound of frequency 277 Hz.

The sound is heard by a person standing on the bridge.

The speed of sound in air is 340 m s^{-1}.

The frequency of the sound heard by the person on the bridge is

A 265 Hz

B 277 Hz

C 291 Hz

D 357 Hz

E 361 Hz.

2. A siren on an ambulance emits sound at a constant frequency of 750 Hz.

The ambulance is travelling at a constant speed of 25·0 m s^{-1} towards a stationary observer.

The speed of sound in air is 340 m s^{-1}.

The frequency of the sound heard by the observer is

A 695 Hz

B 699 Hz

C 750 Hz

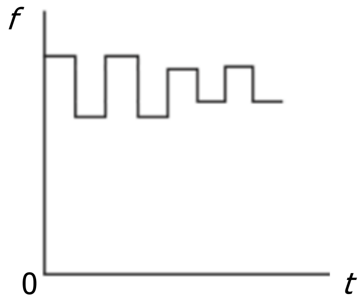
D 805 Hz

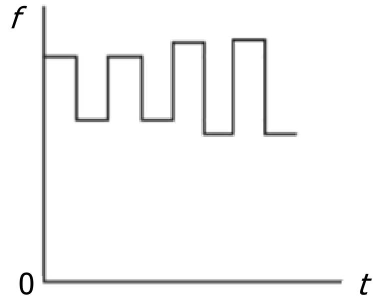
E 810 Hz.

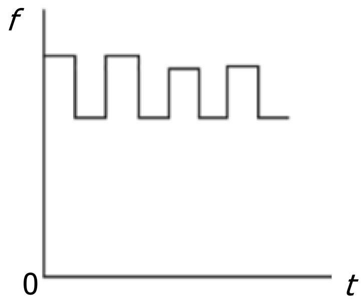
3. The siren on a police car emits sound which alternates between two different frequencies.

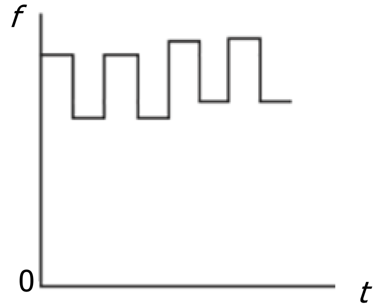
The police car moves at a steady speed as it approaches, passes and moves away from a stationary pedestrian.

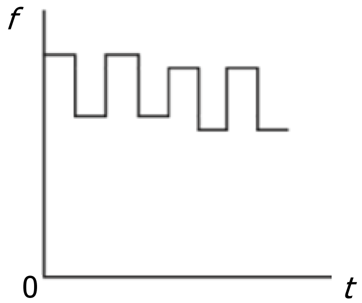
Which graph shows how the frequency f of the sound heard by the pedestrian varies with time t?

A


B


C


D


E


4. A car horn emits a sound with a constant frequency of 405 Hz.

The car is travelling away from a student at 28·0 m s^{-1}.

The speed of sound in air is 335 m s^{-1}.

The frequency of the sound from the horn heard by the student is

A 371 Hz

B 374 Hz

C 405 Hz

D 439 Hz

E 442 Hz.

The ******* Effect; Problem Solver

5. (a) A person is standing at the side of a road. A car travels along the road towards the person, at a constant speed of 12 m s^{-1}. The car emits a sound of frequency 510 Hz.

The person observes that the frequency of the sound heard changes as the car passes.

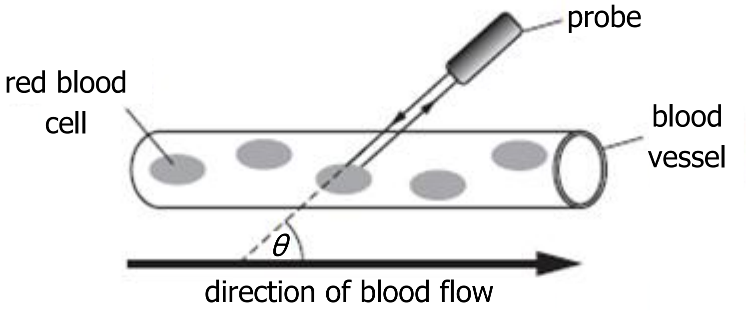
(i) State the name given to this effect. 1

(ii) Calculate the frequency of the sound heard by the person as the car approaches.

The speed of sound in air is 340 m s^{-1}. 3

5. **(continued)**

(b) This same effect is used to determine the speed of red blood cells through blood vessels.



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Ultrasound waves are transmitted by a probe. The frequency of the ultrasound waves changes as they reflect from the blood cells. The probe detects the reflected waves.

The velocity of the red blood cells can be determined using the following relationship

$$\Delta f = \frac{2f\, v_{rbc} \cos\theta}{v}$$

where Δf is the change in frequency

f is the transmitted frequency

v_{rbc} is the velocity of the red blood cells

v is the velocity of the ultrasound

θ is the angle between the direction of the waves and the direction of the blood flow.

The frequency of the ultrasound transmitted by the probe is 3·70 MHz.

The velocity of the ultrasound is 1540 $m\,s^{-1}$.

During one test, the angle between the direction of the waves and blood flow is 60·0°. The change in frequency of the ultrasound is 286 Hz.

Calculate the velocity of the red blood cells during this test. 2

The Doppler Effect

6. An emergency vehicle, travelling at 22 m s^{-1}, emits sound of frequency 1020 Hz. The vehicle approaches a stationary pedestrian, as shown in the diagram below.

(a) Calculate the frequency observed by the stationary pedestrian as the emergency vehicle approaches. 3

(b) A second identical ambulance approaches the stationary observer travelling at a greater speed.

The frequency observed by the stationary pedestrian is 1107 Hz.

Calculate the speed of the second ambulance. 3

The Doppler Effect; Redshift

7. (a) A car horn produces a note of frequency 200 Hz.

The horn is sounded as the car is moving at 30 m s^{-1} away from a stationary observer.

