HIGHER PHYSICS

Unit 1
Our Dynamic Universe

Exam Question Booklet
DATA SHEET
COMMON PHYSICAL QUANTITIES

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Value</th>
<th>Quantity</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of light in vacuum</td>
<td>c</td>
<td>$3 \times 10^8$ m$^2$s$^{-1}$</td>
<td>Planck’s constant</td>
<td>h</td>
<td>$6.63 \times 10^{-34}$ J s</td>
</tr>
<tr>
<td>Magnitude of the charge on an</td>
<td>e</td>
<td>$1.60 \times 10^{-19}$ C</td>
<td>Mass of electron</td>
<td>m$_e$</td>
<td>$9.11 \times 10^{-31}$ kg</td>
</tr>
<tr>
<td>electron</td>
<td></td>
<td></td>
<td>Universal Constant of</td>
<td>G</td>
<td>$6.67 \times 10^{-11}$ m$^3$kg$^{-1}$s$^{-2}$</td>
</tr>
<tr>
<td>Gravitational acceleration on</td>
<td>g</td>
<td>$9.8$ m$^2$s$^{-2}$</td>
<td>Mass of neutron</td>
<td>m$_n$</td>
<td>$1.675 \times 10^{-27}$ kg</td>
</tr>
<tr>
<td>Earth</td>
<td>$H_0$</td>
<td>$2.3 \times 10^{-18}$ s$^{-1}$</td>
<td>Mass of proton</td>
<td>m$_p$</td>
<td>$1.673 \times 10^{-27}$ kg</td>
</tr>
</tbody>
</table>

REFRACTIVE INDICES
The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Refractive index</th>
<th>Substance</th>
<th>Refractive index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>2.42</td>
<td>Water</td>
<td>1.33</td>
</tr>
<tr>
<td>Crown glass</td>
<td>1.50</td>
<td>Air</td>
<td>1.00</td>
</tr>
</tbody>
</table>

SPECTRAL LINES

<table>
<thead>
<tr>
<th>Element</th>
<th>Wavelength/nm</th>
<th>Colour</th>
<th>Element</th>
<th>Wavelength/nm</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>656</td>
<td>Red</td>
<td>Cadmium</td>
<td>644</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>486</td>
<td>Blue-green</td>
<td></td>
<td>509</td>
<td>Green</td>
</tr>
<tr>
<td></td>
<td>434</td>
<td>Blue-violet</td>
<td></td>
<td>480</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>410</td>
<td>Violet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>397</td>
<td>Ultraviolet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>389</td>
<td>Ultraviolet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>589</td>
<td>Yellow</td>
<td>Carbon dioxide</td>
<td>9550$^1$</td>
<td>Infrared</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10590$^1$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Helium-neon</td>
<td>633</td>
<td>Red</td>
</tr>
</tbody>
</table>

The gas densities refer to a temperature of 273 K and a pressure of $1.01 \times 10^5$ Pa.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density/kg m$^{-3}$</th>
<th>Melting Point/K</th>
<th>Boiling Point/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>$2.70 \times 10^3$</td>
<td>933</td>
<td>2623</td>
</tr>
<tr>
<td>Copper</td>
<td>$8.96 \times 10^3$</td>
<td>1357</td>
<td>2853</td>
</tr>
<tr>
<td>Ice</td>
<td>$9.20 \times 10^2$</td>
<td>273</td>
<td></td>
</tr>
<tr>
<td>Sea Water</td>
<td>$1.02 \times 10^3$</td>
<td>264</td>
<td>377</td>
</tr>
<tr>
<td>Water</td>
<td>$1.00 \times 10^3$</td>
<td>273</td>
<td>373</td>
</tr>
<tr>
<td>Air</td>
<td>1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$9.0 \times 10^{-2}$</td>
<td>14</td>
<td>20</td>
</tr>
</tbody>
</table>

The gas densities refer to a temperature of 273 K and a pressure of $1.01 \times 10^5$ Pa.
MULTIPLE CHOICE QUESTIONS

1. A train accelerates uniformly from 5·0 m s\(^{-1}\) to 12·0 m s\(^{-1}\) while travelling a distance of 119 m along a straight track. The acceleration of the train is
   
   A 0·50 m s\(^{-2}\)
   B 0·70 m s\(^{-2}\)
   C 1·2 m s\(^{-2}\)
   D 7·0 m s\(^{-2}\)
   E 14 m s\(^{-2}\).  

2. An object starts from rest and accelerates in a straight line.
   The graph shows how the acceleration of the object varies with time.

   ![Acceleration graph]
   
   The speed of the object at 5 seconds is
   
   A 2 m s\(^{-1}\)
   B 8 m s\(^{-1}\)
   C 12 m s\(^{-1}\)
   D 16 m s\(^{-1}\)
   E 20 m s\(^{-1}\).  

3. A vehicle runs down a slope as shown.
   
   ![Vehicle diagram]
   
   The following results are obtained.
   
   angle of slope, \(\theta = 15·0 \pm 0·5^\circ\)
   length of card on top of vehicle, \(d = 0·020 \pm 0·001\) m
   time for card to pass light gate 1, \(t_1 = 0·40 \pm 0·01\) s
   time for card to pass light gate 2, \(t_2 = 0·25 \pm 0·01\) s
   time for vehicle to travel between the light gates, \(t_3 = 0·50 \pm 0·01\) s
   
   Which quantity has the largest percentage uncertainty?
   
   A \(\theta\)
   B \(d\)
   C \(t_1\)
   D \(t_2\)
   E \(t_3\)

4. Two blocks are linked by a newton balance of negligible mass.
   The blocks are placed on a level, frictionless surface. A force of 18·0 N is applied to the blocks as shown.

   ![Newton balance diagram]
   
   The reading on the newton balance is
   
   A 7·2 N
   B 9·0 N
   C 10·8 N
   D 18·0 N
   E 40·0 N.
5. A box is placed on a horizontal surface.
A force of 15 N acts on the box as shown.

Which entry in the table shows the horizontal and vertical components of the force?

<table>
<thead>
<tr>
<th></th>
<th>Horizontal component/N</th>
<th>Vertical component/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15 \sin 60^\circ</td>
<td>15 \sin 30^\circ</td>
</tr>
<tr>
<td>B</td>
<td>15 \cos 60^\circ</td>
<td>15 \sin 30^\circ</td>
</tr>
<tr>
<td>C</td>
<td>15 \sin 60^\circ</td>
<td>15 \cos 60^\circ</td>
</tr>
<tr>
<td>D</td>
<td>15 \cos 30^\circ</td>
<td>15 \sin 30^\circ</td>
</tr>
<tr>
<td>E</td>
<td>15 \cos 60^\circ</td>
<td>15 \sin 60^\circ</td>
</tr>
</tbody>
</table>

7. A rock of mass 0.80 kg falls towards the surface of a planet.

The graph shows how the gravitational field strength, \( g \), of the planet varies with height, \( h \), above the surface of the planet.

