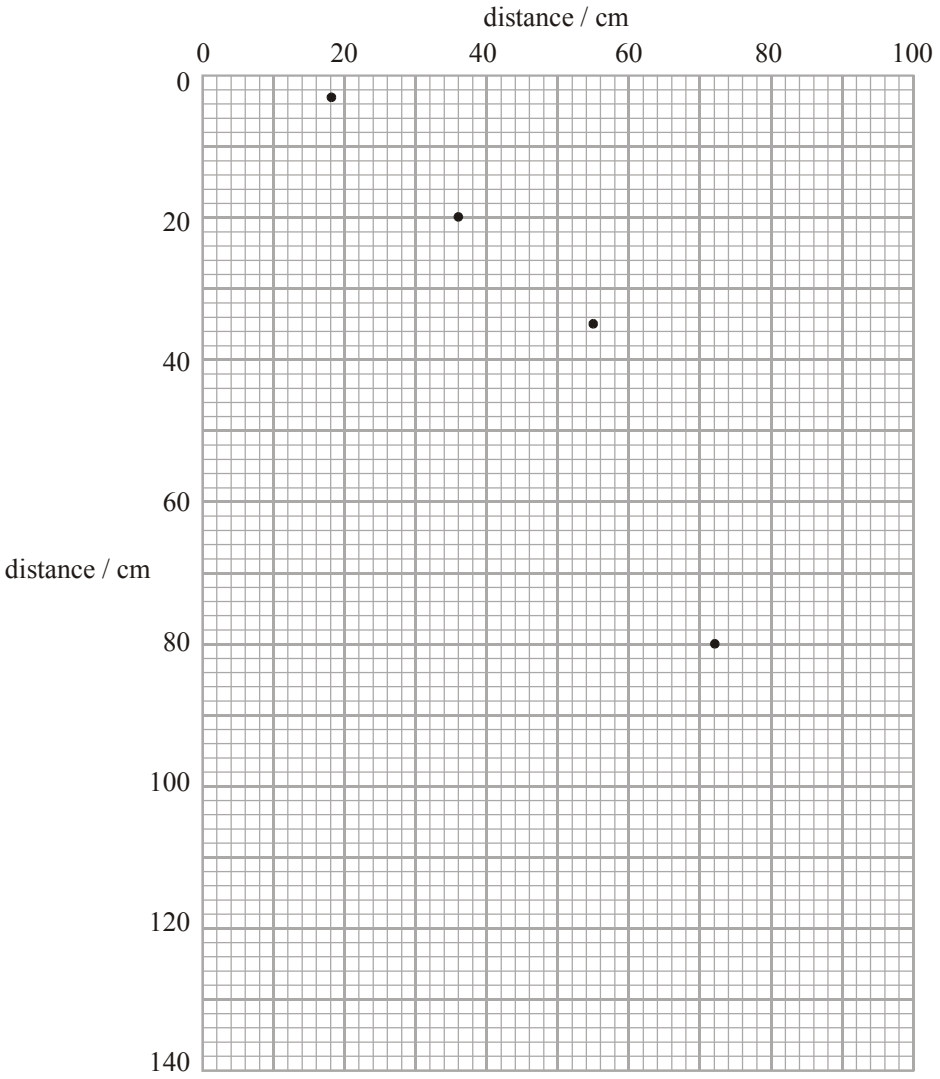
IB Kinematics Problems

1. This question is about projectile motion.

A small steel ball is projected horizontally from the edge of a bench. Flash photographs of the ball are taken at 0.10 s intervals. The resulting images are shown against a scale as in the diagram below.



(a) Use the diagram to determine

(i) the constant horizontal speed of the ball.

(ii) the acceleration of free fall.

(b) Mark on the diagram the position of the ball 0.50 s after projection.

In the space below, you should carry out any calculations so that you can accurately position the ball.