Calculate the frequency heard by the observer. 3

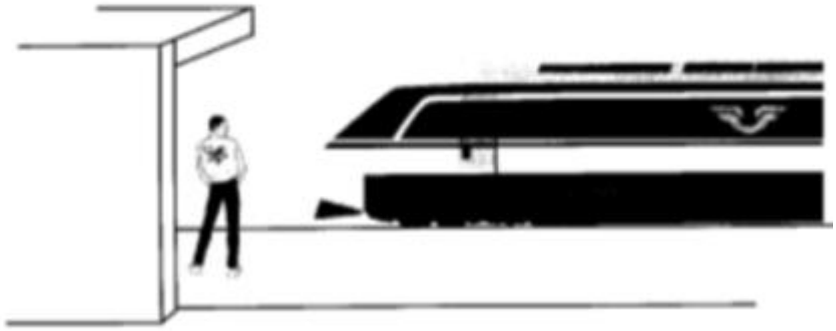
(b) An observer on Earth determines that the frequency of light from a distant galaxy is Doppler shifted towards the red end of the spectrum.

State whether the galaxy is moving towards or away from Earth.

You must justify your answer. 2

The Doppler Effect

8. A train emits a sound of frequency 800 Hz as it passes through a station. A person standing still on the station platform hears the sound as the train travels into the station and then out of the station.



(a) Describe how the frequency of the sound, heard by the person, changes as the train passes through the station. 1

(b) Explain, in terms of wavefronts, why this frequency change occurs.

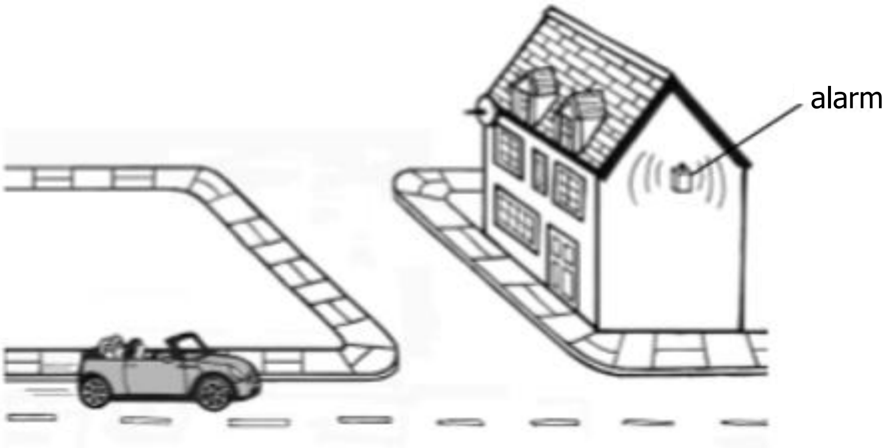
You may wish to include a diagram as part of your answer. 2

(c) At one instant, the person hears a sound of frequency 760 Hz.

Calculate the speed of the train relative to the person on the platform at this time. 3

The Doppler Effect; Redshift

9. (a) The driver of a sports car approaches a building where an alarm is sounding.



The speed of the car is 25·0 m s^{-1} and the frequency of the sound emitted by the alarm is 1250 Hz.

(i) Explain in terms of wavefronts why the sound heard by the driver does not have a frequency of 1250 Hz.

You may wish to include a diagram to support your answer. 2

(ii) When a sound source is stationary and an observer is moving towards the sound source, the equation used to calculate the frequency observed is

$$f_o = f_s \left(\frac{v + v_o}{v}\right)$$

where the symbols have their usual meaning and v_o is the speed of the observer.

Calculate the frequency of the sound from the alarm as observed by the driver. 2

9. **(continued)**

(b) The spectrum of light from most starts contains lines corresponding to helium gas.

Figure 9(a) shows the helium spectrum from the Sun.

Figure 9(b) shows the helium spectrum from a distant star.

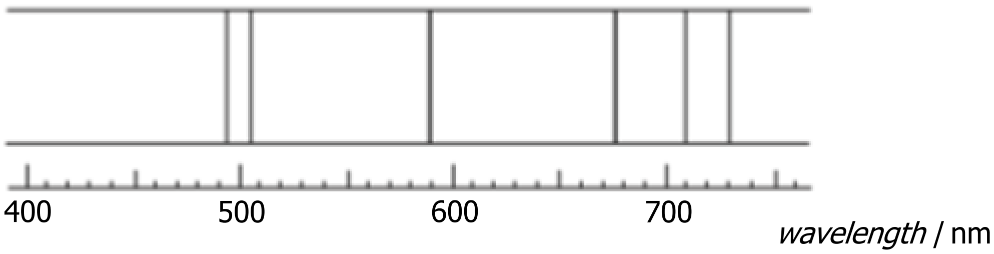


Figure 9(a)

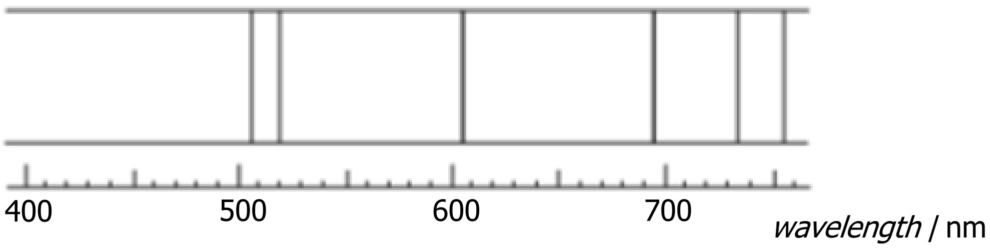


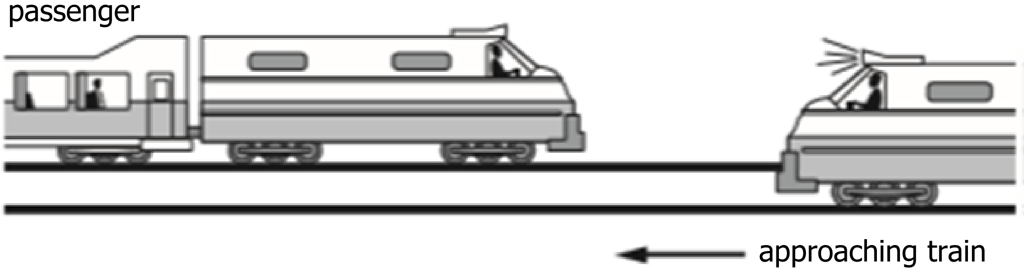
Figure 9(b)

By comparing these spectra, state a conclusion that can be made about the distant star.

