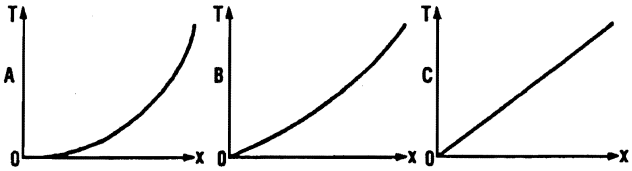
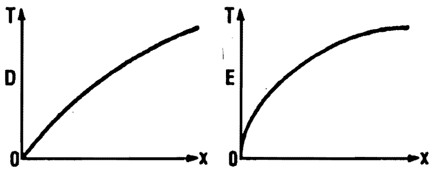
TOPIC 3 Kinematics

Linear Motion

1 A body moves from rest with a constant acceleration. Which one of the following graphs represents the variation of its kinetic energy T with the distance travelled x?

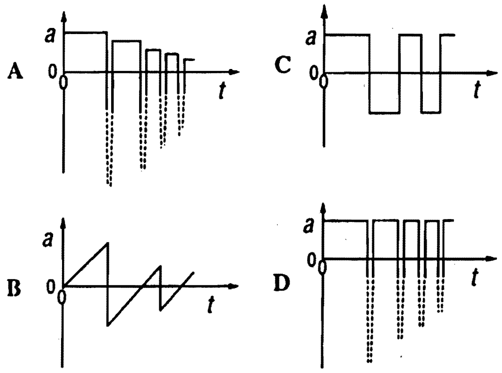




N76/II/4

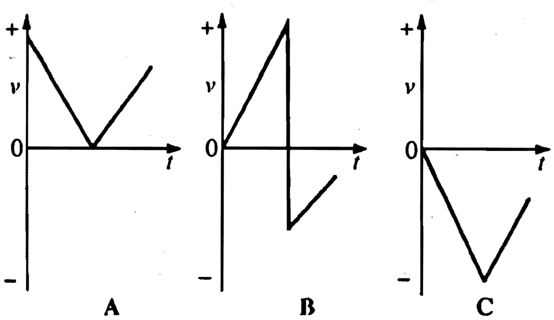
2 A steel ball is released from rest a distance above a rigid horizontal surface and is allowed to bounce.

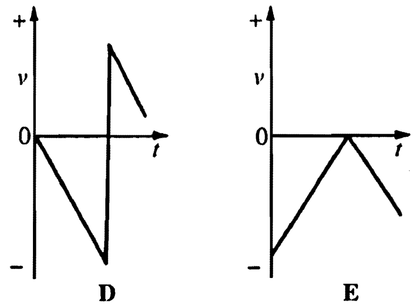
Which graph best represents the variation with time t of acceleration a?



J78/II/4; N92/I/3; N93/I/2; J96/I/3; N2000/I/4

3 A tennis ball is released so that it falls vertically to the floor and bounces back again. Taking velocity upwards as positive, which one of the following graphs best represents the variation of velocity v with time t?

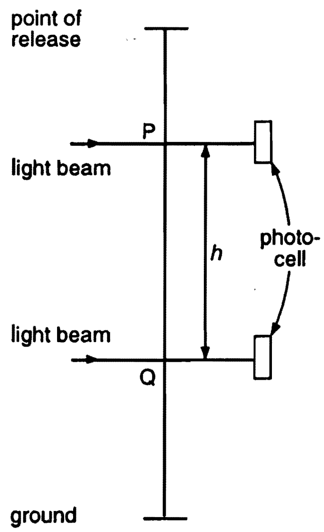




J79/II/5

4 The acceleration of free fall is determined by timing the fall of a steel ball photo-electrically as shown below.

The ball passes P and Q at times t_1 and t_2 after release.



What is the acceleration of free fall?

A $2h/(t_2 - t_1)$

B $h/(t_2^2 - t_1^2)$

C $h^2/(t_2 - t_1)$

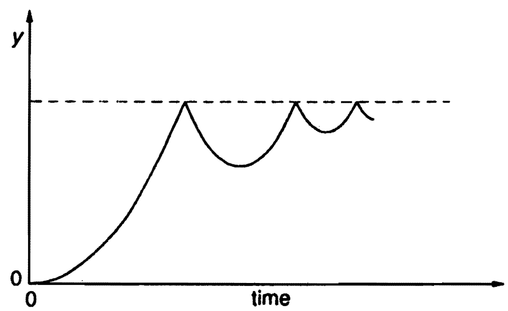
D $2h/(t_2^2 - t_1^2)$

E $h/2(t_2 - t_1)$

N79/II/5; J85/I/4

5 A ball is released from rest above a horizontal surface and bounces several times.

The graph shows how, for this ball, a quantity y varies with time.

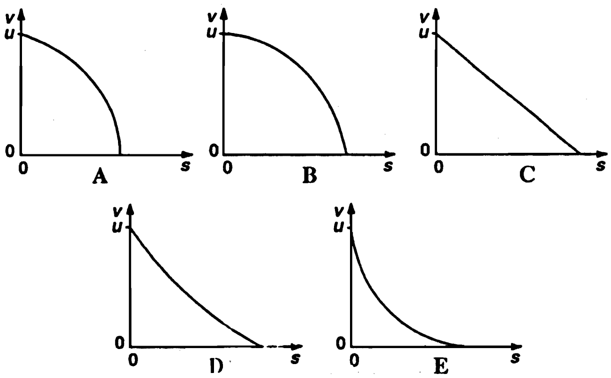


What is the quantity y?

- **A** acceleration
- **B** displacement
- **C** kinetic energy
- **D** velocity

N80/II/2; J84/II/4; J2000/I/3

6 A falling stone strikes some soft ground at speed u and suffers a constant deceleration until it stops. Which one of the following graphs best represents the variation of the stone's speed, v, with distance, s, measured downwards, from the surface of the ground?



N81/II/6

7 The velocity of a car which is decelerating uniformly changes from 30 m s^{-1} to 15 m s^{-1} in 75 m. After what further distance will it come to rest?

- **A** 25 m
- **B** 37.5 m
- **C** 50 m
- **D** 75 m
- **E** 100 m

J82/II/2; J85/I/3

8 A body is thrown vertically upwards in a medium in which the viscous drag cannot be neglected. If the times of flight for the upward motion t_u and the downward motion t_d (to return to the same level) are compared, then

- **A** $t_d > t_u$, because the body moves faster on its downward flight and therefore the viscous force is greater.
- **B** $t_d < t_u$, because the effect of the viscous force is greatest at the moment of projection.
- **C** $t_d = t_u$, because the effect of the viscous force is the same whether the body is moving upwards or downwards.
- **D** $t_d < t_u$, because at a given speed the net accelerating force when the body is moving downwards is greater than the retarding force when it is moving upwards.
- **E** $t_d > t_u$, because at a given speed the net accelerating force when the body is moving downwards is smaller than the retarding force when it is moving upwards.

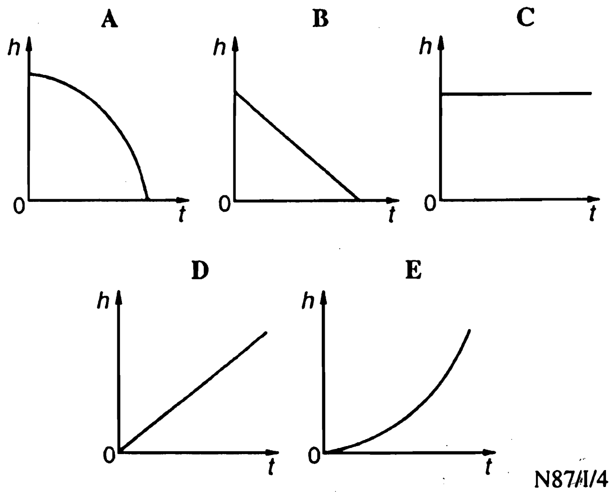
N84/II/5

9 A stone slides across an icy surface and travels a distance x in time t while undergoing uniform deceleration. Which of the following pairs of quantities would give a straight line graph when plotted to represent the motion of the stone?