At one point during its fall the weight of the rock is 4.0 N. The height of this point above the surface of the planet is

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15 km</td>
</tr>
<tr>
<td>B</td>
<td>80 km</td>
</tr>
<tr>
<td>C</td>
<td>105 km</td>
</tr>
<tr>
<td>D</td>
<td>130 km</td>
</tr>
<tr>
<td>E</td>
<td>255 km</td>
</tr>
</tbody>
</table>

8. 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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.011</td>
</tr>
<tr>
<td>B</td>
<td>0.50</td>
</tr>
<tr>
<td>C</td>
<td>0.99</td>
</tr>
<tr>
<td>D</td>
<td>2.0</td>
</tr>
<tr>
<td>E</td>
<td>94.</td>
</tr>
</tbody>
</table>
9. A trolley travels along a straight track. The graph shows how the velocity \( v \) of the trolley varies with time \( t \).

Which graph shows how the acceleration \( a \) of the trolley varies with time \( t \)?

A. 

B. 

C. 

D. 

E. 

10. A rocket of mass 200 kg accelerates vertically upwards from the surface of a planet at 2.0 m/s\(^2\). The gravitational field strength on the planet is 4.0 N/kg\(^{-1}\).

What is the size of the force being exerted by the rocket’s engines?

A. 400 N
B. 800 N
C. 1200 N
D. 2000 N
E. 2400 N

11. The diagram shows the masses and velocities of two trolleys just before they collide on a level bench.

After the collision, the trolleys move along the bench joined together.

How much kinetic energy is lost in this collision?

A. 0 J
B. 6.0 J
C. 12 J
D. 18 J
E. 24 J
12. A satellite orbits a planet at a distance of \(5.0 \times 10^7\) m from the centre of the planet.

The mass of the satellite is \(2.5 \times 10^4\) kg.

The mass of the planet is \(4.0 \times 10^{24}\) kg.

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

A \(1.7 \times 10^{-6}\) N

B \(2.7 \times 10^3\) N

C \(1.3 \times 10^{11}\) N

D \(2.7 \times 10^{14}\) N

E \(2.7 \times 10^{32}\) N.

13. The length of a spaceship at rest is \(L\).

This spaceship passes a planet at a speed of \(0.95c\).

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?

<table>
<thead>
<tr>
<th>Length measured by observer on spaceship</th>
<th>Length measured by observer on planet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (L)</td>
<td>(L)</td>
</tr>
<tr>
<td>B (L)</td>
<td>less than (L)</td>
</tr>
<tr>
<td>C less than (L)</td>
<td>(L)</td>
</tr>
<tr>
<td>D less than (L)</td>
<td>less than (L)</td>
</tr>
<tr>
<td>E greater than (L)</td>
<td>less than (L)</td>
</tr>
</tbody>
</table>

14. A spacecraft travels at a constant speed of \(0.70c\) 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.

15. A galaxy is moving away from the Earth at a velocity of \(1.20 \times 10^7\) 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.

16. 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
17. A trolley has a constant acceleration of 3 m s\(^{-2}\). This means that

A. the distance travelled by the trolley increases by 3 metres per second every second
B. the displacement of the trolley increases by 3 metres per second every second
C. the speed of the trolley is 3 m s\(^{-1}\) every second
D. the velocity of the trolley is 3 m s\(^{-1}\) every second
E. the velocity of the trolley increases by 3 m s\(^{-1}\) every second.

18. Which of the following velocity-time graphs represents the motion of an object that changes direction?

A. [Diagram of a straight line increasing with time]

B. [Diagram of a straight line decreasing with time]

C. [Diagram of a straight line increasing with time]

D. [Diagram of a straight line decreasing with time]

E. [Diagram of a straight line with a peak]
19. A football of mass 0.75 kg is initially at rest. A girl kicks the football and it moves off with an initial speed of 12 ms\(^{-1}\). The time of contact between the girl’s foot and the football is 0.15 s.

The average force applied to the football as it is kicked is

A 1.4 N  
B 1.8 N  
C 2.4 N  
D 60 N  
E 80 N.

20. Two small asteroids are 12 m apart.

The masses of the asteroids are \(2 \times 10^3\) kg and \(0.050 \times 10^3\) kg.

The gravitational force acting between the asteroids is

A \(1.2 \times 10^{-9}\) N  
B \(4.6 \times 10^{-8}\) N  
C \(5.6 \times 10^{-7}\) N  
D \(1.9 \times 10^{-6}\) N  
E \(6.8 \times 10^{-3}\) N.

21. A spaceship on a launch pad is measured to have a length \(L\). This spaceship has a speed of \(2.5 \times 10^8\) m s\(^{-1}\) as it passes a planet.

Which row in the table describes the length of the spaceship as measured by the pilot in the spaceship and an observer on the planet?

<table>
<thead>
<tr>
<th>Length measured by pilot in the spaceship</th>
<th>Length measured by observer on the planet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Less than (L)</td>
</tr>
<tr>
<td>B</td>
<td>Greater than (L)</td>
</tr>
<tr>
<td>C</td>
<td>(L)</td>
</tr>
<tr>
<td>D</td>
<td>Less than (L)</td>
</tr>
<tr>
<td>E</td>
<td>Greater than (L)</td>
</tr>
</tbody>
</table>
The siren on an ambulance is emitting sound with a constant frequency of 900 Hz. The ambulance is travelling at a constant speed of 25 m s\(^{-1}\) as it approaches and passes a stationary observer. The speed of sound in air is 340 m s\(^{-1}\).

Which row in the table shows the frequency of the sound heard by the observer as the ambulance approaches and as it moves away from the observer?

<table>
<thead>
<tr>
<th></th>
<th>Frequency as ambulance approaches (Hz)</th>
<th>Frequency as ambulance moves away (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>B</td>
<td>971</td>
<td>838</td>
</tr>
<tr>
<td>C</td>
<td>838</td>
<td>900</td>
</tr>
<tr>
<td>D</td>
<td>971</td>
<td>900</td>
</tr>
<tr>
<td>E</td>
<td>838</td>
<td>971</td>
</tr>
</tbody>
</table>
23. A ball moves down a frictionless slope from X to Y.

Which graph shows how the acceleration $a$ of the ball varies with time $t$ as it moves down the slope?

A

B

C

D

E

24. A boat is moving at a speed of 6.0 m s$^{-1}$. The boat now accelerates at 3.0 m s$^{-2}$ until it reaches a speed of 12 m s$^{-1}$.

The distance travelled by the boat during this acceleration is

A  6.0 m
B  18 m
C  30 m
D  36 m
E  54 m.