Justify your answer. 2

Doppler Effect; Problem Solver

10. A train is stopped and a passenger hears a siren on another train approaching along a parallel track. The approaching train is travelling at a constant speed of 28·0 m s^{-1} and the siren produces a sound of frequency 294 Hz.



(a) Show that the speed of the approaching train is given by

$$v_s = v - \frac{f_s v}{f_o}$$

where symbols have their usual meaning. 2

(b) Calculate the frequency of the sound heard by the passenger:

(i) as the train approaches; 3

(ii) once the train has passed the passenger. 3

Gravitational Force

1. A satellite orbits a planet at a distance of $5{\cdot}0 \times 10^7$ m from the centre of the planet.

   The mass of the satellite is $2{\cdot}5 \times 10^4$ kg.

   The mass of the planet is $4{\cdot}0 \times 10^{24}$ kg.

   The gravitational force acting on the satellite due to the planet is

   A $1{\cdot}7 \times 10^{-6}$ N

   B $2{\cdot}7 \times 10^3$ N

   C $1{\cdot}3 \times 10^{11}$ N

   D $2{\cdot}7 \times 10^{14}$ N

   E $2{\cdot}7 \times 10^{32}$ N.

2. The distance between a spacecraft and a space station is 0·45 km.

   The mass of the spacecraft is $1{\cdot}08 \times 10^5$ kg.

   The mass of the space station is $3{\cdot}44 \times 10^5$ kg.

   The gravitational force between the spacecraft and the space station is

   A $1{\cdot}8 \times 10^6$ N

   B 5·5 N

   C $1{\cdot}2 \times 10^{-1}$ N

   D $5{\cdot}5 \times 10^{-3}$ N

   E $1{\cdot}2 \times 10^{-5}$ N.

3. A planet orbits a star at a distance of $3{\cdot}0 \times 10^9$ m.

   The star exerts a gravitational force of $1{\cdot}6 \times 10^{27}$ N on the planet.

   The mass of the star is $6{\cdot}0 \times 10^{30}$ kg.

   The mass of the planet is

   A $2{\cdot}4 \times 10^{14}$ kg

   B $1{\cdot}2 \times 10^{16}$ kg

   C $3{\cdot}6 \times 10^{25}$ kg

   D $1{\cdot}6 \times 10^{26}$ kg

   E $2{\cdot}4 \times 10^{37}$ kg.

4. Enceladus is a moon of Saturn. The mass of Enceladus is $1{\cdot}08 \times 10^{20}$ kg.

The mass of Saturn is $5{\cdot}68 \times 10^{26}$ kg.

The graviational force of attraction between Enceladus and Saturn is $7{\cdot}24 \times 10^{19}$ N.

The orbital radius of Enceladus around Saturn is

A $2{\cdot}38 \times 10^{8}$ m

B $9{\cdot}11 \times 10^{13}$ m

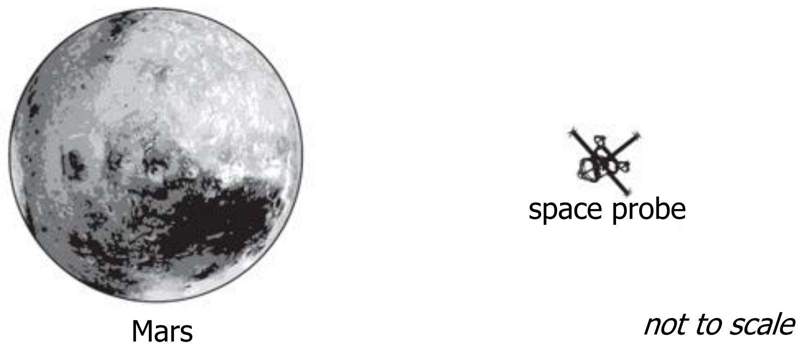
C $5{\cdot}65 \times 10^{16}$ m

D $8{\cdot}30 \times 10^{27}$ m

E $3{\cdot}19 \times 10^{33}$ m.

Gravitational Force

5. A space probe of mass $5{\cdot}60 \times 10^3$ kg is in orbit at a height of $3{\cdot}70 \times 10^6$ m above the surface of Mars.



The mass of Mars is $6{\cdot}42 \times 10^{23}$ kg.

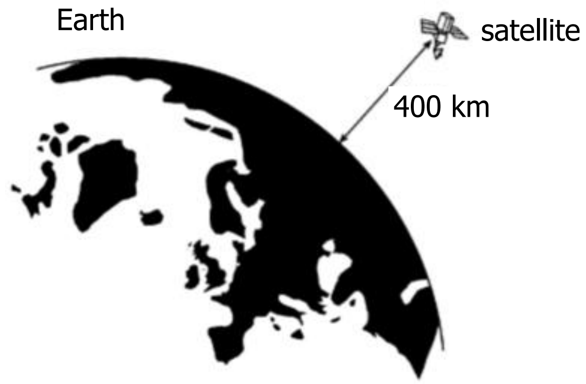
The radius of Mars is $3{\cdot}39 \times 10^6$ m.

