Our Dynamic Universe - Tutorial Questions - Part 2

**Special Relativity**

1. A river flows at a constant speed of 0·5 ms-1 south. A canoeist is able to row at a constant speed of 1·5 ms-1.

(a) Determine the velocity of the canoeist relative to the river bank when the canoeist is paddling north.

(b) Determine the velocity of the canoeist relative to the river bank when the canoeist is paddling south.

2. In an airport, passengers use a moving walkway. The moving walkway is travelling at a constant speed of 0·8 ms-1and is travelling east.

For the following people, determine the velocity of the person relative to the ground:

(a) a woman standing at rest on the walkway

(b) a man walking at 2·0 ms-1 in the same direction as the walkway is moving

1. a boy running west at 3·0 ms-1 .

3. The steps of an escalator move upwards at a steady speed of 1·0 ms-1 relative to the stationary side of the escalator.

(a) A man walks up the steps of the escalator at 2·0 ms-1. Determine the speed of the man relative to the side of the escalator.

(b) A boy runs down the steps of the escalator at 3·0 m s-1 . Determine the speed of the boy relative to the side of the escalator.

4. In the following sentences the words represented by the letters A, B, C, D, E, F and G are missing:

In A Theory of Special Relativity the laws of physics are the B for all observers, at rest or moving at constant velocity with respect to each other ie C acceleration.

An observer, at rest or moving at constant D has their own frame of reference.

In all frames of reference the E , c, remains the same regardless of whether the source or observer is in motion.

Einstein’s principles that the laws of physics and the speed of light are the same for all observers leads to the conclusion that moving clocks run F (time dilation) and moving objects are G (length contraction).

Match each letter with the correct word from the list below:

acceleration different Einstein’s fast

lengthened Newton’s same shortened

slow speed of light velocity zero

5. An observer at rest on the Earth sees an aeroplane fly overhead at a constant speed of 2000 kmh-1. At what speed, in kmh-1, does the pilot of the aeroplane see the Earth moving? [TQ]

6. A scientist is in a windowless lift. Can the scientist determine whether the lift is moving with a:

(a) uniform velocity

(b) uniform acceleration?

7. Spaceship A is moving at a speed of 2·4 × 108 ms-1. It sends out a light beam in the forwards direction. Meanwhile another spaceship B moves towards spaceship A at 2·4 × 108 ms-1. At what speed does spaceship B see the light beam from spaceship A pass?

8. A spacecraft is travelling at a constant speed of 7·5 × 107 ms-1. It emits a pulse of light when it is

3·0 × 1010m from the Earth as measured by an observer on the Earth.

Calculate the time taken for the pulse of light to reach the Earth according to a clock on the Earth when the spacecraft is moving:

(a) away from the Earth

(b) towards the Earth.

9. A spaceship is travelling away from the Earth at a constant speed of 1·5 × 108 ms-1 . A light pulse is emitted by a lamp on the Earth and travels towards the spaceship. Find the speed of the light pulse according to an observer on:

(a) the Earth

(b) the spaceship.

10. Convert the following fraction of the speed of light into a value in ms-1 :

(a) 0·1 c

(b) 0·5 c

(c) 0·6 c

(d) 0·8 c

11. Convert the following speeds into a fraction of the speed of light:

(a) 3·0 × 108 m s-1

(b) 2·0 × 10 8 m s-1

(c) 1·5 × 10 8 m s-1

1. 1·0 × 10 8 m s-1

**Time dilation**

1. Write down the relationship involving the proper time t and dilated time t’ between two events which are observed in two different frames of reference moving at a speed, v, relative to one another (where the proper time is the time measured by an observer at rest with respect to the two events and the dilated time is the time measured by another observer moving at a speed, v, relative to the two events).