- **A** x and $1/t^2$
- **B** x and $1/t$
- **C** x/t and t
- **D** x/t^2 and t
- **E** x/t^3 and t

N85/I/2; J88/I/2

10 A brick is dislodged from a tall building and falls vertically under gravity. Which one of the following curves represents the variation of its height h above the ground with time t if air resistance is negligible?



N87/I/4

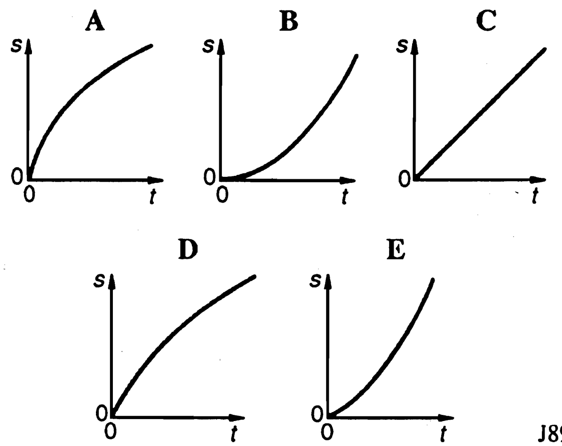
11 A lunar landing module is descending to the Moon's surface at a steady velocity of 10 m s^{-1}. At a height of 120 m, a small object falls from its landing gear.

Taking the Moon's gravitational acceleration as 1.6 m s^{-2}, at what speed does the object strike the Moon?

- **A** 30 m s^{-1}
- **B** 22 m s^{-1}
- **C** 20 m s^{-1}
- **D** 17 m s^{-1}
- **E** 10 m s^{-1}

N88/I/3

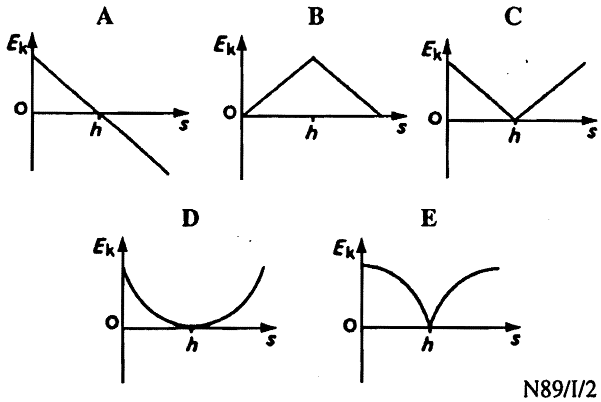
12 A body starts from rest at time $t = 0$ and moves with constant acceleration. Which graph best represents how s, the displacement of the body, varies with time?



J89/I/4

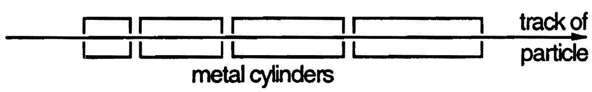
13 A stone, thrown vertically upwards from ground level, rises to a height h and then falls back to its starting point.

Assuming that air resistance is negligible, which of the following graphs best shows how E_k, the kinetic energy of the stone, varies with s, the distance travelled?

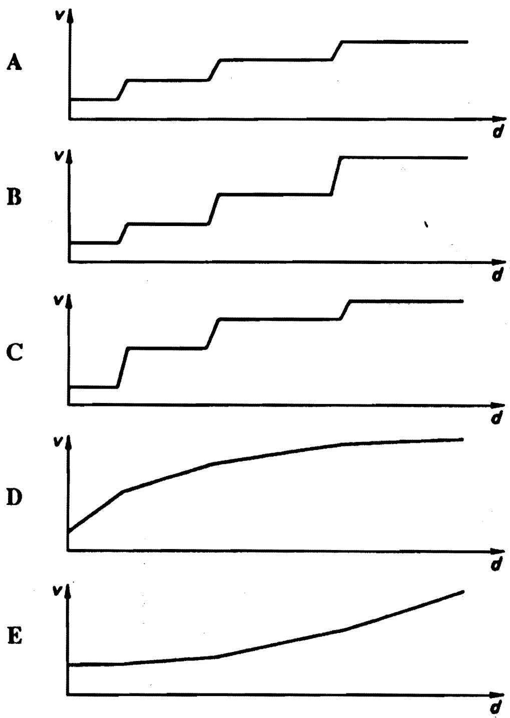


N89/I/2

14 A linear accelerator sends a charged particle along the axis of a set of coaxial hollow metal cylinders as shown in the diagram.

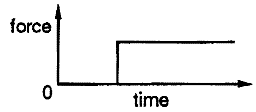


The particle travels at constant speed inside each cylinder. The particle crosses the gaps between the cylinders at equal time intervals, and at each gap its kinetic energy increases by a fixed amount. Which of the graphs best represents the way in which v, the velocity of the particle varies with d, the distance along its tracks?

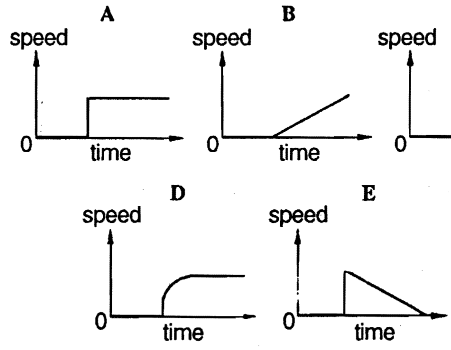


J90/I/6

15 A car driver presses the accelerator sharply down when the traffic lights go green. The force on the car varies with time as shown.

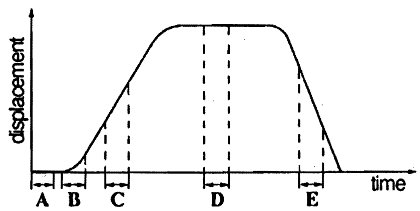


Which graph shows the variation with time of the car's speed?



J91/I/3

16 The graph represents how displacement varies with time for a vehicle moving along a straight line.



During which time interval does the acceleration of the vehicle have its greatest numerical value? J92/I/3

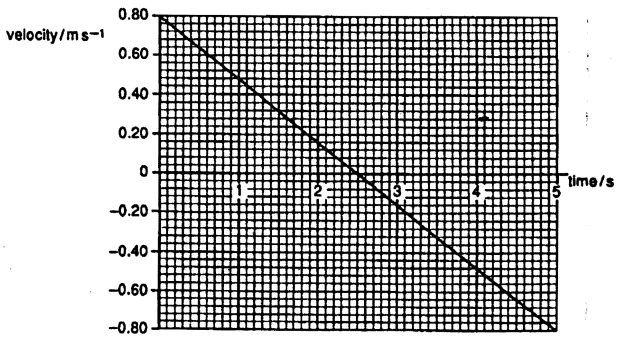
17 A racing car accelerates uniformly through three gear changes with the following average speeds:

20 m s^{-1} for 2.0 s
40 m s^{-1} for 2.0 s
60 m s^{-1} for 6.0 s

What is the overall average speed of the car?