(a) Calculate the gravitational force between the probe and Mars. 3

(b) Calculate the gravitational field strength of Mars at this height. 3

Gravitational Force

6. A satellite orbits at a height of 400 km above Earth's surface as shown in the diagram below.



The satellite has a mass of 900 kg.

Earth has a radius of 6370 km and a mass of $5{\cdot}97 \times 10^{24}$ kg.

(a) Calculate the gravitational force between the satellite and Earth. 3

(b) Calculate the gravitational field strength of Earth at this height. 3

Projectile Motion; Gravitational Force

7. (a) Explain why people on-board a satellite orbiting a planet appear to float. 1

(b) The gravitational field strength at the surface of Jupiter is 25 $N\,kg^{-1}$.

The radius of Jupiter is $69{\cdot}9 \times 10^3$ km.

(i) Use Newton's universal law of gravitation to show that the mass of Jupiter is given by the equation

$$m_1 = \frac{gr^2}{G}$$

where the symbols have their usual meaning. 2

(ii) Calculate the mass of Jupiter (*to 3 significant figures*). 2

(c) A spacecraft of mass 100 kg is in circular orbit 7×10^3 km above the surface of Jupiter. It is travelling at an orbital speed of 40 $km\,s^{-1}$.

(i) Show that the gravitational force exerted by Jupiter on the spacecraft is 2060 N. 2

(ii) Assuming the spacecraft follows a circular orbit, calculate the period of the spacecraft's orbit. 4

Gravitational Force

8. The Moon orbits Earth due to the gravitational force between them.

The Moon has a mass of $7{\cdot}35 \times 10^{22}$ kg and a radius of $1{\cdot}74 \times 10^3$ km.

Earth has a mass of $5{\cdot}97 \times 10^{24}$ kg and a radius of $6{\cdot}37 \times 10^3$ km.

The average distance between the Moon and Earth is $3{\cdot}84 \times 10^5$ km.

(a) Sketch a labelled diagram of the Moon and Earth with all the above information shown. 2

(b) Calculate the magnitude of the gravitational force between the Moon and Earth. 3

(c) Calculate the gravitational field strength of Earth at the distance that the Moon is from Earth. 3

Gravitational Force

9. The gravitational field strength g on the surface of Mars is $3 \cdot 7\ N\ kg^{-1}$.

The mass of Mars is $6 \cdot 4 \times 10^{23}$ kg.

Show that the radius of Mars is $3 \cdot 4 \times 10^{6}$ m. 2

Gravitational Force

10.

not to scale

A space probe of mass 320 kg is in orbit above Pluto.

The mass of Pluto is $1 \cdot 31 \times 10^{22}$ kg and its radius is $1 \cdot 89 \times 10^{6}$ m.

The gravitational force between the space probe and Pluto is 4.47×10^{-2} N.

Calculate the distance between the space probe and the <u>surface</u> of Pluto. 4

Gravitational Force

11. Satellite **X** is $3 \cdot 00 \times 10^{8}$ m from the centre of a moon called Io.

Io has a mass of $8 \cdot 93 \times 10^{22}$ kg and the satellite has a mass of 500 kg.

The gravitational force acting between Io and Satellite **X** is $3 \cdot 31 \times 10^{-2}$ N.

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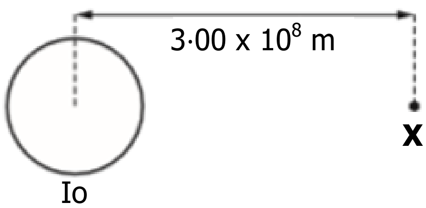
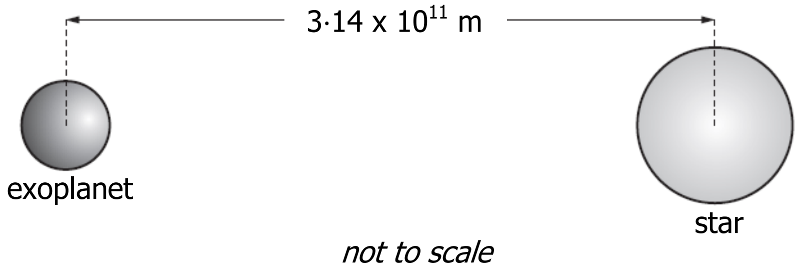


Show by calculation that the universal gravitational constant is $6 \cdot 67 \times 10^{-11}\ N\ m^{2}\ kg^{-2}$. 2

Gravitational Force; Redshift

12. Planets outside our solar system are called exoplanets.

An exoplanet of mass $5{\cdot}69 \times 10^{27}$ kg orbits a star of mass $3{\cdot}83 \times 10^{30}$ kg.



(a) (i) Compare the mass of the star with the mass of the exoplanet in terms of orders of magnitude. **2**

(ii) The distance between the exoplanet and the star is $3{\cdot}14 \times 10^{11}$ m.

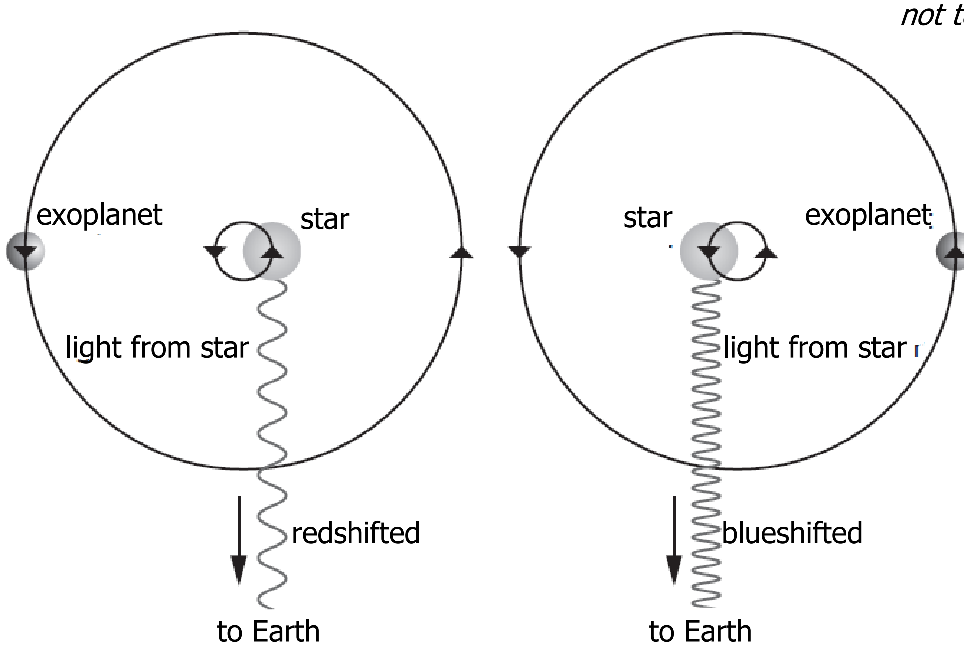
Calculate the gravitational force between the star and the exoplanet. **3**