2. In the table shown, use the relativity equation for time dilation to calculate the value of each missing quantity (a) to (f) for an object moving at a constant speed relative to the Earth.

|  |  |  |
| --- | --- | --- |
| Dilated time | Proper time | Speed of object / ms-1 |
| (a) | 20 h | 1·00 × 108 |
| (b) | 10 year | 2·25 × 108 |
| 1400 s | (c) | 2·00 × 108 |
| 1.40 × 10-4s | (d) | 1·00 × 108 |
| 84 s | 60 s | (e) |
| 21 minutes | 20 minutes | (f) |

3. Two observers P, on Earth, and Q, in a rocket, synchronise their watches at 11.00 am just as observer Q passes the Earth at a speed of 2 × 108 ms -1.

(a) At 11.15 am according to observer P’s watch, observer P looks at Q’s watch through a telescope. Calculate the time, to the nearest minute, that observer P sees on Q’s watch.

(b) At 11.15 am according to observer Q’s watch, observer Q looks at P’s watch through a telescope. Calculate the time, to the nearest minute, that observer Q sees on P’s watch.

4. The lifetime of a star is 10 billion years as measured by an observer at rest with respect to the star. The star is moving away from the Earth at a speed of 0·81 c.

Calculate the lifetime of the star according to an observer on the Earth.

5. A spacecraft moving with a constant speed of 0·75 c passes the Earth.

An astronaut on the spacecraft measures the time taken for Usain Bolt

to run 100 m in the sprint final at the 2008 Olympic Games. The astronaut

measures this time to be 14·65 s. Calculate Usain Bolt’s winning time as

measured on the Earth.

6. A scientist in the laboratory measures the time taken for a nuclear reaction to occur in an atom. When the atom is travelling at 8·0 × 107 ms-1 the reaction takes 4·0 × 10-4 s. Calculate the time for the reaction to occur when the atom is at rest.

7. The light beam from a lighthouse sweeps its beam of light around in a circle once every 10 s. To an astronaut on a spacecraft moving towards the Earth, the beam of light completes one complete circle every 14 s. Calculate the speed of the spacecraft relative to the Earth.

8. A rocket passes two beacons that are at rest relative to the Earth. An astronaut in the rocket measures the time taken for the rocket to travel from the first beacon to the second beacon to be 10·0 s. An observer on Earth measures the time taken for the rocket to travel from the first beacon to the second beacon to be 40·0 s. Calculate the speed of the rocket relative to the Earth.

9. A spacecraft travels to a distant planet at a constant speed relative to the Earth. A clock on the spacecraft records a time of 1 year for the journey while an observer on Earth measures a time of 2 years for the journey. Calculate the speed, in ms-1, of the spacecraft relative to the Earth.

**Length Contraction**

1. Write down the relationship involving the proper length l and contracted length l’ of a moving object observed in two different frames of reference moving at a speed, v, relative to one another (where the proper length is the length measured by an observer at rest with respect to the object and the contracted length is the length measured by another observer moving at a speed, v, relative to the object).

2. In the table shown, use the relativity equation for length contraction to calculate the value of each missing quantity (a) to (f) for an object moving at a constant speed relative to the Earth.

|  |  |  |
| --- | --- | --- |
| Contracted length | Proper length | Speed of object / m s -1 |
| (a) | 5·00 m | 1·00 × 108 |
| (b) | 15.0 m | 2·00 × 108 |
| 0·15 km | (c) | 2·25 × 108 |
| 150 mm | (d) | 1·04 × 108 |
| 30 m | 35 m | (e) |
| 10 m | 11 m | (f) |

3. A rocket has a length of 20 m when at rest on the Earth. An observer, at rest on the Earth, watches the rocket as it passes at a constant speed of 1·8 × 108 ms-1. Calculate the length of the rocket as measured by the observer.

4. A pi meson is moving at 0·90 c relative to a magnet. The magnet has a length of 2·00 m when at rest to the Earth. Calculate the length of the magnet in the reference frame of the pi meson.

5. In the year 2050 a spacecraft flies over a base station on the Earth. The spacecraft has a speed of 0·8 c. The length of the moving spacecraft is measured as 160 m by a person on the Earth. The spacecraft later lands and the same person measures the length of the now stationary spacecraft.