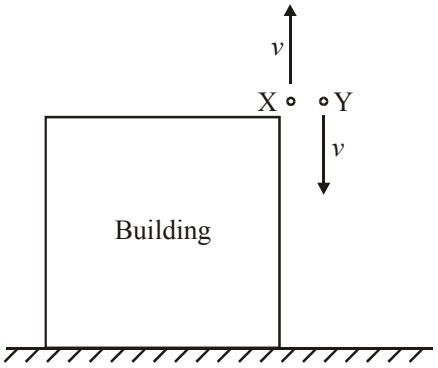
(3)

(c) A second ball is projected from the bench at the same speed as the original ball. The ball has small mass so that air resistance cannot be neglected. Draw on the diagram the approximate shape of the path you would expect the ball to take.

(3)

(Total 10 marks)

2. A stone X is thrown vertically upwards with speed *v* from the top of a building. At the same time, a second stone Y is thrown vertically downwards with the same speed *v* as shown.



Air resistance is negligible. Which **one** of the following statements is **true** about the speeds with which the stones hit the ground at the base of the building?

A. The speed of stone X is greater than that of stone Y.

B. The speed of stone Y is greater than that of stone X.

C. The speed of stone X is equal to that of stone Y.

D. Any statement about the speeds depends on the height of the building.

(1)

3. This question is about linear motion.

A police car P is stationary by the side of a road. A car S, exceeding the speed limit, passes the police car P at a constant speed of 18 m s^{-1}. The police car P sets off to catch car S just as car S passes the police car P. Car P accelerates at 4.5 m s^{-2} for a time of 6.0 s and then continues at constant speed. Car P takes a time *t* seconds to draw level with car S.

(a) (i) State an expression, in terms of *t*, for the distance car S travels in *t* seconds.

(1)

(ii) Calculate the distance travelled by the police car P during the first 6.0 seconds of its motion.

(1)

(iii) Calculate the speed of the police car P after it has completed its acceleration.

(1)

(iv) State an expression, in terms of t, for the distance travelled by the police car P during the time that it is travelling at constant speed.

(1)

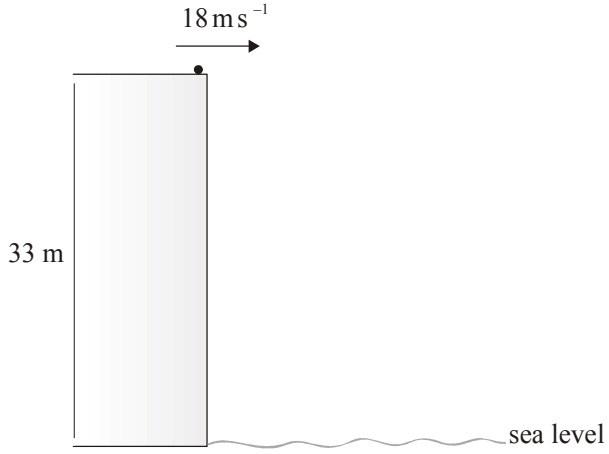
(b) Using your answers to (a), determine the total time *t* taken for the police car P to draw level with car S.

(2)

(Total 6 marks)

4. This question is about projectile motion.

A stone is thrown horizontally from the top of a vertical cliff of height 33 m as shown below.



The initial horizontal velocity of the stone is 18 m s^{-1} and air resistance may be assumed to be negligible.

(a) State values for the horizontal and for the vertical acceleration of the stone.

Horizontal acceleration: .....

Vertical acceleration: .....

(2)

(b) Determine the time taken for the stone to reach sea level.

(2)

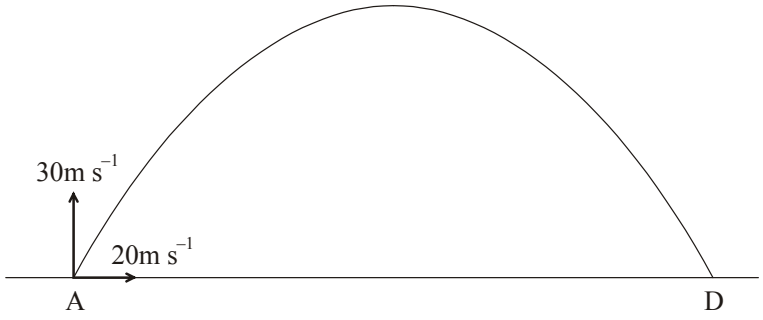
(c) Calculate the distance of the stone from the base of the cliff when it reaches sea level.