A 12 m s^{-1} **C** 40 m s^{-1}
B 13.3 m s^{-1} **D** 48 m s^{-1} J94/I/5

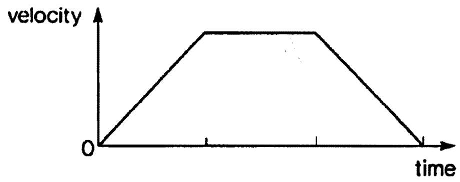
18 The graph shows the variation with time of the velocity of a trolley, initially projected up an inclined runway.



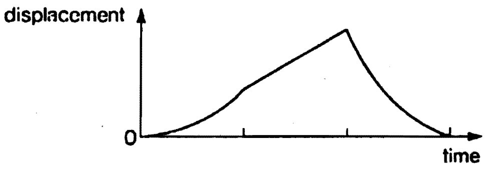
What is the maximum distance up the slope which the trolley reaches?

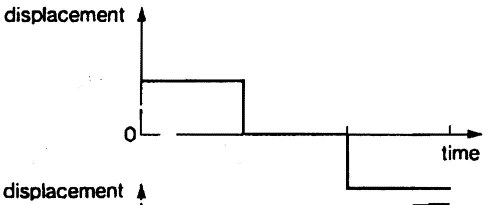
A 0.80 m C 2.0 m
B 1.0 m D 4.0 m N94/I/3

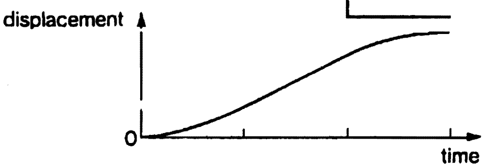
19 The graph of velocity against time for a moving object is shown.

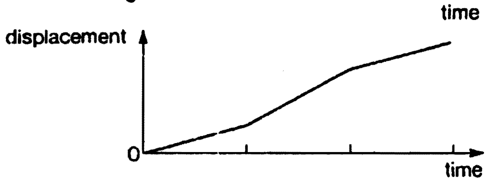


Which of the following is the corresponding graph of displacement against time?

A


B


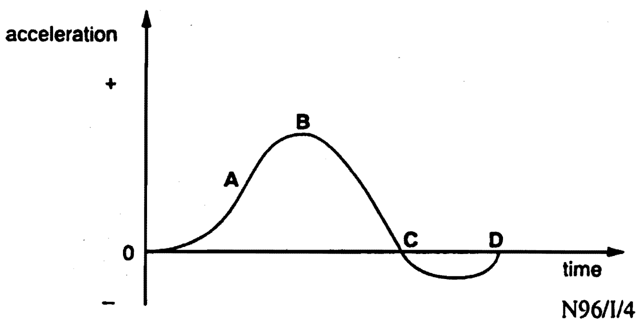
C


D


N95/I/5

20 A car is travelling along a straight road. The graph shows the variation with time of its acceleration during part of the journey.

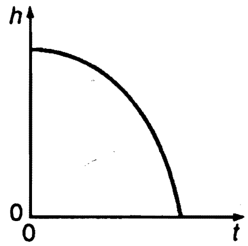
At which point on the graph does the car have its greatest velocity?

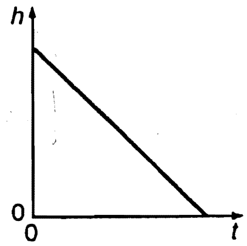


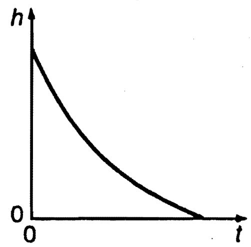
N96/I/4

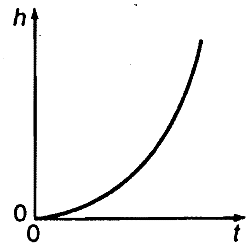
21 A small steel ball falls freely under gravity after being released from rest.

Which graph best represents the variation of the height h of the ball with time t?

A


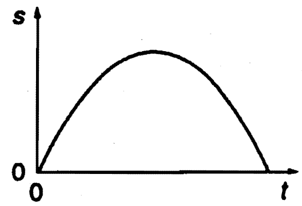
B


C


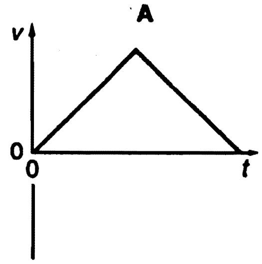
D


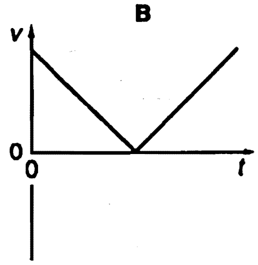
J97/I/3

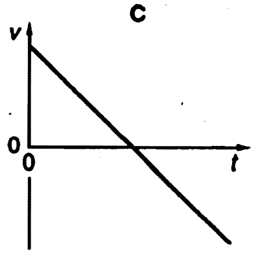
22 The diagram shows the graph of displacement s against time t for a body moving in a straight line.

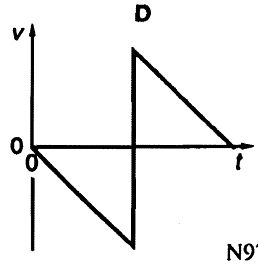


Which graph of velocity v against time t represents the motion of the body over this period?

A


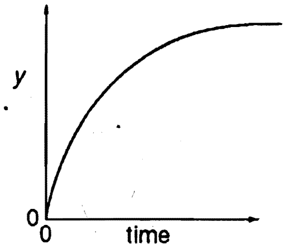
B


C


D


N97/I/3

23 The graph relates to the motion of a falling body.

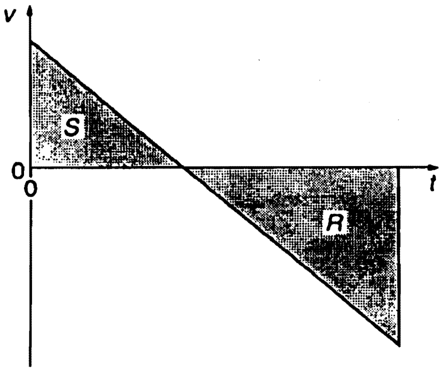


What could y represent on the vertical axis?

A distance when air resistance is negligible
B distance when air resistance is not negligible
C speed when air resistance is negligible
D speed when air resistance is not negligible J98/I/1

24 A stone is thrown upwards from the top of a cliff. After reaching its maximum height, it falls past the cliff-top and into the sea.

The graph shows how the vertical velocity v of the stone varies with time t after being thrown upwards. R and S are the magnitudes of the areas of the two triangles.



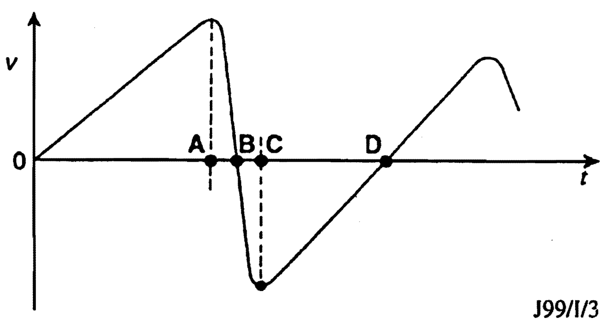
What is the height of the cliff-top above the sea?

A	R	**C**	$R+S$
B	S	**D**	$R-S$

N98/I/3

25 The graph shows the variation with time t of the velocity v of a bouncing ball, released from rest. Downward velocities are taken as positive.

At which time does the ball reach its maximum height after bouncing?