Calculate the length of the stationary spacecraft.

6. A rocket is travelling at 0·50 c relative to a space station. Astronauts on the rocket measure the length of the space station to be 0.80 km.

Calculate the length of the space station according to a technician on the space station.

7. A metre stick has a length of 1·00 m when at rest on the Earth. When in motion relative to an observer on the Earth the same metre stick has a length of 0·50 m. Calculate the speed, in ms−1, of the metre stick.

8. A spaceship has a length of 220 m when measured at rest on the Earth. The spaceship moves away from the Earth at a constant speed and an observer, on the Earth, now measures its length to be 150 m.

Calculate the speed of the spaceship in ms-1.

9. The length of a rocket is measured when at rest and also when moving at a constant speed by an observer at rest relative to the rocket. The observed length is 99·0 % of its length when at rest. Calculate the speed of the rocket.

**Relativity Miscellaneous**

1. Two points A and B are separated by 240 m as measured by metre sticks at rest on the Earth. A rocket passes along the line connecting A and B at a constant speed. The time taken for the rocket to travel from A to B, as measured by an observer on the Earth, is 1·00 × 10-6s.

(a) Show that the speed of the rocket relative to the Earth is 2·40 × 108 ms-1.

(b) Calculate the time taken, as measured by a clock in the rocket, for the rocket to travel from A to B.

(c) What is the distance between points A and B as measured by metre sticks carried by an observer travelling in the rocket?

2. A spacecraft is travelling at a constant speed of 0·95 c. The spacecraft travels at this speed for 1 year, as measured by a clock on the Earth.

(a) Calculate the time elapsed, in years, as measured by a clock in the spacecraft.

(b) Show that the distance travelled by the spacecraft as measured by an observer on the spacecraft is 2·8 × 1015m.

(c) Calculate the distance, in m, the spacecraft will have travelled as measured by an observer on the Earth.

3. A pi meson has a mean lifetime of 2·6 × 10-8 s when at rest. A pi meson moves with a speed of 0·99 c towards the surface of the Earth.

(a) Calculate the mean lifetime of this pi meson as measured by an observer on the Earth.

(b) Calculate the mean distance travelled by the pi meson as measured by the observer on the Earth.

4. A spacecraft moving at 2·4 × 108 ms-1 passes the Earth. An astronaut on the spacecraft finds that it takes 5·0 × 10-7 s for the spacecraft to pass a small marker which is at rest on the Earth.

(a) Calculate the length, in m, of the spacecraft as measured by the astronaut.

(b) Calculate the length of the spacecraft as measured by an observer at rest on the Earth.

5. A neon sign flashes with a frequency of 0·2 Hz.

(a) Calculate the time between flashes.

(b) An astronaut on a spacecraft passes the Earth at a speed of 0·84 c and sees the neon light flashing. Calculate the time between flashes as observed by the astronaut on the spacecraft.

6. When at rest, a subatomic particle has a lifetime of 0·15 ns. When in motion relative to the Earth the particle’s lifetime is measured by an observer on the Earth as 0·25 ns. Calculate the speed of the particle.

1. A meson is 10·0 km above the Earth’s surface and is moving towards the Earth at a speed of 0·999 c.
2. (a) Calculate the distance, according to the meson, travelled before it strikes the Earth.

(b) Calculate the time taken, according to the meson, for it to travel to the surface of the Earth.

8. The star Alpha Centauri is 4·2 light years away from the Earth. A spacecraft is sent from the Earth to Alpha Centauri. The distance travelled, as measured by the spacecraft, is 3·6 light years.

(a) Calculate the speed of the spacecraft relative to the Earth.

(b) Calculate the time taken, in seconds, for the spacecraft to reach Alpha Centauri as measured by an observer on the Earth.

(c) Calculate the time taken, in seconds, for the spacecraft to reach Alpha Centauri as measured by a clock on the spacecraft.