(1)

(Total 5 marks)

5. This question is about the trajectory of a golf ball.

A golfer hits a golf ball at point A on a golf course. The ball lands at point D as shown on the diagram. Points A and D are on the same horizontal level.



The initial horizontal component of the velocity of the ball is 20 m s^{-1} and the initial vertical component is 30 m s^{-1}. The time of flight of the golf ball between point A and point D is 6.0 s. Air resistance is negligible and the acceleration of free fall g = 10 m s^{-2}.

Calculate

(a) the maximum height reached by the golf ball.

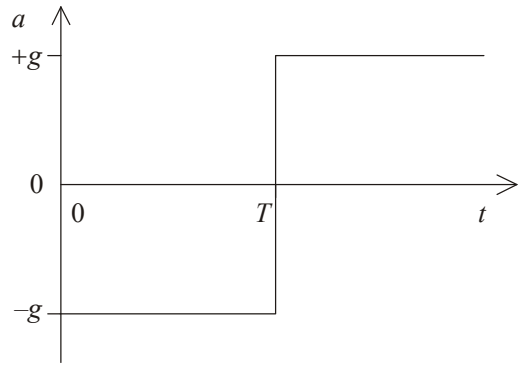
(3)

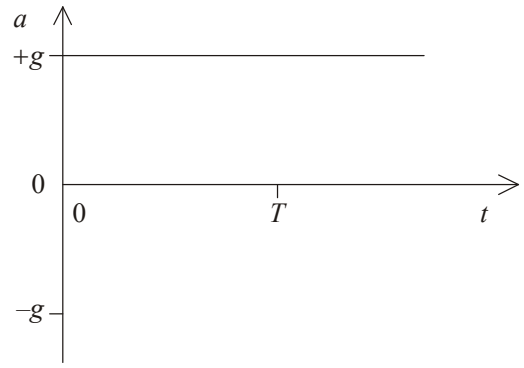
(b) the range of the golf ball.

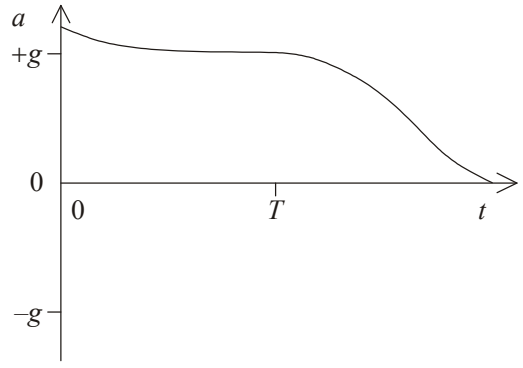
(2)
(Total 5 marks)

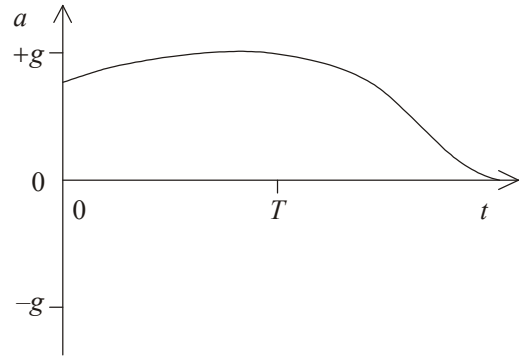
6. A ball is thrown vertically upwards at time $t = 0$. Air resistance is **not** negligible and the acceleration of free fall is g. The ball reaches a maximum height at time $t = T$ and then descends, reaching a terminal speed.

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

A.