J99/I/3

26 A motorist travelling at 13 m s^{-1} approaches traffic lights, which turn red when he is 25 m away from the stop line. His reaction time (i.e. the interval between seeing the red light and applying the brakes) is 0.7 s and the condition of the road and his tyres is such that the car cannot slow down at a rate of more than 4.5 m s^{-2}. If he brakes fully, how far from the stop line will he stop, and on which side of it? J82/I/1

27

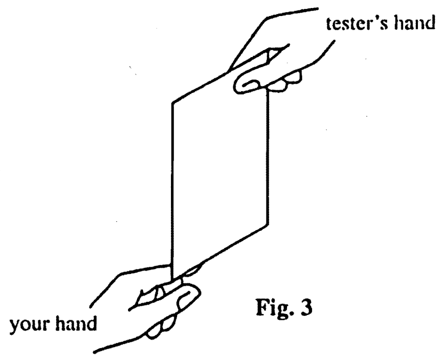


Fig. 3

The following experiment may be used to test reaction time. A new banknote, 135 mm long, is held vertically at the upper edge by the tester (Fig. 3). You are to hold your thumb and first finger open at the bottom of the note. When the tester releases the note without warning, you must try to close your fingers in time to catch it. If you succeed, you can keep the note. What is the maximum possible value of your reaction time that will allow you to succeed? N84/I/1

28 The graph, Fig. 4, shows the speeds of two cars **A** and **B** which are travelling in the same direction over a period of time of 40 s. Car **A**, travelling at a constant speed of 40 m s^{-1}, overtakes car **B** at time t = 0. In order to catch up with car **A**, car **B** immediately accelerates uniformly for 20 s to reach a constant speed of 50 m s^{-1}.

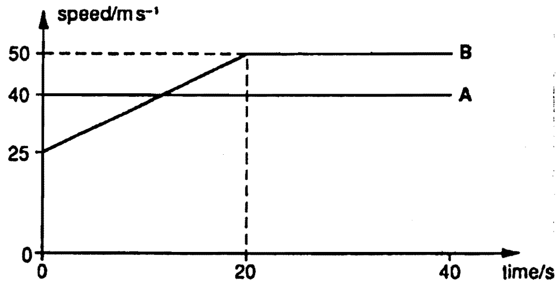


Fig. 4

(a) How far does car **A** travel during the first 20 s? [1]

(b) Calculate the acceleration of car **B** in the first 20s. [1]

(c) How far does car **B** travel in this time? [2]

(d) What additional time will it take for car **B** to catch up with car **A**? [2]

(e) How far will each car have then travelled since t = 0? [1]

(f) What is the maximum distance between the cars before car **B** catches up with car **A**? [3]

N93/II/2

29 *(a)* Define *acceleration.* [1]

(b) Divers in Acapulco dive from a height of 36 m into the sea. Calculate, ignoring air resistance,

(i) the time they take to reach the water,

(ii) their speed of entry into the water. [4]

J96/II/1 (part)

30 Fig. 5, shows a velocity-time graph for a journey lasting 65 s. It has been divided up into six sections for ease of reference.

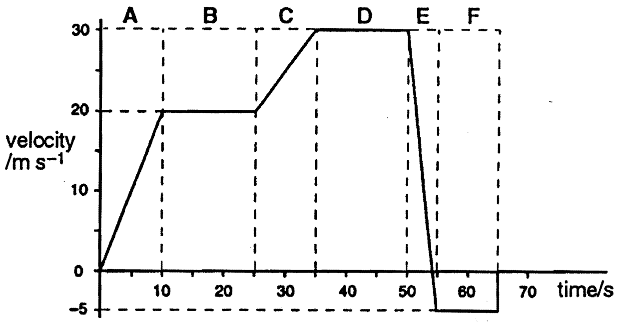


Fig. 5

(a) Using information from the graph obtain

(i) the velocity 10 s after the start,

velocity = ... ms^{-1}

(ii) the acceleration in section A,

acceleration = ... ms^{-2}

(iii) the acceleration in section E,

acceleration = ... ms^{-2}

(iv) the distance travelled in section B,

distance = ... m

(v) the distance travelled in section C.

distance = ... m[5]

(b) Describe qualitatively in words what happens in sections E and F of the journey. [4]

(c) On Fig. 6, sketch the shape of the corresponding distance-time graph. You are not expected to make detailed calculations of the distance travelled. [3]

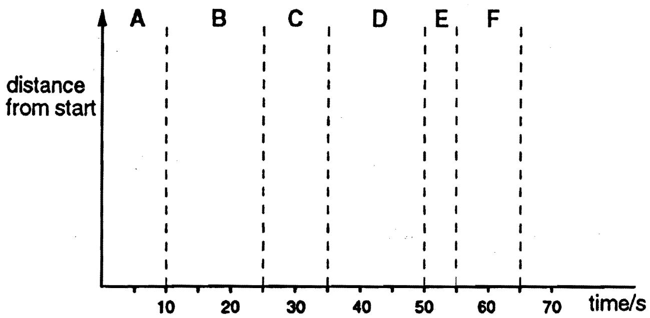


Fig. 6

N97/II/1

31 *(a)* Define *acceleration.* [2]

(b) A body has an initial velocity u and an acceleration a. After a time t, the body has moved a distance s and has a final velocity v. The motion is summarised by the equations

$$v = u + at,$$
$$s = \tfrac{1}{2}(u + v)t.$$

(i) State the assumption made about the acceleration a in these equations.

(ii) Use the equations to derive an expression for v in terms of u, a and s. [3]

(c) A photographer wishes to check the time for which the shutter on a camera stays open when a photograph is being taken. To do this, a metal ball is photographed as it falls from rest. It is found that before the shutter opens, the ball falls 2.50 m from rest and, during the time that the shutter remains open, the ball falls a further 0.12 m, as illustrated in Fig. 7.

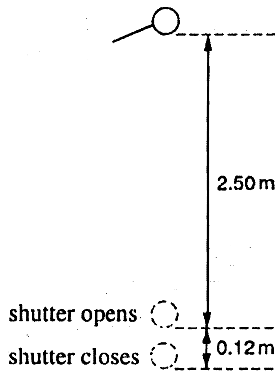


Fig. 7

Assuming that air resistance is negligible, calculate

(i) the speed of the ball after falling 2.50 m,

speed = ... $m\,s^{-1}$

(ii) the time to fall the further 0.12 m.

[You may wish to use an equation of the form

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.]$$

time = ... s

(iii) The time for which the shutter stays open is marked on the camera as 1/60s. Comment on whether the test confirms this time. [6]

N99/II/2

Long Questions

32 A particle moves in a straight line with uniform acceleration. At time $t = 0$, its speed is u and its displacement from the origin is zero. Sketch labelled graphs to show the way in which (i) the speed v of the particle, (ii) the displacement s from the origin, vary with time t. Explain the relation between the graphs. J78/I/13 (part)

33 A body accelerates uniformly from rest along a straight line. Sketch a graph showing how the displacement of the body varies with time. How is the instantaneous velocity of a particle obtained from a graph of displacement against time?

A cricketer throws a ball vertically upwards and catches it 3.0 s later. Neglecting air resistance, find

(a) the speed with which the ball leaves his hands,

(b) the maximum height to which it rises.

Draw a sketch graph showing how the velocity of the ball depends on time during its flight. Mark on your graph the times at which

(i) the ball leaves the cricketer's hands (t_1),

(ii) it comes to its maximum height (t_2),

(iii) it reaches his hands again (t_3).

(There is no need to calculate further particular values of the velocity.)