9. Muons, when at rest, have a mean lifetime of 2·60 × 10-8 s. Muons are produced 10 km above the Earth. They move with a speed of 0·995 c towards the surface of the Earth.

(a) Calculate the mean lifetime of the moving muons as measured by an observer on the Earth.

(b) Calculate the mean distance travelled by the muons as measured by an observer on the Earth.

(c) Calculate the mean distance travelled by the muons as measured by the muons.

**The Expanding Universe**

In the following questions, when required, use the approximation for speed of sound in air = 340 ms-1 .

1. In the following sentences the words represented by the letters A, B, C and D are missing:

A moving source emits a sound with frequency fs. When the source is moving towards a stationary observer, the observer hears a A frequency fo. When the source is moving away from a stationary observer, the observer hears a B frequency fo . This is known as the C D .

Match each letter with the correct word from the list below:

Doppler effect higher louder

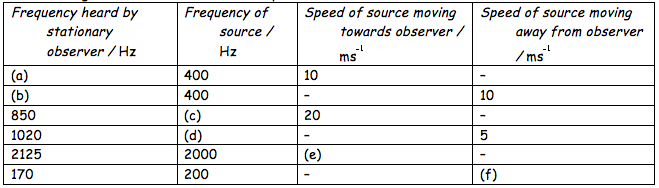
lower quieter softer

2. Write down the expression for the observed frequency fo, detected when a source of sound waves in air of frequency fs moves:

(a) towards a stationary observer at a constant speed, vs

(b) away from a stationary observer at a constant speed, vs .

3. In the table shown, calculate the value of each missing quantity (a) to (f), for a source of sound moving in air relative to a stationary observer.



4. A girl tries out an experiment to illustrate the Doppler effect by spinning a battery-operated siren around her head. The siren emits sound waves with a frequency of 1200 Hz. Describe what would be heard by a stationary observer standing a few metres away.

5. A police car emits sound waves with a frequency of 1000 Hz from its siren. The car is travelling at 20 ms-1 .

(a) Calculate the frequency heard by a stationary observer as the police car moves towards her.

(b) Calculate the frequency heard by the same observer as the police car moves away from her.

6. A student is standing on a station platform. A train approaching the station sounds its horn as it passes through the station. The train is travelling at a speed of 25 ms-1 . The horn has a frequency of 200 Hz.

(a) Calculate the frequency heard as the train is approaching the student.

(b) Calculate the frequency heard as the train is moving away from the student.

7. A man standing at the side of the road hears the horn of an approaching car. He hears a frequency of 470 Hz. The horn on the car has a frequency of 450 Hz. Calculate the speed of the car.

8. A source of sound emits waves of frequency 500 Hz. This is detected as 540 Hz by a stationary observer as the source of sound approaches. Calculate the frequency of the sound detected as the source moves away from the stationary observer.

9. A whistle of frequency 540 vibrations per second rotates in a circle of radius 0·75 m with a speed of 10 ms-1 . Calculate the lowest and highest frequency heard by a listener some distance away at rest with respect to the centre of the circle.

10. A woman is standing at the side of a road. A lorry, moving at 20 ms-1, sounds its horn as it is passing her. The lorry is moving at 20 ms-1 and the horn has a frequency of 300 Hz.

(a) Calculate the wavelength heard by the woman when the lorry is approaching her.

(b) Calculate the wavelength heard by the woman when the lorry is moving away from her.

11. A siren emitting a sound of frequency 1000 vibrations per second moves away from you towards the base of a vertical cliff at a speed of 10 ms-1 .

(a) Calculate the frequency of the sound you hear coming directly from the siren.

(b) Calculate the frequency of the sound you hear reflected from the cliff.

12. A sound source moves away from a stationary listener. The listener hears a frequency that is 10% lower than the source frequency. Calculate the speed of the source.

13. A bat flies towards a tree at a speed of 3·60 ms-1 while emitting sound of frequency 350 kHz. A moth is resting on the tree directly in front of the bat.