25. The graph shows how the force acting on an object of mass 5.0 kg varies with time.

The change in momentum of the object is

A  7.0 kg m s$^{-1}$
B  30 kg m s$^{-1}$
C  35 kg m s$^{-1}$
D  60 kg m s$^{-1}$
E  175 kg m s$^{-1}$.
26. A spaceship is moving with a constant speed of $0.6c$ towards the Earth. The spaceship emits 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?

<table>
<thead>
<tr>
<th></th>
<th>Speed of emitted light as measured by astronaut</th>
<th>Speed of emitted light as measured by observer on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$0.4c$</td>
<td>$1.6c$</td>
</tr>
<tr>
<td>B</td>
<td>$c$</td>
<td>$c$</td>
</tr>
<tr>
<td>C</td>
<td>$c$</td>
<td>$1.6c$</td>
</tr>
<tr>
<td>D</td>
<td>$1.6c$</td>
<td>$0.4c$</td>
</tr>
<tr>
<td>E</td>
<td>$1.6c$</td>
<td>$c$</td>
</tr>
</tbody>
</table>

27. Astronomers use the following relationship to determine the distance, $d$, to a star.

$$b = \frac{L}{4\pi d^2}$$

For a particular star the following data is recorded:

apparent brightness, $b = 4.4 \times 10^{-10}$ W m$^{-2}$

luminosity, $L = 6.1 \times 10^{36}$ W

Based on this information, the distance to this star is

A $3.3 \times 10^{19}$ m  
B $1.5 \times 10^{21}$ m  
C $3.7 \times 10^{36}$ m  
D $1.1 \times 10^{39}$ m  
E $3.9 \times 10^{39}$ m.

28. The graph shows how the energy emitted per second from the surface of a hot object varies with the wavelength, $\lambda$, 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

29. 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  
MOTION – EQUATIONS AND GRAPHS

1. In a “handicap” sprint race, sprinters P and Q both start at the same time but from
different starting lines on the track.
The handicapping is such that both sprinters reach line XY, as shown below, at the
same.

![Diagram showing sprinters P and Q with starting lines and line XY]

Sprinter P has a constant acceleration of 1·6 m s\(^{-2}\) from the start line to the line XY.
Sprinter Q has a constant acceleration of 1·2 m s\(^{-2}\) from the start line to line XY.

(a) Calculate the time taken by the sprinters to reach line XY.
(b) Find the speed of each sprinter at this line.
(c) What is the distance, in metres, between the starting lines for sprinters P and Q?

2. (a) An object starts from rest and moves with constant acceleration a. After a time t,
the velocity v and displacement s are given by

\[ v = at \quad \text{and} \quad s = \frac{1}{2}at^2 \]

Use these relationships, to show that

\[ v^2 = 2as. \]
3. (a) A sports car is being tested along a straight track.

(i) In the first test, the car starts from rest and has a constant acceleration of $4.0 \text{ m s}^{-2}$ in a straight line for $7.0 \text{ s}$.
Calculate the distance the car travels in the $7.0 \text{ s}$. 3

(ii) In a second test, the car reaches a speed of $40 \text{ m s}^{-1}$. It then decelerates at $2.5 \text{ m s}^{-2}$ until it comes to rest.
Calculate the distance travelled by the car while it decelerates to rest. 3

(b) A student measures the acceleration of a trolley as it moves freely down a sloping track.

The trolley has a card mounted on it. As it moves down the track the card cuts off the light at each of the light gates in turn. Both the light gates are connected to a computer which is used for timing.

The student uses a stopclock to measure the time it takes the trolley to move from the first light gate to the second light gate.

(i) List all the measurements that have to be made by the student and the computer to allow the acceleration of the trolley to be calculated. 2

(ii) Explain fully how each of these measurements is used in calculating the acceleration of the trolley as it moves down the slope. 3

(11)
4. A car is travelling at a constant speed of 15 m s\(^{-1}\) along a straight, level road. It passes a motorcycle which is stationary at the roadside.

At the instant the car passes, the motorcycle starts to move in the same direction as the car. The graph shows the motion of each vehicle from the instant the car passes the motorcycle.

(a) Show that the initial acceleration of the motorcycle is 5·0 m s\(^{-2}\).

(b) Calculate the distance between the car and the motorcycle at 4·0 s.
5. To test the braking system of cars, a test track is set up as shown.

The sensors are connected to a datalogger which records the speed of a car at both P and Q.

A car is driven at a constant speed of 30 ms\(^{-1}\) until it reaches the start of the braking zone at P. The brakes are then applied.

(a) In one test, the datalogger records the speed at P as 30 ms\(^{-1}\) and the speed at Q as 12 ms\(^{-1}\). The car slows down at a constant rate of 9.0 ms\(^{-2}\) between P and Q. Calculate the length of the braking zone.

(b) The test is repeated. The same car is used but now with passengers in the car. The speed at P is again recorded as 30 ms\(^{-1}\). The same braking force is applied to the car as in part (a). How does the speed of the car at Q compare with its speed at Q in part (a)? Justify your answer.
FORCES, ENERGY AND POWER

1. (a) An aircraft of mass 1000 kg has a speed of 33 m s\(^{-1}\) before it takes off from a runway. The engine of the aircraft provides a constant thrust of 3150 N. A constant frictional force of 450 N acts on the aircraft as it moves along the runway.

(i) Calculate the acceleration of the aircraft along the runway.

(ii) The aircraft starts from rest. Calculate the minimum length of runway required for a take-off.

(b) During a flight the aircraft is travelling with a velocity of 36 m s\(^{-1}\) due north (000). A wind with a speed of 12 m s\(^{-1}\) starts to blow towards the direction of 40° west of north (320).

Find the magnitude and direction of the resultant velocity of the aircraft.

2. A motorcycle is accelerating at 5.0 ms\(^{-2}\). The total mass of the motorcycle and rider is 290 kg. At a particular time in the acceleration the driving force on the motorcycle is 1800 N.

(a) Calculate the frictional force acting on the motorcycle at this time.

(b) Explain why the driving force must be increased with time to maintain a constant acceleration.
3. (a) A box of mass 18 kg is at rest on a horizontal frictionless surface. A force of 4·0 N is applied to the box at an angle of 26° to the horizontal.

\[ \text{force diagram} \]

(i) Show that the horizontal component of the force is 3·6 N.

(ii) Calculate the acceleration of the box along the horizontal surface.

(iii) Calculate the horizontal distance travelled by the box in a time of 7·0 s.

(b) The box is replaced at rest at its starting position. The force of 4·0 N is now applied to the box at an angle of less than 26° to the horizontal.

\[ \text{force diagram} \]

The force is applied for a time of 7·0 s as before. How does the distance travelled by the box compare with your answer to part (a)(iii)? You must justify your answer.

4. A helicopter is flying at a constant height above ground. The helicopter is carrying a crate suspended from a cable as shown.

\[ \text{helicopter diagram} \]

The helicopter reaches its destination and hovers above a drop zone.