* You are told to neglect air resistance in these calculations. In fact, air resistance provides a retarding force which is approximately proportional to the square of the speed of the ball. Without carrying out any calculations, explain how air resistance would affect

(iv) the time taken for the ball to reach its maximum height,

(v) the maximum height to which its rises,

if it were projected vertically upwards with the same speed as that calculated in *(a)* above. J81/I/13 (part)

34 A table from a car driver's handbook reads as follows:

On a dry road, a car in good condition driven by an alert driver will stop in the distances shown in the table.

Speed /m s^{-1}	Thinking* distance /m	Braking† distance /m	Overall distance /m
5.0	3.0	1.9	4.9
10	6.0	7.5	13.5
15	9.0	17	26
20	12	30	42
25	15	47	62
30	18	68	86
35	21	92	113

* The *Thinking distance* is the distance travelled by the car during the driver's reaction time.

† The *Braking distance* is the distance in which the car stops after the brakes have been applied.

(a) Explain why thinking distance is directly proportional to speed whereas braking distance is not. Describe in words the relationship between braking distance and speed. [7]

(b) What constant value of negative acceleration has the author of the table used in calculating the braking distances? [4]

(c) Calculate the overall stopping distance for a car travelling at 50 m s^{-1}. [4]

(d) What would be the effects on the thinking distance and the braking distance of each of the following conditions?

(i) The road is wet.

(ii) The driver is not fully alert. [3]

(e) Calculate the overall stopping distance for a car travelling at a speed of 35 m s^{-1} down a hill at an angle of 10° to the horizontal. [4]

J89/II/9

35 *(a)* (i) Define *velocity.*

(ii) Explain how the displacement and the acceleration of an object may be found from a velocity-time graph of its motion. [5]

(b) A train has mass 450 000 kg and a normal operating speed of 50 m s^{-1}. It can be considered to be accelerated by a constant force of 180 kN and braked by a constant force of 330 kN. The train starts from rest. Calculate its acceleration and the time it takes to reach its operating speed. [4]

(c) The inhabitants of a certain town would like trains to make an additional stop at their station. The train would stand for two minutes to allow passengers to get on and off and further delay would be caused by having to slow down and speed up.

(i) Sketch speed-time graphs for a train which does stop at the town and for a train which does not.

(ii) Calculate the total delay caused by making the additional stop.

(iii) Why could this delay be reduced by having fewer carriages? [8]

(d) Explain why, in practice, trains do not have a constant acceleration. [3]

N90/III/1

36 *(a)* Define *acceleration.* An object is thrown vertically upwards from the surface of the Earth. Air resistance can be neglected. Sketch labelled graphs on the same axes to show how (i) the velocity, (ii) the acceleration of the object, vary with time. Mark on the graphs the time at which the object reaches maximum height and the time at which it returns to its original position. [6]

J91/III/1 (part)

37 *(a)* Define *acceleration.* Explain how it is possible for a body to be undergoing an acceleration although its speed remains constant. [4]

(b) A ball is placed at the top of a slope as shown in Fig. 8.

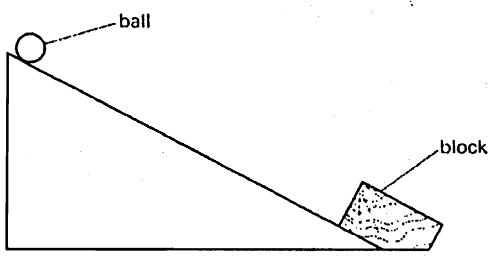


Fig. 8

A block is fixed rigidly to the lower end of the slope. The ball of mass 0.70 kg is released at time $t = 0$ from the top of the incline and v, the velocity of the ball down the slope, is found to vary with t as shown in Fig. 9.

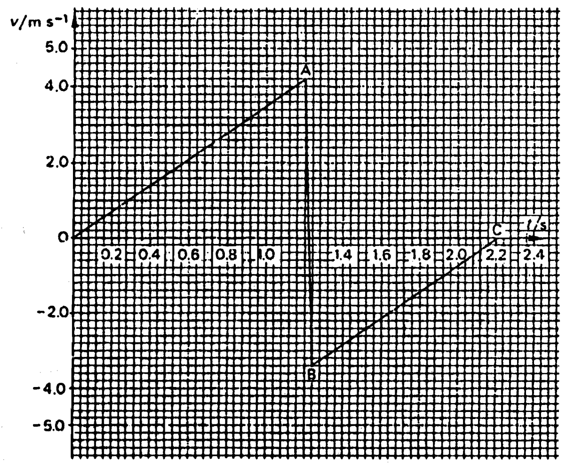


Fig. 9

(i) Describe qualitatively the motion of the ball during the periods OA, AB and BC. [7]

(ii) Calculate

(1) the acceleration of the ball down the incline,

(2) the length of the incline,

(3) the mean force experienced by the ball during impact with the block. [7]

(iii) Discuss whether the collision between the block and the ball is elastic. [2]

J92/III/1

38 The graph, Fig. 10, shows how the velocity v of an athlete varies with time t during a 100 m race. The race starts at time $t = 0$.

(a) It takes a short time for the athlete's velocity to increase above zero.

(i) By reference to the graph deduce a value for this time.

(ii) Give a reason for this delay. [2]

(b) Use the graph to deduce

(i) the maximum velocity of the athlete,

(ii) the athlete's maximum acceleration,

(iii) the distance the athlete travels between the times $t = 4.0$ s and $t = 8.0$ s. [7]

(c) Assuming that, say, 10 people with stop watches are available, outline what they would need to do in order to obtain such a graph experimentally. [6]

(d) Sketch the shape of the acceleration-time graph for this 100 m race. [3]

(e) Suggest why the men's olympic record for 200 m is less than twice the time for 100 m. [2]

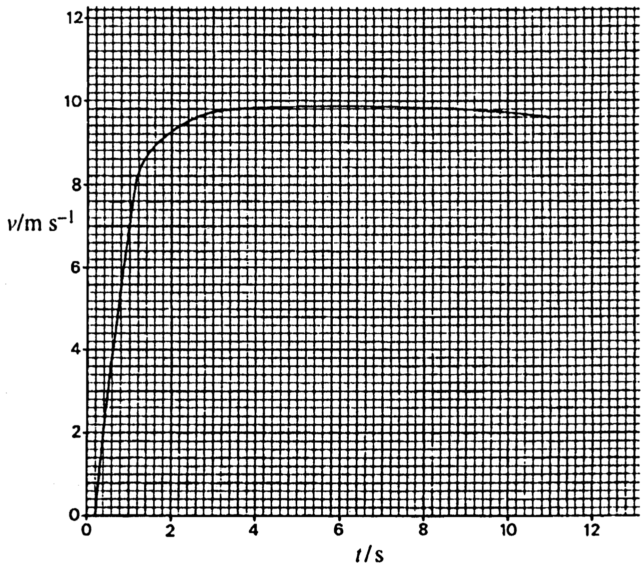


Fig. 10

J93/III/1

39 (a) An object accelerates uniformly in a straight line from velocity u to velocity v in time t, as shown in Fig. 11.

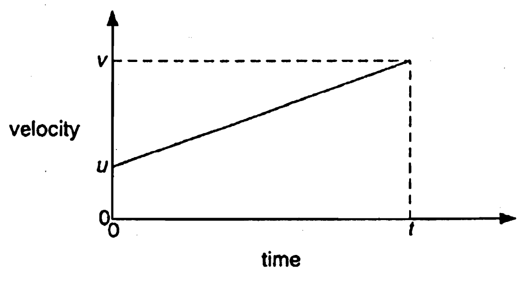


Fig. 11

(i) Write down an expression for the acceleration a in terms of u, v and t.