(a) Calculate the frequency of sound heard by the bat.

(b) The bat decreases its speed towards the tree. Does the frequency of sound heard by the moth increase, decrease or stays the same? Justify your answer.

(c) The bat now flies directly away from the tree with a speed of

4·50 ms-1 while emitting the same frequency of sound.

Calculate the new frequency of sound heard by the moth.

14. The siren on a police car has a frequency of 1500 Hz. The police car is moving at a constant speed of 54 km h-1 .

(a) Show that the police car is moving at 15 ms-1.

(b) Calculate the frequency heard when the car is moving towards a stationary observer.

(c) Calculate the frequency heard when the car is moving away from a stationary observer.

15. A source of sound emits a signal at 600 Hz. This is observed as 640 Hz by a stationary observer as the source approaches. Calculate the speed of the moving source.

16. A battery-operated siren emits a constant note of 2200 Hz. It is rotated in a circle of radius 0·8 m at 3·0 revolutions per second. A stationary observer, standing some distance away, listens to the note made by the siren.

(a) Show that the siren has a constant speed of 15·1 ms-1.

(b) Calculate the minimum frequency heard by the observer.

(c) Calculate the maximum frequency heard by the observer.

17. You are standing at the side of the road. An ambulance approaches you with its siren on. As the ambulance approaches, you hear a frequency of 460 Hz and as the ambulance moves away from you, a frequency of 410 Hz. The nearest hospital is 3 km from where you are standing.

Estimate the time for the ambulance to reach the hospital. Assume that the ambulance maintains a constant speed during its journey to the hospital.

18. On the planet Lots, a poobah moves towards a stationary glonk at 10 ms-1. The poobah emits sound waves of frequency 1100 Hz. The stationary glonk hears a frequency of 1200 Hz.

Calculate the speed of sound on the planet Lots.

19. In the following sentences the words represented by the letters A, B, C, D and E are missing:

A hydrogen source gives out a number of emission lines. λ for one of these lines is measured. When the light source is at rest, the value of this wavelength is λrest. When the same emission line is observed in light coming from a distant star the value of the wavelength is λobserved.

When a star is moving away from the Earth λobserved is \_ A\_ than λrest . This is known as the

\_B\_ shift.

When the distant star is moving towards the Earth λobserved is

\_\_C\_\_ than λrest . This is known as the \_\_D\_\_ shift.

Measurements on many stars indicate that most stars are moving \_E\_\_ from the Earth.

Match each letter with the correct word from the list below:

away blue longer

red shorter towards.

20. In the table shown, calculate the value of each missing quantity.

|  |  |  |
| --- | --- | --- |
| Fractional change in wavelength, z | Wavelength of light on Earth λrest/ nm | Wavelength of light observed from star, λ observed / nm |
| (a) | 365 | 402 |
| (b) | 434 | 456 |
| 8·00 × 10-2 | 486 | (c) |
| 4·00 × 10-2 | 656 | (d) |
| 5·00 × 10-2 | (e) | 456 |
| 1·00 × 10-1 | (f) | 402 |

**Hubble’s Law**

In the following questions, when required, use the approximation for

Ho = 2·4 × 10-18 s-1

1. Convert the following distances in light years into distances in metres.

(a) 1 light year

(b) 50 light years

(c) 100, 000 light years

(d) 16, 000, 000, 000 light years

2. Convert the following distances in metres into distances in light years.

(a) Earth to our Sun = 1·44 × 1011m.

(b) Earth to next nearest star Alpha Centauri = 3.97 × 1016 m.

(c) Earth to a galaxy in the constellation of Virgo = 4·91 × 1023 m.