(a) The total mass of the helicopter and crate is $1.21 \times 10^4$ kg. Show that the helicopter produces a lift force of 119 kN.

(b) The helicopter now drops the crate which has a mass of $2.30 \times 10^3$ kg. Describe the vertical motion of the helicopter immediately after the crate is dropped. Justify your answer in terms of the forces acting on the helicopter.
5. A “giant catapult” is part of a fairground ride.

Two people are strapped into a capsule. The capsule and the occupants have a combined mass of 236 kg. The capsule is held stationary by an electromagnet while the tension in the elastic cords is increased using the winches. The mass of the elastic cords and the effects of air resistance can be ignored.

(a) When the tension in each cord reaches $4.5 \times 10^3$ N the electromagnet is switched off and the capsule and occupants are propelled vertically upwards.

(i) Calculate the vertical component of the force exerted by each cord just before the capsule is released.

(ii) Calculate the initial acceleration of the capsule.

(ii) Explain why the acceleration of the capsule decreases as it rises.

(b) Throughout the ride the occupants remain upright in the capsule. A short time after release the occupants feel no force between themselves and the seats. Explain why this happens.
6. A van of mass 2600 kg moves down a slope which is inclined at 12° to the horizontal as shown.

(a) Calculate the component of the van’s weight parallel to the slope.

(b) A constant frictional force of 1400 N acts on the van as it moves down the slope. Calculate the acceleration of the van.

(c) The speed of the van as it passes point A is 5·0 m s\(^{-1}\). Point B is 75 m further down the slope. Calculate the kinetic energy of the van at B.

7. A fairground ride consists of rafts which slide down a slope into water.

The slope is at an angle of 22° to the horizontal. Each raft has a mass of 8·0 kg. The length of the slope is 50 m.

A child of mass 52 kg sits in a raft at the top of the slope. The raft is released from rest. The child and raft slide together down the slope into the water. The force of friction between the raft and the slope remains constant at 180 N.

(a) Calculate the component of weight, in newtons, of the child and raft down the slope.

(b) Show by calculation that the acceleration of the child and raft down the slope is 0·67 m s\(^{-2}\).

(c) Calculate the speed of the child and raft at the bottom of the slope.

(d) A second child of smaller mass is released from rest in an identical raft at the same starting point. The force of friction is the same as before. How does the speed of the child and raft at the bottom of the slope compare with the answer to part (c)? Justify your answer.
8. A crate of mass 40.0 kg is pulled up a slope using a rope. The slope is at an angle of 30° to the horizontal.

A force of 240 N is applied to the crate parallel to the slope. The crate moves at a constant speed of 3.0 m s⁻¹.

(a) (i) Calculate the component of the weight acting parallel to the slope, 1

(ii) Calculate the frictional force acting on the crate. 3

(b) As the crate is moving up the slope, the rope snaps. The graph shows how the velocity of the crate changes from the moment the rope snaps.

(i) Describe the motion of the crate during the first 0.5 s after the rope snaps. 1

(ii) Copy the axes shown below and sketch the graph to show the acceleration of the crate between 0 and 1.0 s. Appropriate numerical values are also required on the acceleration axis. 2

(iii) Explain, in terms of the forces acting on the crate, why the magnitude of the acceleration changes at 0.5 s. 2
9. A bungee jumper is attached to a high bridge by a thick elastic cord.

The graph shows how the velocity of the bungee jumper varies with time during the first 6 s of a jump.

(a) Using the information on the graph, state the time at which the bungee rope is at its maximum length.

(b) Calculate the average unbalanced force, in newtons, acting on the bungee jumper between points A and B on the graph.

(c) Explain, in terms of the force of the rope on the bungee jumper, why an elastic rope is used rather than a rope which cannot stretch very much.
Section 3: Collisions and Explosions

1. The apparatus shown below is used to test concrete pipes.

When the rope is released, the 15 kg mass is dropped and falls freely through a distance of 2·0 m on to the pipe.

(a) In one test, the mass is dropped on to an uncovered pipe.

(i) Calculate the speed of the mass just before it hits the pipe.

(ii) When the 15 kg mass hits the pipe the mass is brought to rest in a time of 0·020 s. Calculate the size and direction of the average unbalanced force on the pipe.

(b) The same 15 kg mass is now dropped through the same distance on to an identical pipe which is covered with a thick layer of soft material. Describe and explain the effect this layer has on the size of the average unbalanced force on the pipe.

(c) Two 15 kg, X and Y, shaped as shown, are dropped through the same distance on to identical uncovered concrete pipes.

When the masses hit the pipes, the masses are brought to rest in the same time.

Using your knowledge of physics, explain which mass causes more damage to a pipe.
2. Two ice skaters are initially skating together, each with a velocity of \(2.2 \text{ m s}^{-1}\) to the right as shown.

The mass of skater R is 54 kg. The mass of skater S is 38 kg.

Skater R now pushes skater S with an average force of 130 N for a short time. This force is in the same direction as their original velocity.

As a result, the velocity of skater S increases to \(4.6 \text{ m s}^{-1}\) to the right.

(a) Calculate the magnitude of the change in momentum of skater S. 3

(b) Calculate how long skater R exerts the force on skater S. 3

(c) Calculate the velocity of skater R immediately after pushing skater S. 3

(d) Is this interaction between the skaters elastic? You must justify your answer by calculation. 4

(13)
3. (a) A space vehicle of mass 2500 kg is moving with a constant speed of 0·50 m s\(^{-1}\) in the direction shown. It is about to dock with a space probe of mass 1500 kg which is moving with a constant speed in the opposite direction.

![Diagram of space vehicle and space probe with arrows showing 0.50 m s\(^{-1}\) and 0.20 m s\(^{-1}\) speeds]

After docking, the space vehicle and the space probe move off together at 0·20 m s\(^{-1}\) in the original direction in which the space vehicle was moving.

![Diagram showing space vehicle and space probe moving at 0.20 m s\(^{-1}\)]

Calculate the speed of the space probe before it docked with the space vehicle.

(b) The space vehicle has a rocket engine which produces a constant thrust of 1000 N. The space probe has a rocket engine which produces a constant thrust of 500 N.

The space vehicle and space probe are now brought to rest from their combined speed of 0·20 m s\(^{-1}\).

(i) Which rocket engine was switched on to bring the vehicle and probe to rest?

(ii) Calculate the time for which this rocket engine was switched on. You may assume that a negligible mass of fuel was used during this time.

(c) The space vehicle and space probe are to be moved from their stationary position at A and brought to rest at position B, as shown.

![Diagram showing space vehicle and space probe at positions A and B]

Explain clearly how the rocket engines of the space vehicle and the space probe are used to complete this manoeuvre. Your explanation must include an indication of the relative time for which each rocket engine must be fired. You may assume that a negligible mass of fuel is used during this manoeuvre.
4. A force sensor is used to investigate the impact of a ball as it bounces on a flat horizontal surface. The ball has a mass of 0.050 kg and is dropped, vertically from rest, through a height of 1.6 m as shown.