12. **(continued)**

(b) The gravitational force between the star and the exoplanet causes the star to follow a circular path as the exoplanet orbits the star. Small differences in the wavelength of the light from the star are observed on Earth.

Light from the star is redshifted when the star moves away from Earth and blueshifted when the star moves towards the Earth.

not to scale



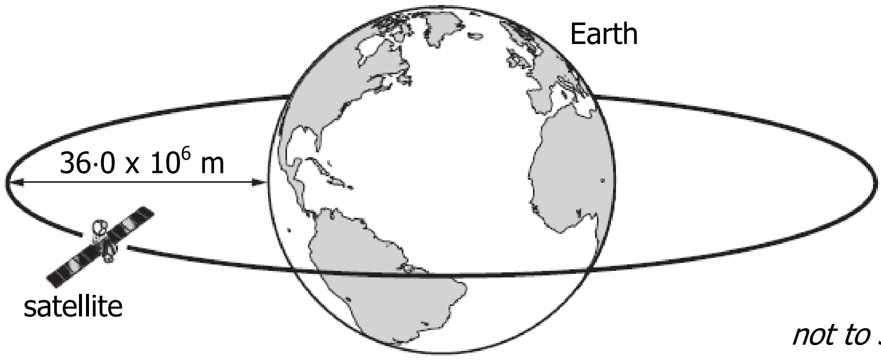
(i) Calculate the redshift of light from the star observed on Earth when the star is moving away from Earth at $6{\cdot}60 \times 10^{3}\ \mathrm{m\,s^{-1}}$. 3

(ii) For an exoplanet of greater mass at the same distance from the star, suggest whether the radius of the circular path followed by the star would be greater than, less than, or the same as that for an exoplanet of smaller mass.

Explain your answer. 2

Gravitational Force

13. A communication satellite orbits the Earth at a height of $36 \cdot 0 \times 10^6$ m above the surface of the Earth.



not to scale

The mass of the Earth is $6 \cdot 0 \times 10^{24}$ kg and the radius of the Earth is $6 \cdot 4 \times 10^6$ m.

(a) Determine the distance between the centre of the Earth and the satellite. 1

(b) The gravitational force of attraction between the Earth and the satellite is 57 N.

Calculate the mass of the satellite. 3

(c) Determine the value of the Earth's gravitational field strength *g* at the satellite. 3

(d) A second satellite has a **quarter** of the mass of the first satellite.

The distance from the centre of the Earth to the second satellite is **half** the distance from the centre of the Earth to the first satellite.

State how the gravitational force of attraction between the second satellite and the Earth compares to the gravitational force of attraction between the first satellite and the Earth.

Justify your answer. 3

Redshift

1. A galaxy is moving away from the Earth at a velocity of $1{\cdot}20 \times 10^{7}$ m s^{-1}.

   Light of wavelength 450 nm is emitted from this galaxy.

   When detected and measured on Earth this light has a wavelength of

   A 425 nm

   B 432 nm

   C 468 nm

   D 475 nm

   E 630 nm.

2. An astronomer observes the spectrum of light from a star. The spectrum contains the emission lines for hydrogen.

   The astronomer compares this spectrum with the spectrum from a hydrogen lamp. The line, which has a wavelength of 656 nm from the lamp, is found to be shifted to 663 nm in the spectrum from the star.

   The redshift of the light from this star is

   A 0·011

   B 0·50

   C 0·99

   D 2·0

   E 94.

3. The redshift of a distant galaxy is 0·014.

   According to Hubble's law, the distance of the galaxy from Earth is

   A $9{\cdot}66 \times 10^{-12}$ m

   B $1{\cdot}83 \times 10^{24}$ m

   C $1{\cdot}30 \times 10^{26}$ m

   D $9{\cdot}32 \times 10^{27}$ m

   E $6{\cdot}33 \times 10^{39}$ m.

Special Relativity

1. A spacecraft travels at a constant speed of $0{\cdot}70c$ relative to the Earth.

   A clock on the spacecraft records a flight time of 3·0 hours.

   A clock on Earth records this flight time to be

   A 1·6 hours

   B 2·1 hours

   C 4·2 hours

   D 5·5 hours

   E 5·9 hours.

2. The length of a spacecraft at rest is *L*.

   This spaceship passes a planet at a speed of $0{\cdot}95c$.

   Which row in the table gives the measured lengths of the spaceship according to an observer on the spaceship and an observer on the planet?

	Length measured by observer on spaceship	*Length measured by observer on planet*
A	*L*	*L*
B	*L*	less than *L*
C	less than *L*	*L*
D	less than *L*	less than *L*
E	greater than *L*	less than *L*

3. A spacecraft is travelling at $0{\cdot}10c$ relative to a star.

   An observer on the spacecraft measures the speed of light emitted by the star to be

   A $0{\cdot}90c$

   B $0{\cdot}99c$

   C $1{\cdot}00c$

   D $1{\cdot}01c$

   E $1{\cdot}10c$.