3. In the table shown, calculate the value of each missing quantity.

|  |  |  |
| --- | --- | --- |
| Speed of galaxy relative to Earth / m s-1 | Approximate distance from Earth to galaxy / m | Fractional change in wavelength, z |
| (a) | 7.10 × 1022 | (b) |
| (c) | 1.89 × 1024 | (d) |
| 1·70 × 106 | (e) | (f) |
| 2·21 × 106 | (g) | (h) |

4. Light from a distant galaxy is found to contain the spectral lines of hydrogen. The light causing one of these lines has a measured wavelength of 466 nm. When the same line is observed from a hydrogen source on Earth it has a wavelength of 434 nm.

(a) Calculate the Doppler shift, z, for this galaxy.

(b) Calculate the speed at which the galaxy is moving relative to the Earth.

(c) In which direction, towards or away from the Earth, is the galaxy moving?

5. Light of wavelength 505 nm forms a line in the spectrum of an element on Earth. The same spectrum from light from a galaxy in Ursa Major shows this line shifted to correspond to light of wavelength 530 nm.

(a) Calculate the speed that the galaxy is moving relative to the Earth.

(b) Calculate the approximate distance, in metres, the galaxy is from the Earth.

6. A galaxy is moving away from the Earth at a speed of 0·074 c.

(a) Convert 0·074 c into a speed in ms-1.

(b) Calculate the approximate distance, in metres, of the galaxy from the Earth.

7. A distant star is travelling directly away from the Earth at a speed of 2·4 × 107 ms-1 .

(a) Calculate the value of z for this star.

(b) A hydrogen line in the spectrum of light from this star is measured to be 443 nm. Calculate the wavelength of this line when it observed from a hydrogen source on the Earth.

8. A line in the spectrum from a hydrogen atom has a wavelength of 489 nm on the Earth. The same line is observed in the spectrum of a distant star but with a longer wavelength of 538 nm.

(a) Calculate the speed, in ms-1, at which the star is moving away from the Earth.

(b) Calculate the approximate distance, in metres and in light years, of the star from the Earth.

9. The galaxy Corona Borealis is approximately 1 000 million light years away from the Earth. Calculate the speed at which Corona Borealis is moving away from the Earth.

10. A galaxy is moving away from the Earth at 3·0 × 107 ms -1. The frequency of an emission line coming from the galaxy is measured. The light forming the same emission line, from a source on Earth, is observed to have a frequency of 5·00 × 1014 Hz.

(a) Show that λ for the light of the emission line from the source on the Earth is 6·00 × 10-7m.

(b) Calculate the frequency of the light forming the emission line coming from the galaxy.

11. A distant quasar is moving away from the Earth. Hydrogen lines are observed coming from this quasar. One of these lines is measured to be 20 nm longer than the same line, of wavelength 486 nm from a source on Earth.

(a) Calculate the speed at which the quasar is moving away from the Earth.

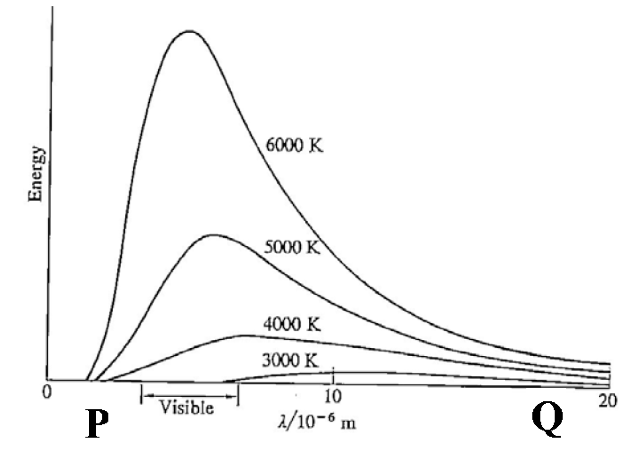
(b) Calculate the approximate distance, in millions of light years, that the quasar is from the Earth.

12. A hydrogen source, when viewed on the Earth, emits a red emission line of wavelength 656 nm. Observations, for the same line in the spectrum of light from a distant star, give a wavelength of 660 nm. Calculate the speed of the star relative to the Earth.