(a) The graph shows how the force on the ball varies with time during the impact.

(i) Show by calculation that the magnitude of the impulse on the ball is 0.35 Ns.

(ii) What is the magnitude and direction of the change in momentum of the ball?

(iii) The ball is travelling at 5.6 m s\(^{-1}\) just before it hits the force sensor. Calculate the speed of the ball just as it leaves the force sensor.

(b) Another ball of identical size and mass, but made of harder material, is dropped from rest and from the same height on to the same force sensor. Sketch the force-time graph shown above and, on the same axes, sketch another graph to show how the force on the harder ball varies with time. Numerical values are not required but you must label the graphs clearly.
5. An experiment is set up to investigate the motion of a cart as it collides with a force sensor.

The cart moves along the horizontal track at 0.48 m s\(^{-1}\) to the right. As the cart approaches the force sensor, the magnets repel each other and exert a force on the cart. The computer attached to the force sensor displays the following force-time graph for the collision.

![Force-time graph](image1)

The computer attached to the motion sensor displays the following velocity-time graph for the cart.

![Velocity-time graph](image2)

(a) (i) Calculate the magnitude of the impulse on the cart during the collision.

(ii) Determine the magnitude and direction of the change in momentum of the cart.

(iii) Calculate the mass of the cart.

(b) The experiment is repeated using different magnets which produce a greater average force on the cart during the collision. As before, the cart is initially travelling at 0.48 m s\(^{-1}\) to the right and the collision causes the same change in its velocity.

Copy the force-time graph shown and, on the same axes, draw another graph to show how the magnitude of the force varies with time in this collision. Numerical values are not required but you must label each graph clearly.
6. (a) State the law of conservation of linear momentum.

(b) The diagram shows a linear air track on which two vehicles are free to move. Vehicle A moves towards vehicle B which is initially at rest.

A computer displays the speeds of the two vehicles before and after the collision.

The table of results below shows the mass and velocity of each vehicle before and after the collision.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Mass</th>
<th>Velocity before collision</th>
<th>Velocity after collision</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.75 kg</td>
<td>0.82 m s(^{-1}) to the right</td>
<td>0.40 m s(^{-1}) to the right</td>
</tr>
<tr>
<td>B</td>
<td>0.50 kg</td>
<td>0.00 m s(^{-1})</td>
<td>0.63 m s(^{-1}) to the right</td>
</tr>
</tbody>
</table>

(i) Use these results to show that the change in momentum of vehicle A is equal in size but opposite in direction to the change in momentum of vehicle B.

(ii) Use the data in the table to show whether the collision is elastic or inelastic.
7. (a) A bullet of mass 25 g is fired horizontally into a sand-filled box which is suspended by long strings from the ceiling. The combined mass of the bullet, box and sand is 10 kg.

After impact, the box swings upwards to reach a maximum height as show in the diagram.

Calculate:

(i) the maximum velocity of the box after impact;  
(ii) the velocity of the bullet just before impact.

(b) The experiment is repeated with a metal plate fixed to one end of the box as shown.

The mass of sand is reduced so that the combined mass of the sand, box and metal plate is 10 kg.

In this experiment, the bullet bounces back from the metal plate. Explain how this would affect the maximum height reached by the box compared with the maximum height reached in part (a).
8. During a test on car safety, two cars are crashed together on a test track as shown below.

(a) Car A, which has a mass of 1200 kg and is moving at 18.0 m s\(^{-1}\), approaches car B, which has a mass of 1000 kg and is moving at 10.8 m s\(^{-1}\), in the opposite direction. The cars collide head on, lock together and move off in the direction of car A.

(i) Calculate the speed of the cars immediately after the collision. 3

(ii) Show by calculation that the collision is inelastic. 5

(b) During a second safety test, a dummy in a car is used to demonstrate the effects of a collision.

During the collision, the head of the dummy strikes the dashboard at 20 m s\(^{-1}\) as shown and comes to rest in 0.020 s.

The mass of the head is 5.0 kg.

(i) Calculate the average force exerted by the dashboard on the head of the dummy during the collision. 3

(ii) The test on the dummy is repeated with an airbag which inflates during the collision. During the collision, the head of the dummy again travels forward at 20 m s\(^{-1}\) and is brought to rest by the airbag.

Explain why there is less risk of damage to the head of the dummy when the airbag is used. 2

(13)
Section 4: Gravitation

1. At a funfair, a prize is awarded if a coin is tossed into a small dish. The dish is mounted on a shelf above the ground as shown.

A contestant projects the coin with a speed of 7.0 m s\(^{-1}\) at an angle of 60° to the horizontal. When the coin leaves his hand, the horizontal distance between the coin and the dish is 2.8 m. The coin lands in the dish.

The effect of air resistance on the coin may be neglected.

(a) Calculate:

(i) the horizontal component of the initial velocity of the coin;  
(ii) the vertical component of the initial velocity of the coin.

(b) Show that the time taken for the coin to reach the dish is 0.8 s.

(c) What is the height, h, of the shelf above the point where the coin leaves the contestant’s hand?

(d) How does the value of the kinetic energy of the coin when it enters the dish compare with the kinetic energy of the coin just as it leaves the contestant’s hand? Justify your answer.
2. A golfer on an elevated tee hits a golf ball with an initial velocity of 35·0 m s$^{-1}$ at an angle of 40° to the horizontal.

The ball travels through the air and hits the ground at point R.

Point R is 12 m below the height of the tee, as shown.

(a) Calculate:
   (i) the horizontal component of the initial velocity of the ball;
   (ii) the vertical component of the initial velocity of the ball;
   (iii) the time taken for the ball to reach its maximum height at point P.

(b) From its maximum height at point P, the ball falls to point Q, which is at the same height as the tee.

It then takes a further 0·48 s to travel from Q unit it hits the ground at R.

Calculate the total horizontal distance d travelled by the ball.
3. A basketball player throws a ball with an initial velocity of 6·5 m s$^{-1}$ at an angle of 50° to the horizontal. The ball is 2·3 m above the ground when released.

The ball travels a horizontal distance of 2·9 m to reach the top of the basket.

The effects of air resistance can be ignored.

(a) Calculate:

(i) the horizontal component of the initial velocity of the ball; 1

(ii) the vertical component of the initial velocity of the ball. 1

(b) Show that the time taken for the ball to reach the basket is 0·69 s. 1

(c) Calculate the height h of the top of the basket. 3

(d) A student observing the player makes the following statement.

"The player should throw the ball with a higher speed at the same angle. The ball would then land in the basket as before but it would take a shorter time to travel the 2·9 m."