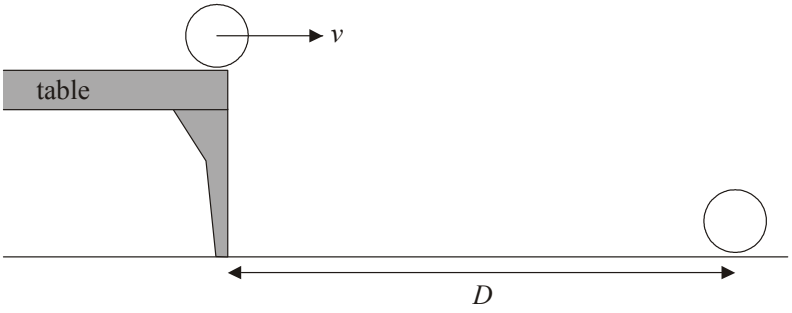
B.


C.


D.


(1)

7. A ball rolls off a horizontal table with velocity v. It lands on the ground a time T later at a distance D from the foot of the table as shown in the diagram below. Air resistance is negligible.



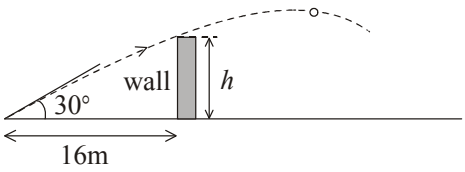
A second **heavier** ball rolls off the table with velocity v. Which **one** of the following is correct for the heavier ball?

	Time to land	Distance from table
A.	T	D
B.	T	less than D
C.	less than T	D
D.	less than T	less than D

(1)

8. This question is about projectile motion.

A ball is projected from ground level with a speed of 28 m s^{-1} at an angle of 30° to the horizontal as shown below.



There is a wall of height h at a distance of 16 m from the point of projection of the ball. Air resistance is negligible.

(a) Calculate the initial magnitudes of

(i) the horizontal velocity of the ball;

(1)

(ii) the vertical velocity of the ball.

(1)

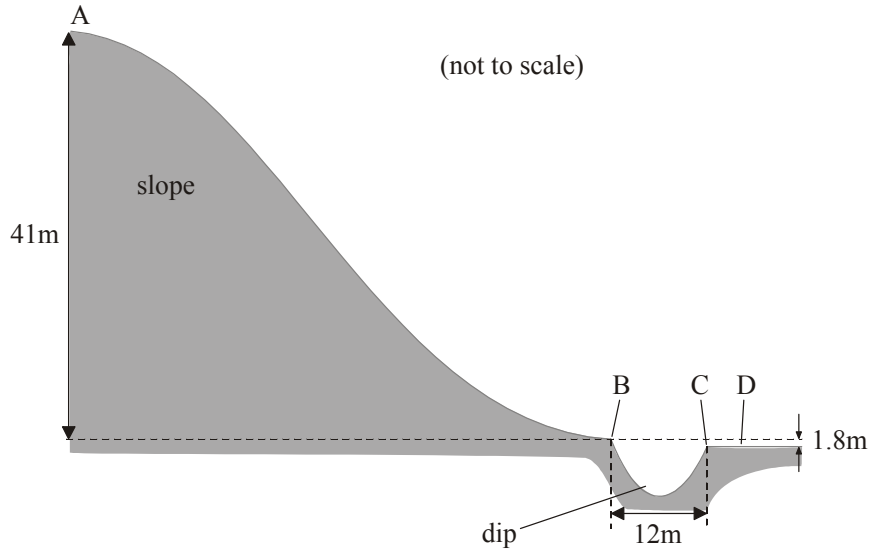
(b) The ball just passes over the wall. Determine the maximum height of the wall.