13. Due to the rotation of the Sun, light waves received from opposite ends of a diameter on the Sun show equal but opposite Doppler shifts. The relative speed of rotation of a point on the end of a diameter of the Sun relative to the Earth is 2 kms-1. Calculate the wavelength shift for a hydrogen line of wavelength 486·1 nm on the Earth.

**The Big Bang Theory**

1. The graphs below are obtained by measuring the energy emitted at different wavelengths from an object at different temperatures.



(a) Which part of the x-axis, P or Q, corresponds to ultraviolet radiation?

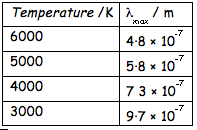
(b) What do the graphs show happens to the amount of energy emitted at a certain wavelength as the temperature of the object increases?

(c) What do the graphs show happens to the total energy radiated by the object as its temperature increases?

(d) Each graph shows that there is a wavelength λmaxat which the maximum amount of energy is emitted.

(i) Explain why the value of λ max decreases as the temperature of the object increases.

The table shows the values of λmax at different temperatures of the object.



(ii) Use this data to determine the relationship between temperature T and λmax .

(e) Use your answer to (d) (ii) to calculate:

(i) T of the star Sirius where λmax is 2·7 × 10-7m

(ii) the value of λmax for the star Alpha Crucis which has a temperature of 23,000 K

(iii) T of the present universe when λmax for the cosmic microwave radiation is measured as 1·1 × 10-3m.

(iv) the approximate wavelength and type of the radiation emitted by your skin, assumed to be at a temperature of 33 o C.

**TUTORIAL SOLUTIONS**

Special relativity

1. (a) 1·0 ms -1north (b) 2·0 ms -1 south

2. (a) 0·8 ms -1east (b) 2·8 ms -1east (c) 2·2 ms -1 west

3. (a) 3·0 ms-1  (b) 2·0 ms -1

4. A = Einstein’s; B = same; C = zero; D = velocity; E = speed of light; F = slow; G = shortened

5. 2000 kmh -1

6. (a) No (b) Yes

7. 3 × 108 ms -1

8. (a) 100 s (b) 100 s

9. (a) 3 × 108 ms -1 (b) 3 × 10 8 ms -1

10. (a) 0·3 × 108 ms-1  (b) 1·5 × 10 8 ms -1 (c) 1·8 × 10 8 m s -1 (d) 2·4 × 10 8 m s -1