4. A spaceship is moving with a constant speed of $0{\cdot}6c$ towards the Earth. The spaceship emit a beam of light towards the Earth. An astronaut in the spaceship and an observer on Earth both measure the speed of the emitted light.

Which row in the table shows the speed of the emitted light as measured by the astronaut and by the observer on Earth?

	Speed of emitted light as measured by astronaut	*Speed of emitted light as measured by observer on Earth*
A	$0{\cdot}4c$	$1{\cdot}6c$
B	c	c
C	c	$1{\cdot}6c$
D	$1{\cdot}6c$	$0{\cdot}4c$
E	$1{\cdot}6c$	c

5. A spacecraft is travelling at a constant speed of $0{\cdot}60c$ relative to the Moon.

An observer on the Moon measurers the length of the moving spacecraft to be 190 m.

The length of the spacecraft as measured by an astronaut on the spacecraft is

A 120 m

B 152 m

C 238 m

D 297 m

E 300 m.

6. A spacecraft is travelling at a constant speed of $2{\cdot}75 \times 10^8$ m s^{-1} relative to a planet.

A technician on the spacecraft measures the length of the spacecraft as 125 m.

An observer on the planet measures the length of the spacecraft as

A 36 m

B 50 m

C 124 m

D 314 m

E 433 m.

7. A spacecraft is travelling at a speed of $0{\cdot}200c$ relative to the Earth.

The spacecraft emits a signal for 20·0 seconds as measured in the frame of reference of the spacecraft.

An observer on Earth measures the duration of the signal as

A 19·2 s

B 19·6 s

C 20·0 s

D 20·4 s

E 20·8 s.

8. A spacecraft is travelling at a constant speed relative to a nearby planet.

A technician on the spacecraft measures the length of the spacecraft as 275 m.

An observer on the planet measures the length of the spacecraft as 125 m.

The speed of the spacecraft relative to the observer on the nearby planet is

A $1{\cdot}54 \times 10^4$ m s^{-1}

B $2{\cdot}22 \times 10^8$ m s^{-1}

C $2{\cdot}67 \times 10^8$ m s^{-1}

D $3{\cdot}00 \times 10^8$ m s^{-1}

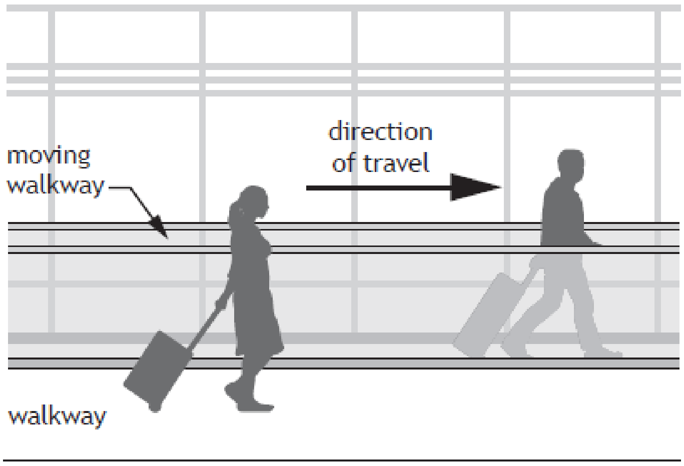
E $7{\cdot}14 \times 10^{16}$ m s^{-1}.

Special Relativity

9. Two physics students are in an airport building on their way to visit CERN.

(a) The first student steps onto a moving walkway, which is travelling at $0{\cdot}83\ \text{m s}^{-1}$ relative to the building. This student walks along the walkway at a speed of $1{\cdot}20\ \text{m s}^{-1}$ relative to the walkway.

The second student walks alongside the walkway at a speed of $1{\cdot}80\ \text{m s}^{-1}$ relative to the building.



Determine the speed of the first student relative to the second student. 2

(b) On the plane, the students discuss the possibility of travelling at relativistic speeds.

(i) The students consider the plane travelling at $0{\cdot}8c$ relative to a stationary observer. The plane emits a beam of light towards the observer.

State the speed of the emitted light as measured by the observer.

Justify your answer. 2

(ii) According to the manufacturer, the length of the plane is 71 m.

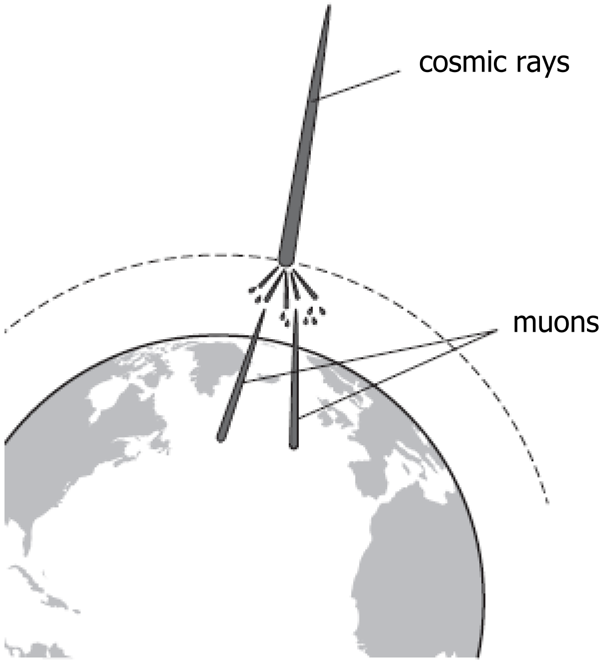
Calculate the length of the plane travelling at $0{\cdot}8c$ as measured by the stationary observer. 3

(iii) One of the students states that the clocks on board the plane will run slower when the plane is travelling at relativistic speeds.

Explain whether or not this statement is correct. 1

Special Relativity

10. Muons are sub-atomic particles produced when cosmic rays enter the atmosphere about 10 km above the surface of the Earth.