(ii) Use Fig. 11 and your answer to (i) to show that s, the distance travelled, is given by

$$s = \frac{v^2 - u^2}{2a}.$$ [4]

J95/III/1 (part)

40 *(a)* Define *velocity* and *acceleration.* [2]

(b) Use your definitions in *(a)* to deduce the equations

(i) $v = u + at$,

(ii) $v^2 = u^2 + 2as$,

where v is the final velocity, u the initial velocity, a the acceleration, t the time and s the distance travelled.

State the conditions necessary for these two equations to be applicable. [5]

N98/III/1 (part)

41 *(c)* Fig. 12 shows the variation with time t of the distance d fallen from rest by an object in a vacuum near the Earth's surface.

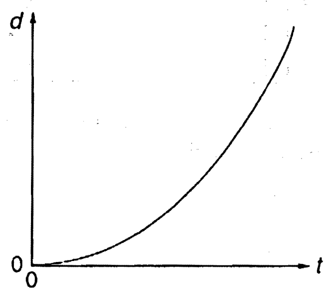


Fig. 12

(i) Explain how it is possible to deduce from Fig. 12 that the object is undergoing accelerated motion.

(ii) Copy Fig. 12 and on it draw a line to represent the variation with time t of distance d when the object is falling from rest *through air* at the same location on the Earth's surface. Label the line A. [4]

J99/III/3 (part)

Projectile Motion

42 A projectile is fired with an initial velocity u at an angle θ to the horizontal (Fig. 13).

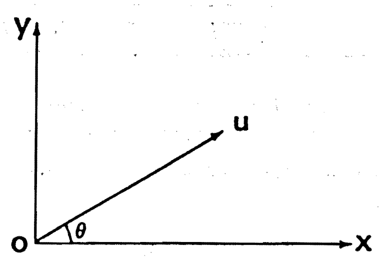


Fig. 13

Neglecting air resistance, its height y, and the horizontal distance x it has travelled, at time t after projection are

A $y = ut\cos\theta - \frac{1}{2}gt^2$, $x = ut\sin\theta$
B $y = ut\sin\theta - \frac{1}{2}gt^2$, $x = ut\cos\theta + \frac{1}{2}gt^2$
C $y = ut\sin\theta + \frac{1}{2}gt^2$, $x = ut\cos\theta$
D $y = ut\cos\theta$, $x = ut\sin\theta - \frac{1}{2}gt^2$
E $y = ut\sin\theta - \frac{1}{2}gt^2$, $x = ut\cos\theta$

J79/II/4

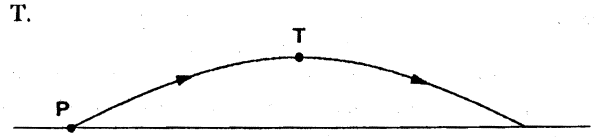
43 An object is projected at an angle to the horizontal in a gravitational field and it follows a parabolic path, PQRST. These points are the positions of the object after successive equal time intervals, T being the highest point reached.

The displacements PQ, QR, RS and ST

A are equal.
B decrease at a constant rate.
C have equal horizontal components.
D increase at a constant rate.
E have equal vertical components.

N79/II/4

44 In the absence of air resistance, a stone is thrown from **P** and follows a parabolic path in which the highest point reached is **T.**



The vertical component of acceleration of the stone is

A zero at **T.**
B greatest at **T.**
C greatest at **P.**
D the same at **P** as at **T.**

J80/II/4; N84/II/2; J94/I/3

45 A projectile of mass m is fired with velocity v from a point P, as shown below (Fig. 14).

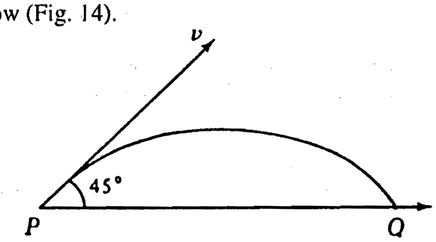


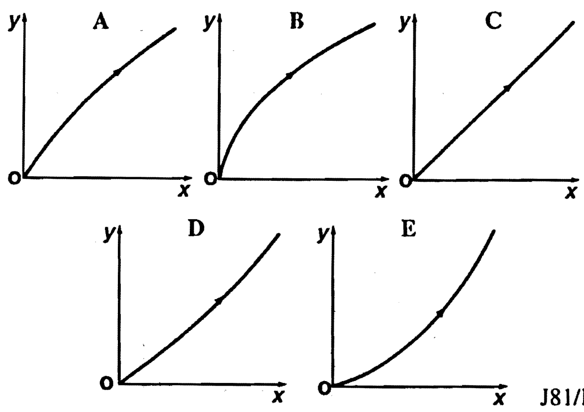
Fig. 14

Neglecting air resistance, the magnitude of the change in momentum between leaving P and arriving at Q is

A zero
B $\frac{1}{2}mv$
C $mv\sqrt{2}$
D mv
E $2mv$

N80/II/6

46 A body is moving with constant speed in the y-direction. For positive values of y, it experiences a uniform acceleration in the x-direction. Which one of the paths **A** to **E** does it follow?



J81/II/4

47 An aeroplane, flying in a straight line at a constant height of 500 m with a speed of 200 m s^{-1}, drops an object. The object takes a time t to reach the ground and travels a horizontal distance d in doing so. Taking g as 10 m s^{-2} and ignoring air resistance, which one of the following gives the values of t and d?

	t	d
A	25 s	10 km
B	25 s	5 km
C	10 s	5 km
D	10 s	2 km
E	5 s	1 km

J82/II/3

48 When a rifle is fired horizontally at a target P on a screen at a range of 25 m, the bullet strikes the screen at a point 5.0 mm below P. The screen is now moved to a distance of 50 m and the rifle again fire horizontally at P in its new position. See Fig. 15 below.

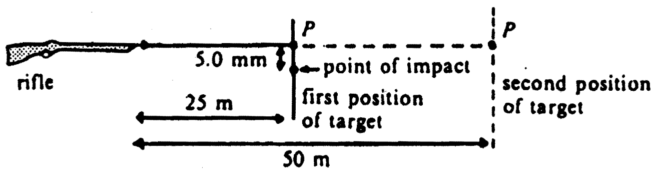


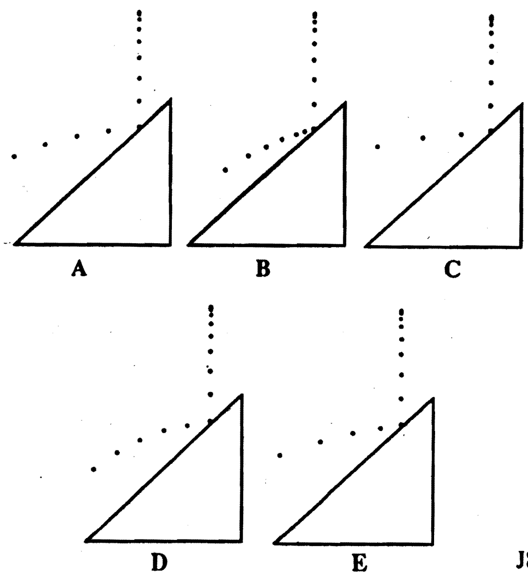
Fig. 15

Assuming that air resistance may be neglected, what is the new distance below P at which the screen would now be struck?

A $5\sqrt{2}$ mm
B 10 mm
C 15 mm
D 20 mm
E 25 mm

N82/II/4

49 A ball, dropped on to a 45° inclined plane, makes an elastic collision with the surface. Stroboscopic photographs (a series of exposures on the same film at equal time intervals) are taken of the path of the ball. Which one of the following diagrams best represents the photographs?