11. (a) c (b) 0·67 c (c) 0·5 c (d) 0·33 c

Time dilation

2. (a) 21·2 h (b) 15·1 year (c) 1043 s (d) 1·32 × 10-4s

(e) 2·10 × 108 m s -1 (f) 9·15 × 10 7 m s -1

3. (a) 11.11 am (b) 11.11 am or 11.20 am depending on interpretation of question

4. 17·1 billion years

5. 9·69 s

6. 3·9 × 10-4 s

7. 2·1 × 108 m s -1 or 0·70 c

8. 2·90 108 m s -1 or 0·97 c

9. 2·60 × 108 m s -1

Length contraction

2. (a) 4·71 m (b) 11·2 m (c) 0·227 km (d) 160 mm

(e) 1·55 × 108 m s -1 (f) 1·25 × 10 8 m s -1

3. 16 m

4. 0·872 m

5. 267 m

6. 0·92 km

7. 2·60 × 108 m s -1

8. 2·19 × 108 m s -1

9. 4·23 × 107 m s -1 or 0.14 c

Relativity Miscellaneous

1 (b) 6 × 10-7s (c) 144 m

2. (a) 0·31 of a year (b) 2.8 x 1015 m (c) 8·99 × 1015 m

3. (a) 1·84 × 10-7s (b) 54·6 m

4. (a) 120 m (b) 72 m

5. (a) 5 s (b) 9·22 s

6. 0·8 c

7. (a) 447 m (b) 1·49 × 10-6 s

8. (a) 0·52 c (b) 2·58 × 108s (c) 2·21 × 10 8 s

9. (a) 2·60 × 10-7s (b) 77·6 m (c) 7·75 m

The Expanding Universe

1. A = higher; B= lower; C = Doppler; D = effect

3. (a) 412 Hz (b) 389 Hz (c) 800 Hz (d) 1035 Hz

(e) 20 m s -1 (f) 60 m s -1

5. (a) 1063 Hz (b) 944 Hz

6. (a) 216 Hz (b) 186 Hz

7. 14·5 m s -1

8. 466 Hz

9. 556 Hz, 525 Hz

10. (a) 1·07 m (b) 1·2 m

11. (a) 971 Hz (b) 1030 Hz

12. 37·8 m s -1

13. (a) 354 kHz (b) Decrease – denominator is larger (c) 346 kHz

14. (a) 15 ms-1  (b) 1569 Hz (c) 1437 Hz

15. 21·3 m s -1

16. (a) 15.1 ms-1 (b) 2106 Hz (c) 2302 Hz

17. 154 s

18. 120 m s -1

19. A = longer; B = red; C = shorter; D = blue; E = away

20. (a) 1·01 × 10-1 (b) 5·07 × 10 -2 (c) 525 nm (d) 682 nm

(e) 434 nm (f) 365 nm

Hubble’s Law

1. (a) 9·46 × 1015m (b) 4·75 × 10 17m (c) 9·46 × 10 20m (d) 1·51 × 10 26 m

2. (a) 1·52 × 10-5light years (b) 4·2 light years (c) 5·19 × 107 light years

4. (a) 7·37 × 10-2

(b) 2·21 × 107 ms

(c) Away

5. (a) 1·49 × 107 ms-1

(b) 6·21 × 10 24 m

6. (a) 2·22 × 107 ms-1

(b) 9·25 × 10 24 m

7. (a) 8 × 10-2

(b) 410 nm

8. (a) 3·0 × 107 ms-1

(b) 1·25 × 10 25 m, 1·32 × 109 light years

9. 2·27 × 107 ms -1

10. (a) Teacher Check

(b) 4·55 × 1014 Hz

11. (a) 1·23 × 107 ms -1

(b) 542 million light years

12. 1·83 × 106 ms -1

13. 3·24 × 10-12 m

The Big Bang Theory

1. (a) P

(b) Energy emitted increases

(c) Increases

(d) (ii) T λmax = 2·9 × 10-3m K

(e) (i) T =11, 000 K

(ii) λmax = 1·3 × 10-7m

(iii) T = 2·6 K

(iv) λ = 9·5 × 10-6 m, infrared

3.

|  |  |  |
| --- | --- | --- |
| v / m s-1 | d / m | z |
| 1·70 × 105 | 7·10 × 1022 | 5·67 × 10-4 |
| 4·54 × 106 | 1·89 × 1024 | 1·51 × 10-2 |
| 1·70 × 106 | 7·08 × 1023 | 5·667 × 10-3 |
| 2·21 × 106 | 9·21 × 1023 | 7·37 × 10-3 |

4. (a) 7·37 × 10-2  (b) 2·21 × 107 ms (c) Away

5. (a) 1·49 × 107 ms-1  (b) 6·21 × 10 24 m

6. (a) 2·22 × 107 ms-1  (b) 9·25 × 10 24 m

7. (a) 8 × 10-2  (b) 410 nm

8. (a) 3·0 × 107 ms-1  (b) 1·25 × 10 25 m, 1·32 × 109 light years

9. 2·27 × 107 ms -1

10. (b) 4·55 × 1014 Hz

11. (a) 1·23 × 107 ms -1 (b) 542 million light years

12. 1·83 × 106 ms -1

13. 3·24 × 10-12 m

The Big Bang Theory

1. (a) P (b) Energy emitted increases (c) Increases (d) (ii) T λmax = 2·9 × 10-3m K

(e) (i) T =11, 000 K

(ii) λmax = 1·3 × 10-7m

(iii) T = 2·6 K

(iv) λ = 9·5 × 10-6 m, infrared