Muons have a mean lifetime of $2{\cdot}2 \times 10^{-6}$ s in their frame of reference. Muons are travelling at $0{\cdot}995c$ relative to an observer on Earth.

(a) Show that the mean distance travelled by the muons in their frame of reference is 660 m. 2

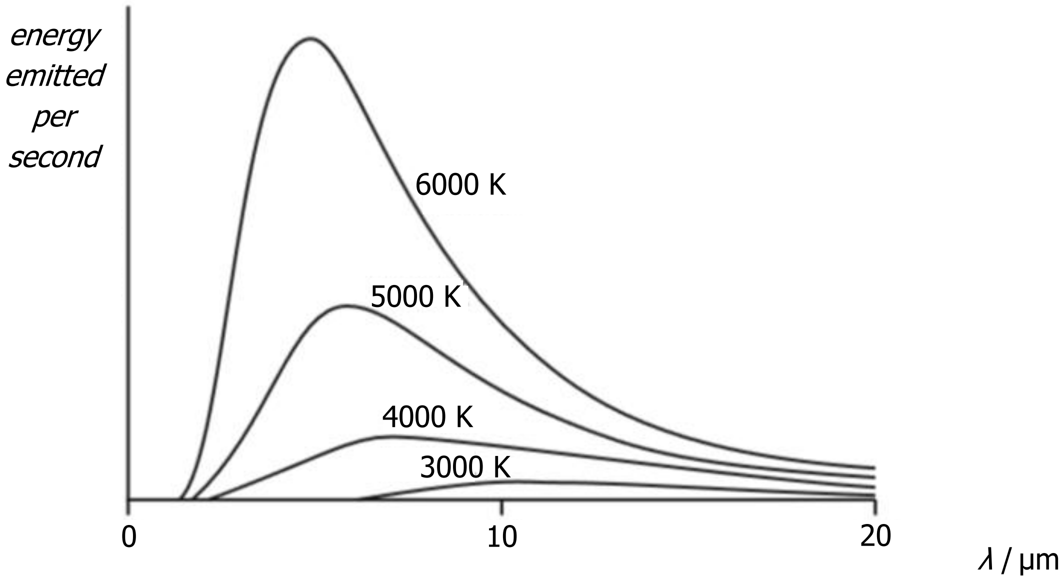
(b) Calculate the mean lifetime of the muons measured by an observer on Earth. 3

(c) If the speed of the muons relative to an observer on Earth was found to be $2{\cdot}95 \times 10^{8}$ m s^{-1}, state whether the mean lifetime measured by the observer on Earth would be more than, less than or the same as your answer given in (b).

Justify your answer. 2

Temperature of Stars

1. The graph shows how the energy emitted per second from the surface of a hot object varies with the wavelength, λ, of the emitted radiation at different temperatures.



A student makes the following statements based on the information shown in the graph.

I As the temperature of the object increases, the total energy emitted per second decreases.

II As the temperature of the object increases, the peak wavelength of the emitted radiation decreases.

III The frequency of the emitted radiation steadily increases as the emitted energy per second decreases.

Which of the statements is/are correct?

A I only

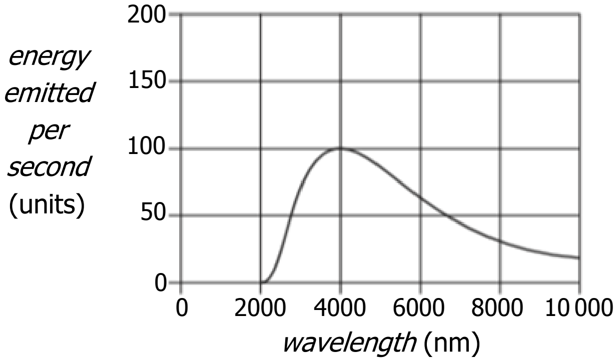
B II only

C III only

D I and II only

E II and III only

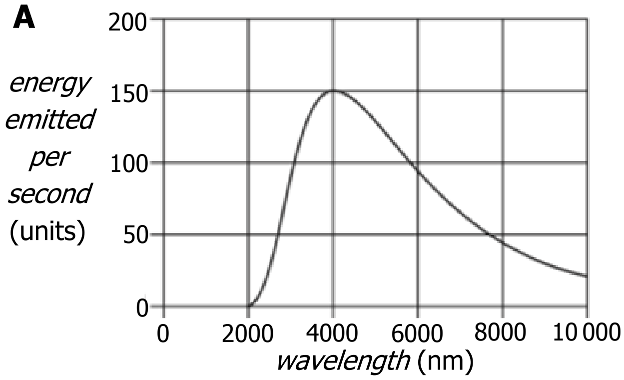
2. The graph shows how the energy emitted per second from an object varies with the wavelength of the radiation emitted by the object.



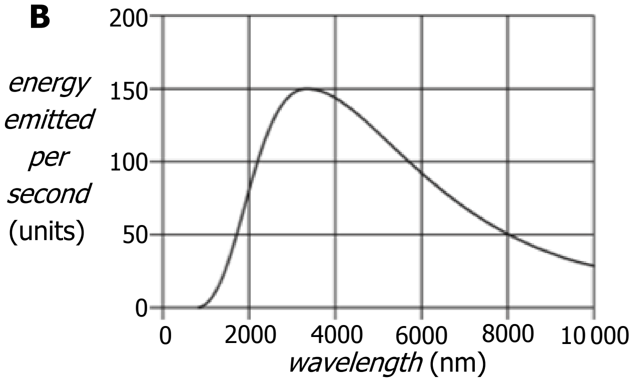
The temperature of the object is increased.

Which graph shows how the energy emitted per second now varies with the wavelength of the radiation?