Explain why the student's statement is incorrect. 2

(8)
4. A ball is rolled up a slope so that it is travelling at 14 m s\(^{-1}\) as it leaves the end of the slope.

(a) The slope is set so that the angle to the horizontal, \(\theta\), is 30°.

Calculate the vertical component of the velocity of the ball as it leaves the slope.

(b) The slope is now tilted so that the angle to the horizontal, \(\theta\), is increased. The ball is rolled so that it still leaves the end of the slope at 14 m s\(^{-1}\).

Describe and explain what happens to the maximum height reached by the ball.

5. An archer fires an arrow at a target which is 30 m away.

The arrow is fired horizontally from a height of 1·5 m and leaves the bow with a velocity of 100 m s\(^{-1}\).

The bottom of the target is 0·90 m above the ground.

Show by calculation that the arrow hits the target.
6. The fairway on a golf course is in two horizontal parts separated by a steep bank as shown below.

A golf ball at point O is given an initial velocity of 41.7 m s\(^{-1}\) at 36° to the horizontal.

The ball reaches a maximum vertical height at point P above the upper fairway. Point P is 19.6 m above the upper fairway as shown. The ball hits the ground at point Q.

The effect of air resistance on the ball may be neglected.

(a) Calculate:

(i) the horizontal component of the initial velocity of the ball; 1

(ii) the vertical component of the initial velocity of the ball. 1

(b) Show that the time taken for the ball to travel from point O to point Q is 4.5 s. 7

(c) Calculate the horizontal distance travelled by the ball. 3

(12)
7. (a) A long jumper devises a method for estimating the horizontal component of his velocity during a jump.

His method involves first finding out how high he can jump vertically.

He finds that the maximum height he can jump is 0·86 m.

(i) Show that his initial vertical velocity is 4·1 m s$^{-1}$.

(ii) He now assumes that when he is long jumping, the initial vertical component of his velocity at take-off is 4·1 m s$^{-1}$.

The length of his long jump is 7·8 m.

Calculate the value that he should obtain for the horizontal component of his velocity, $v_H$.

(b) His coach tells him that, during his 7·8 m jump, his maximum height above the ground was less than 0·86 m. Ignoring air resistance, state whether his actual horizontal component of velocity was greater or less than the value calculated in part (a) (ii). You must justify your answer.
8. A satellite orbits 400 km above the surface of the Earth as shown.

The Earth has a mass of $6\cdot0 \times 10^{24}$ kg and a radius of $6\cdot4 \times 10^{6}$ m.

The satellite has a mass of 900 kg and a speed of $7\cdot7 \times 10^{3}$ m s$^{-1}$.

(a) Explain why the satellite remains in orbit around the Earth.

(b) Calculate the gravitational force acting on the satellite.

9. (a) (i) State what is meant by the term *gravitational field strength*.

(ii) The gravitational field strength $g$ at the surface of Mars is $3\cdot7$ N kg$^{-1}$.

The radius $r$ of Mars is $3\cdot4 \times 10^{3}$ km.

(A) Use Newton’s universal law of gravitation to show that the mass of Mars is given by the equation

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

where $G = 6\cdot67 \times 10^{-11}$ m$^3$ kg$^{-1}$ s$^{-2}$.

(B) Calculate the mass of Mars.

(b) A spacecraft of mass 100 kg is in a circular orbit 300 km above the surface of Mars.

Calculate the force exerted by Mars on the satellite.
Section 5: Special Relativity

1. A page from a website on special relativity is shown.

(a) Explain what is meant by the term length contraction.

(b) Calculate the Lorentz factor when the ratio \( \frac{v}{c} = 0.80 \).

(c) Length contraction calculations use the relationship

\[ l' = l \sqrt{1 - \left(\frac{v}{c}\right)^2} \]

where the symbols have their usual meanings.

State this relationship in terms of \( l' \), \( l \) and \( \gamma \).

(d) Explain, in terms of the Lorentz factor, why an observer can ignore relativistic effects for an object which is moving with a velocity much less than \( c \).

2. A beam of charged particles is accelerated in particle accelerators to a speed of \( 2.0 \times 10^8 \) m s\(^{-1} \).

(a) The particles are unstable and decay with a half-life of \( 8.2 \times 10^{-7} \) s when at rest. Calculate the half-life of the particles in the beam as observed by a stationary observer.

(b) Calculate the mean distance travelled by a particle in the beam before it decays as observed by a stationary observer.
Section 6: The Expanding Universe

1. (a) A car approaches a building where there is a stationary observer. The car sounds its horn.

The speed of the car is 25.0 m s\(^{-1}\) and the frequency of the sound emitted by the horn is 1250 Hz.

(i) Explain in terms of wavefronts why the sound heard by the observer does not have a frequency of 1250 Hz. You may wish to include a diagram to support your answer.

(ii) Calculate the frequency of the sound from the horn heard by the observer.

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

The diagram below shows the helium spectrum from the Sun.

```
<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

wavelength/nm

The diagram below shows the helium spectrum from a distant star.

```
<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

wavelength/nm

By comparing these spectra, what conclusion can be made about the distant star? Justify your answer.
2. A train emits a sound of frequency 800 Hz as it passes through a station. The sound is heard by a person on the station platform as shown.

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

(b) Explain, in terms of wavefronts, why this frequency change occurs. You may wish to include a diagram as part of your answer.

(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. (a) A car horn produces a note of frequency 300 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.

(b) An observer on Earth notes that the frequency of light from a distant galaxy is Doppler shifted towards the red end of the spectrum. Describe how the galaxy is moving relative to the Earth. You must justify your answer.

4. By observing the spectrum of light received from galaxy M101, astronomers have determined that the galaxy is moving away from us with a velocity of \(5.5 \times 10^5\) m s\(^{-1}\).

(a) Calculate the distance of the galaxy from us.

(b) The observation that galaxies are moving away from us is evidence for the expanding universe. As the universe expands it cools down. What property of the Cosmic Microwave Background has been measured by astronomers to determine the present temperature of the universe?
5. (a) Explain what is meant by red shift and why it provides evidence for the Big Bang Theory.

(b) (i) Explain what is meant by the term dark matter.

   (iii) Explain why the study of dark matter is important to the understanding of the fate of the Universe.

6. (a) In 1929 Edwin Hubble suggested that distant galaxies are moving away (receding) from our own galaxy with velocities that are directly proportional to the distance to the galaxy. This is known as Hubble’s Law.

   Some data collected by Hubble are given in the table below.

<table>
<thead>
<tr>
<th>galaxy</th>
<th>distance to galaxy /light years</th>
<th>velocity of recession /m s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGC 221</td>
<td>9.0 \times 10^5</td>
<td>2.0 \times 10^5</td>
</tr>
<tr>
<td>NGC 379</td>
<td>2.3 \times 10^7</td>
<td>2.2 \times 10^6</td>
</tr>
<tr>
<td>Gemini cluster</td>
<td>1.4 \times 10^8</td>
<td>2.3 \times 10^7</td>
</tr>
</tbody>
</table>

   (i) Using all of the data, determine whether or not this data supports Hubble’s Law.

