1991 Q31

A tennis player hits a ball at a height of 2.4 m. The ball has an initial horizontal velocity.

![Diagram of tennis player hitting a ball]

The ball just passes over the net which is 0.6 m high and 6 m away from her. (Neglect air friction.)

(a) Calculate the time required for the ball to reach the net.

(b) What was the speed of the ball as it left the racquet?

1993 Q31

During a visit to the Moon, an astronaut fires a small experimental projectile across a level surface. The projectile is launched, from point P, at a speed of 24.0 ms\(^{-1}\) and at an angle of 60° to the horizontal.

The projectile lands 26.0 s later at point X.

![Diagram of projectile trajectory]

(a) Calculate the horizontal speed of the projectile at point P.

(b) Calculate the horizontal distance from P to X.
1994 Q31

The velocity-time graph, shown below is for an object moving with constant acceleration \(a\).

![Velocity-time graph](image)

Show that during the time interval \(t\) the object moves through a displacement \(s\) given by

\[ s = ut + \frac{1}{2} at^2. \]

1995 Q31

An advertising brochure for a car gives the information that the car, starting from rest, can cover 400 m in 17.5 s under constant acceleration.

Calculate the acceleration of the car.

1996 Q31

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

![Diagram of arrow and target](image)

The arrow is fired horizontally from a height of 1.5 m and leaves the bow with a velocity of 100 ms\(^{-1}\).

The bottom of the target is 0.9 m above the ground.

Show by calculation that the arrow hits the target.

Use \(g = 9.8\) ms\(^{-2}\).
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 \(^\circ\).
   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.
1991 Q2

An artificial hare travels along a straight section of track at a constant speed of 14 ms$^{-1}$.

A dog with a reaction time of 0.4 s is released at the instant the hare passes the starting line. The dog accelerates at a constant rate for 2.5 s and reaches a speed of 15 ms$^{-1}$. This speed is maintained for 7.5 s, after which the dog begins to decelerate at a rate of 0.5 ms$^{-2}$ until it has covered 200 m.

(a) Calculate the distance the dog has run, up to the instant at which it starts to decelerate.

(b) Calculate:

(i) the speed of the dog at the 200 m mark;
(ii) the time the dog takes to cover this distance.

(c) Using squared-ruled paper, draw an accurate acceleration-time graph for the motion of the dog from the time of release until it covers 200 m.

(d) Explain whether or not the dog catches the hare before the 200 m mark.
The velocity of a trolley on a slope can be investigated using a computer and a sensor as shown below.

![Diagram](image)

The sensor emits ultrasound pulses which are reflected from the trolley. The computer measures the time between emitted and reflected pulses and uses this information to calculate the velocity at regular times.

In an investigation, the trolley is given a sharp push \textbf{up} the slope and then released. The graph below shows the resulting velocity-time graph as displayed on the screen.

![Graph](image)

Point A on the graph corresponds to the instant at which the trolley is released.

(a) At what time is the trolley at its maximum displacement from the sensor? You must justify your answer.

(b) On the square-ruled paper provided, draw the corresponding acceleration-time graph of the motion.

(c) Draw a diagram to show the forces acting on the trolley as it moves \textbf{up} the slope after the push is removed. Show only forces or components of forces acting parallel to the slope.

(d) Explain, in terms of the forces acting on the trolley, why the magnitude of the acceleration from A to B differs from the magnitude of the acceleration from B to C.
1992 Q2

A rocket-propelled vehicle carrying a dummy is used at a research centre to test the ejection seat for a jet aircraft as shown in the diagram.

The vehicle and dummy have a combined mass of 500 kg. The rocket engines increase the kinetic energy of the vehicle by \(2.80 \times 10^7\) J for each kilogram of fuel used.

In a test run, the vehicle accelerate from rest along the track until 0.70 kg of fuel is used up.

(a)  
(i) Show that the maximum possible speed reached by the vehicle is 280 ms\(^{-1}\). You may ignore the effect of friction.
(ii) The dummy is ejected when the vehicle reaches a speed of 280 ms\(^{-1}\) after 8.0 s. Calculate how far the vehicle is from the start when the dummy is ejected. Assume that the acceleration of the vehicle is constant during the 8.0 s test run.

(b) The dummy is-ejected at the instant the vehicle reaches a horizontal velocity of 280 ms\(^{-1}\). The ejection scat being tested projects the dummy upwards with an initial vertical velocity of 50 ms\(^{-1}\).

(i) Describe and explain the path taken by the dummy after its ejection from the vehicle.
(ii) Calculate the maximum height reached by the dummy. You may ignore the effect of friction.
1994 Q1

(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 ms\(^{-1}\).