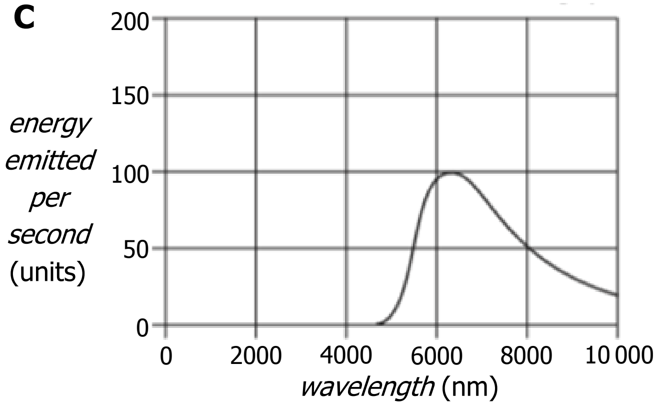
A



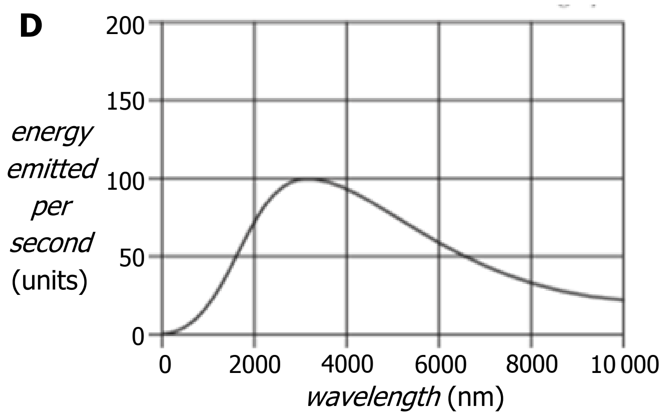
B



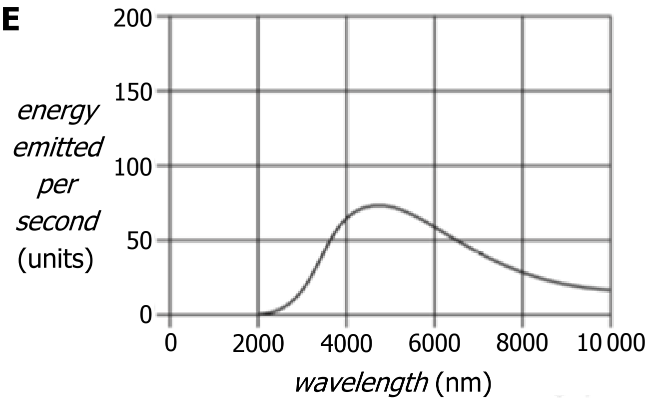
C



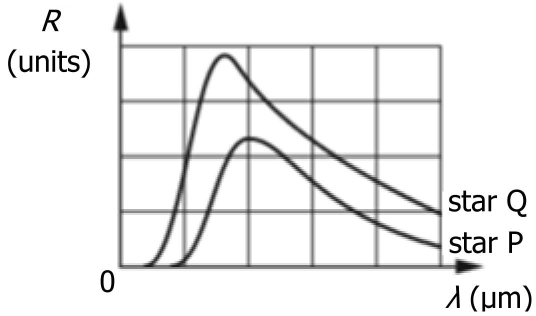
D



E



3. The graphs show how the radiation per unit surface area, R, varies with the wavelength of the emitted radiation for two stars, Q and P.



A student makes the following conclusions based on the information in the graph.

I Star P is hotter than star Q.

II Star P emits more radiation per unit surface area than star Q.

III The peak intensity of the radiation from star Q is at a shorter wavelength than that from star P.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

4. A student makes the following statements about the radiation emitted by stellar objects.

I Stellar objects emit radiation over a wide range of frequencies.

II The peak wavelength of radiation is longer for hotter objects than for cooler objects.

III At all frequencies, hotter objects emit more radiation per unit surface area per unit time than cooler objects.

Which of these statements is/are correct?

A I only

B III only

C I and II only

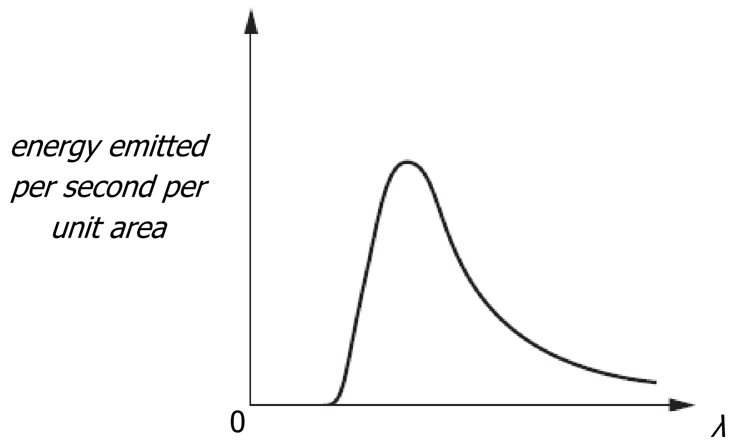
D I and III only

E I, II and III

Temperature of Stars

5. Stars emit radiation with a range of wavelengths. The peak wavelength of the radiation depends on the surface temperature of the star.

(a) The graph shows how the energy emitted per second per unit area varies with the wavelength λ of the radiation for a star with a surface temperature of 5000 K.



A second star has a surface temperature of 6000 K.

Copy the above graph, then add a line to show how the energy emitted per second per unit area varies with the wavelength λ of the radiation for the second star. Label the original and new line. 2

(b) The table gives the surface temperature T, in kelvin, of four different stars and the peak wavelength λ_{peak} of radiation emitted from each star.

T (K)	λ_{peak} (m)
7700	$3{\cdot}76 \times 10^{-7}$
8500	$3{\cdot}42 \times 10^{-7}$
9600	$3{\cdot}01 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

Use **all** the data in the table to show that the relationship between the surface temperature T of a star and the peak wavelength λ_{peak} radiated from the star is

$$T = \frac{2{\cdot}9 \times 10^{-3}}{\lambda_{peak}}$$

3