   (ii) Use the data on the Gemini cluster given in the table to calculate a value for the Hubble constant, H₀.

   (iii) Comment on how this early value for the Hubble constant compares to the accepted value today.

(b) The speed of recession of the galaxies is found from observations of redshift.

   (i) State what is meant by the term redshift.

   (ii) Explain why the expansion of space will cause light from more distant galaxies to show a greater redshift.
Section 7: Big Bang Theory

1. Mu Cephei is possibly the largest star yet discovered. Its radius is $1.2 \times 10^{12}$ m and its surface temperature is 3500 K.

The relationship between the temperature and peak wavelength is given by

$$T = \frac{2.9 \times 10^{-3}}{\lambda_{\text{peak}}}$$

(a) Calculate the wavelength of the peak in the black body radiation curve for Mu Cephei.

(b) Copy the graph axes below and sketch the black body radiation curve for Mu Cephei.

relative intensity

0

wavelength

$2.9 \times 10^{-3} \ \lambda_{\text{peak}}$
2. All stars emit radiation with a range of wavelengths. The peak wavelength of radiation, $\lambda_{\text{peak}}$, emitted from a star is related to the surface temperature, $T$, of the star.

The table gives the surface temperatures, in kelvin, of four different stars and the peak wavelength radiated from each star.

<table>
<thead>
<tr>
<th>Surface temperature of star</th>
<th>T/K</th>
<th>Peak wavelength radiated $\lambda_{\text{peak}}$/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>4200</td>
<td>6·90 $\times 10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>5800</td>
<td>5·00 $\times 10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>7900</td>
<td>3·65 $\times 10^{-7}$</td>
<td></td>
</tr>
<tr>
<td>12 000</td>
<td>2·42 $\times 10^{-7}$</td>
<td></td>
</tr>
</tbody>
</table>

(a) Use all the data in the table to show that the relationship between the surface temperature, $T$, of a star and the peak wavelength radiated, $\lambda_{\text{peak}}$, from the star is

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

(b) The blue supergiant star Eta Carinae is one of the largest and most luminous stars in our galaxy. It emits radiation with a peak wavelength of 76 nm.

Calculate the surface temperature, in kelvin, of this star.

(c) Radiation of peak wavelength 1·06 mm can be detected on Earth coming from all directions in space.

(i) What name is given to this radiation?

(ii) Give a reason why the existence of this radiation supports the Big Bang Theory.
Section 8: Uncertainties in Mechanics

1. A student uses the apparatus shown to measure the average acceleration of a trolley travelling down a track.

The line on the trolley is aligned with line P on the track.

The trolley is released from rest and allowed to run down the track.

The timer measures the time for the card to pass through the light gate.

The procedure is repeated a number of times and the results shown below.

0·015 s  0·013 s  0·014 s  0·019 s  0·017 s  0·018 s

(a) Calculate:

(i) the mean time for the card to pass through the light gate; 1

(ii) the approximate absolute random uncertainty in this value. 1

(b) The length of the card is 0·020 m and the distance PQ is 0·60 m.

Calculate the acceleration of the trolley (an uncertainty in this value is not required). 6

(8)
2. The manufacturers of tennis balls require that the balls meet a given standard.

When dropped from a certain height onto a test surface, the balls must rebound to within a limited range of heights.

The ideal ball is one which, when dropped from rest from a height of 3·15 m, rebounds to a height of 1·75 m as shown below.

(a) Assuming air resistance is negligible, calculate:

(i) the speed of an ideal ball just before contact with the ground; 3

(ii) the speed of this ball just after contact with the ground. 3

(b) When a ball is tested six times, the rebound heights are measured to be

1·71 m  1·78 m  1·72 m  1·76 m  1·73 m  1·74 m

Calculate:

(i) the mean value of the height of the bounce; 1

(ii) the approximate absolute random uncertainty in this value. 1

(8)
3. Golf clubs are tested to ensure they meet certain standards.

(a) In one test, a securely held clubhead is hit by a small steel pendulum. The time of contact between the clubhead and the pendulum is recorded.

The experiment is repeated several times. The results are shown.

<table>
<thead>
<tr>
<th>Time (μs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>248</td>
</tr>
<tr>
<td>259</td>
</tr>
<tr>
<td>251</td>
</tr>
<tr>
<td>263</td>
</tr>
<tr>
<td>254</td>
</tr>
</tbody>
</table>

(i) Calculate:
(A) the mean contact time between the clubhead and the pendulum;  
(B) the approximate absolute random uncertainty in this value.

(ii) In this test, the standard required is that the maximum value of the mean contact time must not be greater than 257 μs.

Does the club meet this standard? You must justify your answer.

(b) In another test, a machine uses a club to hit a stationary golf ball.

The mass of the ball is 4.5 × 10^{-2} kg. The ball leaves the club with a speed of 50.0 m s^{-1}. The time of contact between the club and the ball is 450 μs.

(i) Calculate the average force exerted on the ball by the club.

(ii) The test is repeated using a different club and an identical ball. The machine applies the same average force on the ball but with a longer contact time.

What effect, if any does this have on the speed of the ball as it leaves the club? Justify your answer.
4. A basketball is held below a motion sensor. The basketball is released from rest and falls onto a wooden block. The motion sensor is connected to a computer so that graphs of the motion of the basketball can be displayed.

A displacement-time graph for the motion of the basketball from the instant of its release is shown.
(a)  
(i) What is the distance between the motion sensor and the top of the basketball when it is released?  

(ii) How far does the basketball fall before it hits the wooden block?  

(iii) Show, by calculation, that the acceleration of the basketball as it falls is $8.9 \, \text{m} \, \text{s}^{-2}$.  

(b) The basketball is now dropped several times from the same height. The following values are obtained for the acceleration of the basketball.

$8.9 \, \text{m} \, \text{s}^{-2} \quad 9.1 \, \text{m} \, \text{s}^{-2} \quad 8.4 \, \text{m} \, \text{s}^{-2} \quad 8.5 \, \text{m} \, \text{s}^{-2} \quad 9.0 \, \text{m} \, \text{s}^{-2}$

Calculate:

(i) the mean of these values;  

(ii) the approximate random uncertainty in the mean.

(c) The wooden block is replaced by a block of sponge of the same dimensions. The experiment is repeated and a new graph obtained.

Describe and explain any two differences between this graph and the original graph.
5. The apparatus in the diagram is being used to investigate the average force exerted by a golf club on a golf ball.

The club hits the stationary ball. Timer 1 records the time of contact between the club and the ball. Timer 2 records the time taken for the ball to pass through the light gate beam.