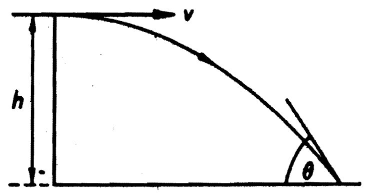
J84/II/3

50 A ball is projected horizontally from the top of a cliff on the surface of the Earth with a speed of 40 m s^{-1}. Assuming that there is no air resistance, what will its speed be 3 s later?

A 30 m s^{-1}
B 40 m s^{-1}
C 50 m s^{-1}
D 60 m s^{-1}
E 70 m s^{-1}

J88/I/3

51 The diagram shows the path of a projectile fired with a horizontal velocity v from the top of a cliff of height h.

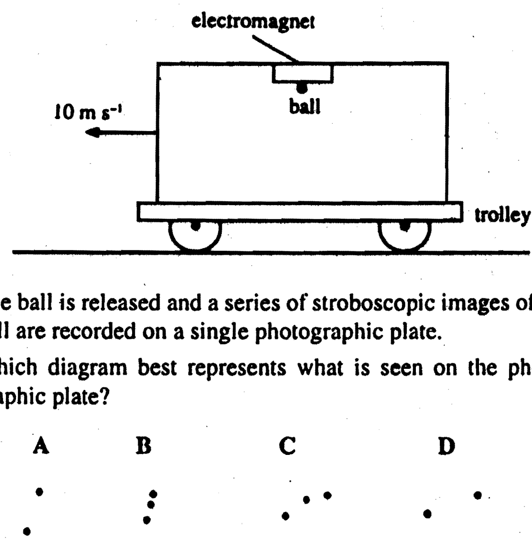


Which of the following values for v and h will give the greatest value of the angle θ?

	v/m s^{-1}	h/m
A	10	30
B	10	50
C	30	30
D	30	50
E	50	10

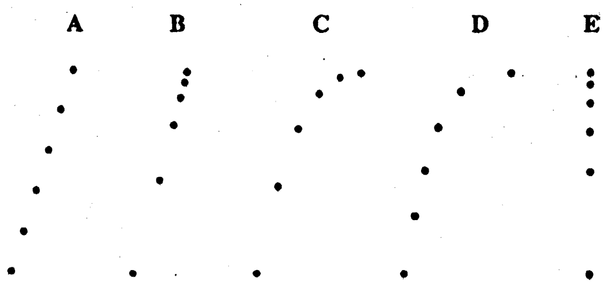
J89/I/3

52 A ball is suspended from an electromagnet attached to a trolley which is travelling at a constant speed of 10 m s^{-1} to the left. The trolley is illuminated by a stroboscope flashing at a constant rate. The diagram represents the viewpoint of a stationary camera.



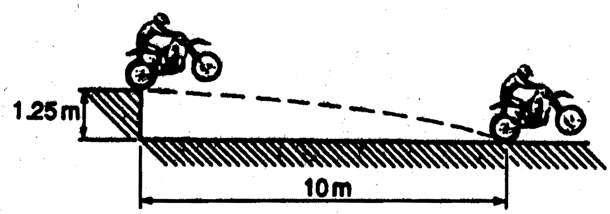
The ball is released and a series of stroboscopic images of the ball are recorded on a single photographic plate.

Which diagram best represents what is seen on the photographic plate?



N91/I/4

53 A motorcycle stunt-rider moving horizontally takes off from a point 1.25m above the ground, landing 10 m away as shown in the diagram.



What was the speed at take-off?

- **A** 5 ms^{-1}
- **B** 10 ms^{-1}
- **C** 15 ms^{-1}
- **D** 20 ms^{-1}
- **E** 25 ms^{-1}

J93/I/3

54 A projectile leaves the ground at an angle of 60° to the horizontal. Its initial kinetic energy is *E*. Neglecting air resistance, find in terms of *E* its kinetic energy at the highest point of the motion. J86/II/1

55 *(a)* A stone is thrown with a velocity of 15 ms^{-1} at an angle of 60° to the horizontal, as shown in Fig. 16.

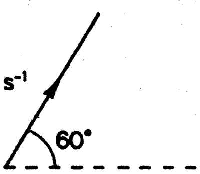


Fig. 16

(i) Will the magnitude of the initial horizontal component of the velocity of the stone be greater, the same, or less than 15 m s^{-1}?

(ii) Calculate the magnitude of the initial horizontal component of the velocity.

(iii) Calculate the magnitude of the initial vertical component of the velocity. [3]

(b) The stone in *(a)* is being thrown from the top of a cliff with the velocity of 15 ms^{-1} at 60° to the horizontal as shown in Fig. 17.

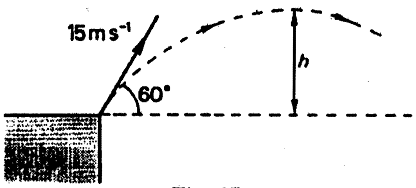


Fig. 17

On the axes of Fig. 18, draw graphs to represent the variation with time of

(i) V_H, the horizontal component of the velocity,

(ii) V_V, the vertical component of the velocity of the stone. Ignore air resistance. Identify your graphs. [4]

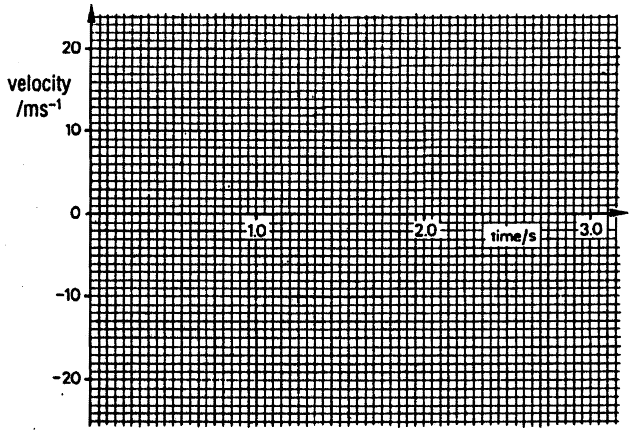


Fig. 18

(c) Use your answer in *(b)* to find *h*, the maximum vertical height of the stone above its point of projection. [3]

N92/II/1

56 *(b)* A ball is thrown into the air and, at one instant, it is moving upwards with a speed of 5.0 m s^{-1} at an angle of 60° to the vertical.

(c) The ball in *(b)* rises into the air and then returns to the ground. Neglecting air resistance, describe qualitatively what happens during this motion to the magnitude of

(i) the vertical component of the velocity,

(ii) the horizontal component of the velocity. [3]

J95/II/1 (part)

57 A stuntman on a motorcycle plans to ride up a ramp in order to jump over a number of cars, as illustrated in Fig. 19.

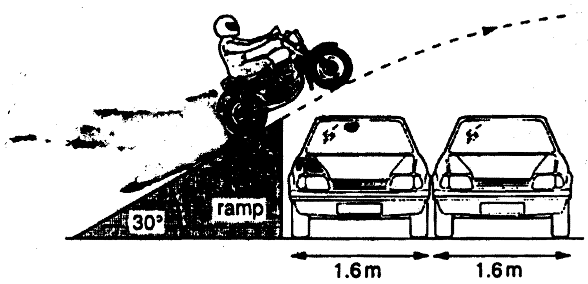


Fig. 19

The speed of the motorcycle as it leaves the ramp is 14 m s^{-1}. Neglect air resistance throughout this question.

(a) On Fig. 20, the line OA represents the velocity of the motorcycle just as it leaves the ramp.