(3)

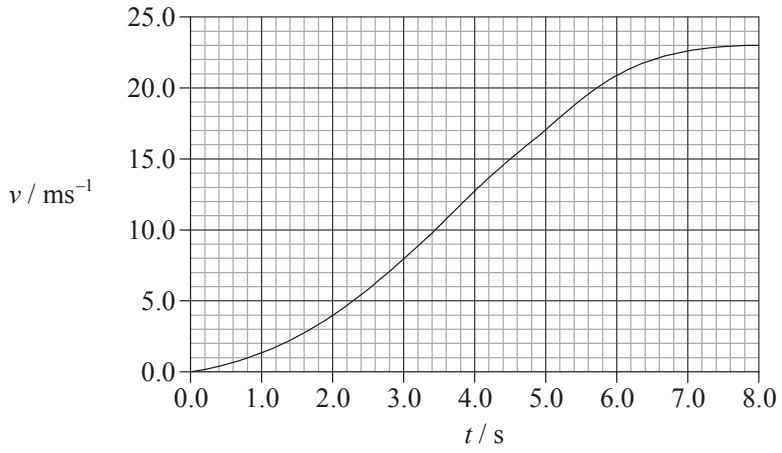
(Total 5 marks)

9. Linear motion

At a sports event, a skier descends a slope AB. At B there is a dip BC of width 12 m. The slope and dip are shown in the diagram below. The vertical height of the slope is 41 m.



The graph below shows the variation with time t of the speed v down the slope of the skier.



The skier, of mass 72 kg, takes 8.0 s to ski, from rest, down the length AB of the slope.

(a) Use the graph to

(i) calculate the kinetic energy E_K of the skier at point B.

(2)

(ii) determine the length of the slope.

(4)

(b) (i) Calculate the change ΔE_P in the gravitational potential energy of the skier between point A and point B.

(2)

(ii) Use your answers to (a) and (b)(i) to determine the average retarding force on the skier between point A and point B.

(3)

(iii) Suggest **two** causes of the retarding force calculated in (ii).

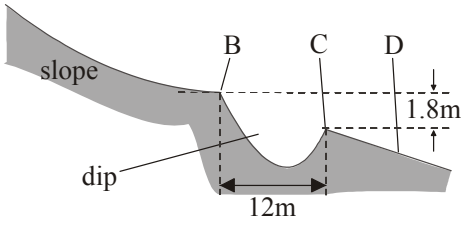
(2)

(c) At point B of the slope, the skier leaves the ground. He "flies" across the dip and lands on the lower side at point D. The lower side C of the dip is 1.8 m below the upper side B.

Determine the distance CD of the point D from the edge C of the dip. Air resistance may be assumed to be negligible.

(4)

(d) The lower side of the dip is altered so that it is inclined to the horizontal, as shown below.



(i) State the effect of this change on the landing position D.

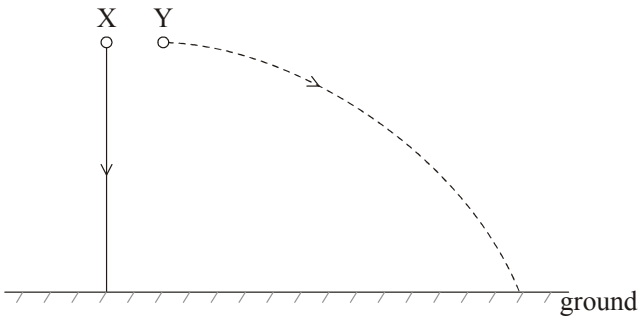
(1)

(ii) Suggest the effect of this change on the impact felt by the skier on landing.

(2)

(Total 20 marks)

10. Two identical metal spheres X and Y are released at the same time from the same height above the horizontal ground. Sphere X falls vertically from rest. Sphere Y is projected horizontally as shown below.



Air resistance is negligible.

Which of the following statements is correct?

A. Sphere X hits the ground before sphere Y because it travels a shorter distance.

B. Sphere Y hits the ground before sphere X because its initial velocity is greater.

C. The spheres hit the ground at the same time because horizontal motion does not affect vertical motion.

D. The spheres hit the ground at the same time because they have equal weights.

(1)