The mass of the ball is 45.00 ± 0.01 g.

The time of the contact between club and ball is 0.005 ± 0.001 s.

The time for the ball to pass through the light gate beam is 0.060 ± 0.001 s.

The diameter of the ball is 24 ± 1 mm.

(a) (i) Calculate the speed of the ball as it passes through the light gate.

(ii) Calculate the average force exerted on the ball by the golf club.

(b) (i) Show by calculation which measurement contributes the largest percentage uncertainty in the final value of the average force on the ball.

(ii) Express your numerical answer to (a) (ii) in the form

final value ± absolute uncertainty

(10)
Section 9: Open-ended Questions

1. In a book in which he describes his childhood experiences, an author describes how he used to drop peanuts down the stairwell of a department store. This would annoy the shop owner ‘who would come flying up the stairs at about the speed that the peanut had gone down, giving you less than five seconds to scramble away to freedom’.

Using physics principles, comment on the way the author has compared the speed of the peanut and the shop owner.

2. A trolley is at rest on a slope. It is pushed then released. The velocity–time graph shows the resultant motion of the trolley.

![Velocity-time graph](image)

Use your knowledge of physics to comment on the shape of the graph.

3. A student holds a ball at rest then allows it to fall. The ball accelerates freely to the ground.

The student notes that before release the momentum of the ball is zero but after release it has a momentum.

The student concludes that this shows that the law of conservation of momentum is not always obeyed.

Use your knowledge of physics to show that the student’s statement is untrue.

4. A comedian remarks that ‘When you fall it is not the falling which hurts but the coming to rest.’

Use your knowledge of physics to comment on this remark.

5. When you jump from a height of 5 m into water it usually does not cause any damage. Jumping from the same height onto a concrete surface usually causes injury.

Use physics principles to comment on these statements.
6. A rubber ball X and a ball Y with a very sticky surface have the same mass. They are thrown, with the same speed, at a wall.

The ball X rebounds back along its original path. Ball Y sticks to the wall.

A student states ‘Ball X will always exert a greater force on the wall than that exerted by Y.’

Use your knowledge of physics to comment on this statement.

7. A rubber ball X and a ball Y with a very sticky surface have the same mass. They are thrown, with the same speed, at a wall.

The ball X rebounds back along its original path. Ball Y sticks to the wall.

A student states ‘The change in momentum of ball X is greater than the change in momentum of ball Y. This means that ball X will always exert a greater force on the wall than that exerted by Y on the wall.’

Use your knowledge of physics to comment on this statement.

8. A trolley is at rest on a slope. It is pushed up the slope then released, as shown in the diagram.

Use your knowledge of physics to describe and explain the resultant motion of the trolley.
9. A ball is thrown vertically into the air.

\[ \text{Z} \]

The ball starts from rest at point X. It leaves the thrower's hand at point Y and travels vertically upwards to point Z.

A student states that 'the magnitude of the acceleration of the ball is always greater when being accelerated from rest (between X and Y) than when it is in the air from Y to Z.'

Use your knowledge of physics to comment on this statement.

10. A student states ‘When a single force acts on an object the object can never remain stationary or move with constant speed.’

Use physics principles to comment this statement.

11. A ball is thrown horizontally from a cliff.

A student states ‘The acceleration of the ball can never be parallel to the velocity of the ball.’

Use your knowledge of physics to comment on the truth or otherwise of this statement.

12. A ball can be thrown into the air at an angle of 45° to the horizontal.

A student states that ‘The acceleration of the ball can never be perpendicular to the velocity of the ball.’

Use your knowledge of physics to comment on the truth or otherwise of this statement.
13. A student observes a gardener pushing a wheelbarrow.

The student knows that the gardener exerts a force on the wheelbarrow and that the wheelbarrow exerts a force of equal size in the opposite direction on the gardener.

The student has difficulty explaining why the wheelbarrow moves forward.

Using physics principles give your explanation for the movement of the wheelbarrow.

14. A student sees a diagram of a force acting on a combination of blocks as shown.

The student reasons that block A exerts a force on block B and block B exerts an equal force in the opposite direction on block A. The student then cannot understand why the blocks move.

Use your knowledge of physics to give an explanation for the movement of the blocks.

15. A commentator at a skateboarding competition describes the movement of a competitor on a ramp as shown in the diagram.

‘The skateboarder has gained enough force on the downslope to let her reach the very top of the upslope.’

Using physics principles, comment on the way the commentator has described the movement of this competitor.

16. A book has a drawing of an ‘invention’ that will provide a means of transport.

A magnet is attached to a trolley and a person on the trolley holds a second magnet in front of the first magnet.

The North Pole N of a magnet is known to attract the South Pole S of a magnet.

Using physics principles explain why this invention cannot work.
17. A box is pulled along a floor by a force of 200 N as shown in the diagram.

Use your knowledge of physics to comment on why this is not the most efficient way to move the box.

18. A student is watching the launch of a rocket.

The student states that the rocket takes off because the gas from the rocket engine pushes on the ground.

Using physics principles show that the student’s statement is untrue.

19. A television commentator was heard to describe a free kick in a football match in the following way.

‘It was a magnificent free kick. The ball flew into the net. Once it left his foot it really accelerated into the goal.’

Using physics principles, comment on the way the television commentator has described the motion of the ball.

20. On 1 April, a car manufacturer placed an advertisement for a new system that could be fitted to cars and was called ‘Magnetic Tow Technology’. It was of course an April Fool – the system does not exist.

‘The system locks on to the car in front using an enhanced magnetic beam. Once you are attached, you are free to turn off your engine. The vehicle in front will do the pulling without noticing any changes.’

Using physics principles, suggest how you can tell that the advertisement is an April Fool.
21. Some cars are fitted with a system that stores the energy normally lost as heat in the brakes. Estimate the maximum energy that could be stored as a car is decelerated to rest.

Clearly show your working for the calculation and any estimates you have made. 3

22. A book describing a medieval battle includes the following description of the flight of an arrow.

‘The arrow drew its curve in the sky, then fell fast, plunging, and losing its momentum.’

Using physics principles, comment on the way the author has described the flight of the arrow. 3

23. ‘They don't make them like they used to,’ said old Uncle Willie as a breakdown truck towing a crashed car drove past. ‘In my day, cars were built like tanks. They didn't crumple up in crashes like that one has’, he continued.

Use your knowledge of physics to explain why certain parts of cars are designed to crumple in collisions. 3

24. An iron bar is heated. As the temperature of the bar increases, the colour of the bar changes from red to bluish white.

Use your knowledge of physics to explain this change in colour. 3

25. The star Betelgeuse has a surface temperature of about 2400 K and appears red when viewed.

The star Bellatrix has a surface temperature of about 25,000 K and appears bluish white.

Using your knowledge of physics explain the reason for the difference in colour of these stars. 3