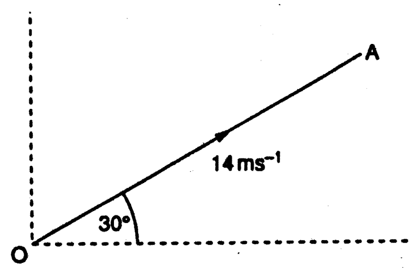


Fig. 20

(i) Explain why OA represents the velocity of the motorcycle and not just its speed.

(ii) What is the scale used in Fig. 20?

(iii) On Fig. 20, construct lines to determine the horizontal and the vertical components of the velocity of the motorcycle. Determine

1. the horizontal component of the velocity,

horizontal component = ...m s^{-1}

2. the vertical component of the velocity.

vertical component = ...m s^{-1} [4]

(b) Calculate the time interval between leaving the end of the ramp and reaching maximum height.

time interval = ...s [2]

(c) The cars are each of width 1.6 m and the same height as the ramp. Estimate the maximum number of cars which the motorcyclist can jump for the take-off speed of 14 m s^{-1}.

number.. [3]

J97/II/1

58 *(c)* The archer fires the arrow with an initial speed v and hits a target which is a distance d away and on the same horizontal level as the bow, as illustrated in Fig. 21.

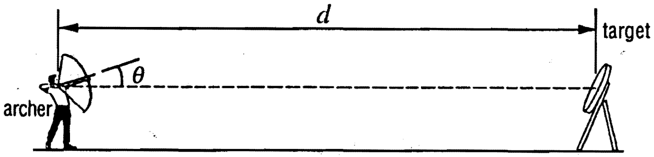


Fig. 21

The arrow is aimed so that, on release, it makes an angle θ with the horizontal.

(i) Assuming air resistance to be negligible, write down an expression for

1. d in terms of v, θ and the time of flight t,

2. the time of flight t in terms of v, θ and the acceleration of free fall g. [3]

(ii) The distance d is given by the expression

$$d = \frac{v^2 \sin 2\theta}{g}.$$

Calculate the angle q for an arrow with initial speed v = 32 ms^{-1} and a target at a distance d of 94 m from the bow.

θ = ... ° [2]

(iii) Suggest with a reason, whether the angle θ would, in practice, be larger or smaller than that calculated in (ii) for the arrow to hit the target. [3]

N2000/II/2 (part)

Long Questions

59

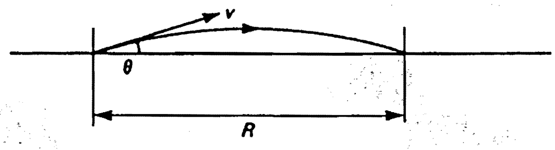


Fig. 22

(a) A stone is projected from the Earth's surface with velocity v at an angle θ to the horizontal (Fig. 22).

(i) Write down expressions for v_y and v_x, the vertical and horizontal components of the stone's velocity, at time t after projection. (Neglect air resistance.)

(ii) Find the time taken for the stone to reach its maximum height, and hence show that the horizontal range R of the stone is ($2v^2 \sin\theta \cos\theta$) / g. N85/II/8 (part)

60 *(b)* An experiment was conducted on the surface of the Moon to investigate the motion of a small sphere. The sphere, mass 50 g, was projected horizontally from a point some distance above the surface of the Moon. Its subsequent motion was monitored by taking a photograph of the sphere using a series of flashes of light at intervals of 1.00 s. The first flash occurred at the instant of projection. The photograph, superimposed on a grid, is illustrated in Fig. 23.

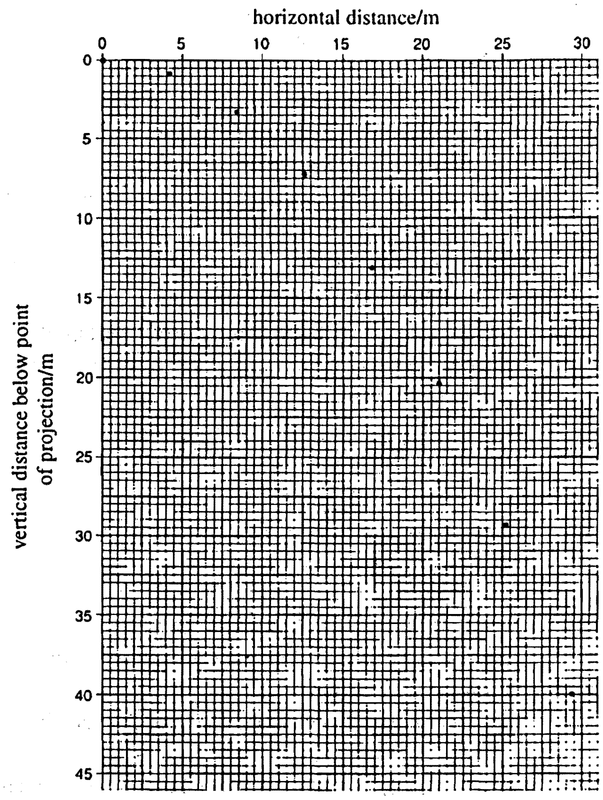


Fig. 23

(i) By considering the horizontal distances moved, show that frictional forces opposing the motion were negligible.

(ii) Calculate the horizontal component of the velocity.

(iii) Use Fig. 23 to determine the vertical distance travelled during the first 7.00 s of the motion .

(iv) Hence calculate

1 a value for the acceleration of free fall on the surface of the Moon,

2 the loss in potential energy of the sphere during the first 7.00 s.

(v) Show that the kinetic energy of the sphere after 7.00 s is about 3.7 J. [11]

(c) Use your answer to *(b)* (ii) and the value of the kinetic energy given in *(b)* (v) to determine the magnitude and direction of the velocity of the sphere 7.00 s after projection. [4]

(d) (i) On your answer paper, sketch the path of the sphere indicated by Fig. 23.

(ii) Add to your sketch two further lines showing the path of the sphere if

1 the Moon had an atmosphere (label this path A),

2 the experiment were repeated on a planet which has no atmosphere and where the acceleration of free fall is less than that on the Moon. (Label this path P.) [3]

N95/III/2 (part)

61 *(a)* (i) Define the *speed* of an object.

(ii) Distinguish between *speed* and *velocity*. [3]

(b) A ball is thrown from horizontal ground with an initial velocity of 15 m s^{-1} at an angle of 60° to the horizontal, as shown in Fig. 24.

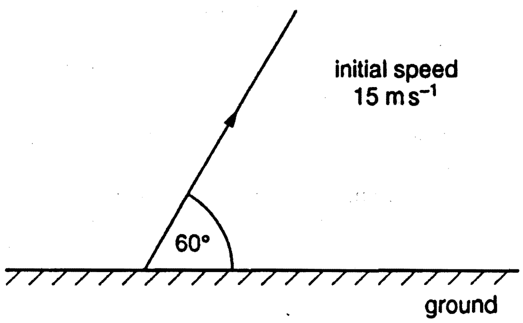


Fig. 24

(i) Calculate, for this ball, the initial values of

1. the vertical component of the velocity,

2. the horizontal component of the velocity. [3]

(ii) Assuming that air resistance can be neglected, use your answers in (i) to determine

1. the maximum height to which the ball rises,

2. the time of flight, i.e. the time interval between the ball being thrown and returning to ground level,

3. the horizontal distance between the point from which the ball was thrown and the point where it strikes the ground. [6]

(iii) Use your answers to (ii) to sketch the path of the ball, assuming air resistance is negligible. Label this path N. [2]

(iv) 1. On your sketch in (iii), draw the path of the ball, assuming that air resistance cannot be neglected. Label this path A.

2. Suggest an explanation for any differences between the two paths N and A. [6]

N97/III/1