(ii) Calculate the value that he should obtain for the horizontal component of his velocity, \(v_H\).

(b) His coach tells him that, during the 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.
In a "handicap" sprint race, sprinters P and Q both start the race at the same time but from different starting lines on the track.

The handicapping is such that both sprinters reach the line XY, as shown below, at the same time.

Sprinter P has a constant acceleration of $1.6 \text{ ms}^{-2}$ from the start line to the line XY. Sprinter Q has a constant acceleration of $1.2 \text{ ms}^{-2}$ from the start line to 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?
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
(ii) the speed of this ball just after contact with the ground.

(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
(ii) the random error in this value.
1997 Q1

(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

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

respectively.

Use these relationships, to show that

$$v^2 = 2as.$$

(b) An aircraft of mass of 1000 kg has to reach a speed of 33 ms$^{-1}$ 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. What is the minimum length of runway required for a take-off?

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

Find the magnitude and direction of the resultant velocity of the aircraft.
1997 Q2

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 friction on the ball may be neglected.

(a) Calculate:

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

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

(c) Calculate the horizontal distance travelled by the ball.
1999 Q1

(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 ms\(^{-2}\) in a straight line for 7.0 seconds. Calculate the distance the car travels in the 7.0 seconds.

(ii) In a second test, the car again starts from rest and accelerates at 4.0 ms\(^{-2}\) over twice the distance covered in the first test. What is the increase in the final speed of the car at the end of the second test compared with the final speed at the end of the first test?

(iii) In a third test, the car reaches a speed of 40 ms\(^{-1}\). It then decelerates at 2.5 ms\(^{-2}\) until it comes to rest. Calculate the distance travelled by the car while it decelerates to rest.

(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 the computer which is used for timing. The student uses a stopwatch 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.

(ii) Explain fully how each of these measurements is used in calculating the acceleration of the trolley as it moves down the slope.
A tennis player strikes a ball with his racket just as the ball reaches the ground. The ball leaves the racket with a speed of 6.0 \, \text{ms}^{-1} \text{ at } 50^\circ \text{ to the ground as shown in the diagram below. The effect of air resistance should be ignored.}

(a)  
(i) Calculate the vertical component of the initial velocity of the ball.  
(ii) Calculate the horizontal component of the initial velocity of the ball.

(b) As shown in the diagram, when the ball is struck, it is 2.0 m from the base of the net.

(i) Calculate the time taken for the ball to travel the 2.0 m to the net after leaving the racket.  
(ii) The net is 0.90 m high in the centre of the court.  
\hspace{1cm} Show by calculation that the ball will go over the net.  
(iii) Calculate the time the ball will be in the air before it hits the ground on the other side of the net.
A sky diver, of mass 85 kg, is equipped with an instrument for measuring her downward speed at different times after leaving the aircraft.

(a) During the first 4 seconds after leaving the aircraft, the following readings are recorded.

<table>
<thead>
<tr>
<th>Time/s</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed/m s(^{-1})</td>
<td>8.0</td>
<td>16.0</td>
<td>24.0</td>
<td>32.0</td>
</tr>
</tbody>
</table>

(i) Calculate the resultant vertical force acting on the sky diver during this time.
(ii) (A) Draw a diagram showing, and naming, the vertical forces acting on the sky diver as she falls. The buoyancy force should be neglected.
(B) Calculate the size of each of these vertical forces.

(b) Later in the dive the following readings are recorded.

<table>
<thead>
<tr>
<th>Time/s</th>
<th>31.0</th>
<th>32.0</th>
<th>33.0</th>
<th>34.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed/m s(^{-1})</td>
<td>60.0</td>
<td>60.0</td>
<td>60.0</td>
<td>60.0</td>
</tr>
</tbody>
</table>

(i) What is the size of each of the vertical forces now acting on the sky diver?
(ii) Describe a change that the sky diver could now make to increase her speed. You must Justify your answer.
A rower is competing in a 2000 m race in still water. Throughout the race, the rower's boat travels in a straight line.

(a) The boat starts from rest and has a constant acceleration of 0.58 ms\(^{-2}\) during the first 16 m of the race.

(i) Calculate the speed reached by the boat 16 m after the start.
(ii) This speed then remains constant until the boat is 500 m from the start of the race. Calculate the total time taken for the boat to travel this 500 m.

(b) During the remaining 1500 m, the speed of the boat changes. As the boat crosses the finishing line, the rower stops rowing. The boat then travels a further 21 m in 10 s as it decelerates uniformly to rest. Calculate the speed of the boat as it crossed the finishing line.