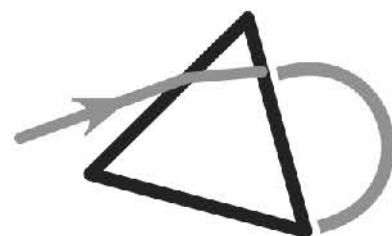


Delta Science Education



Billy Li



HKDSE
Physics

Core 2: Force and Motion

Chapter 5: Momentum

PART 2

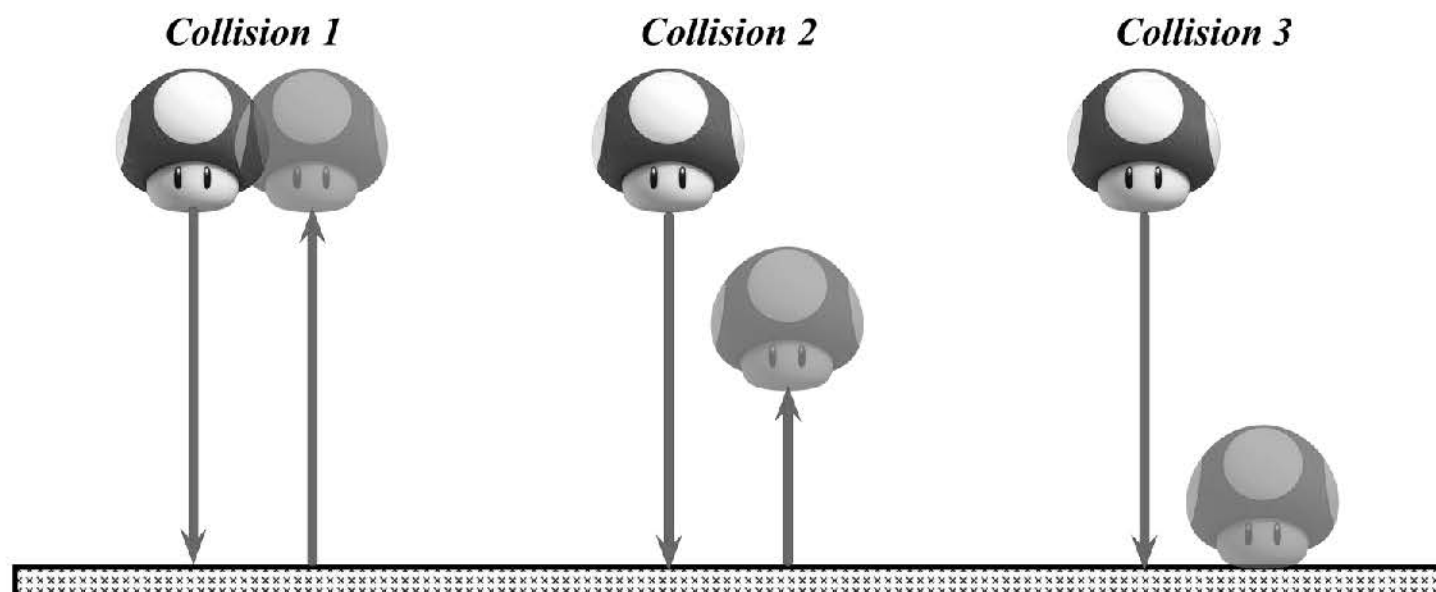
直接 Whatsapp Billy sir: 9558 6290



4. Conservation of energy in collisions

(1) Types of collision

- Collision can be divided into (perfectly) elastic, partly inelastic and (completely) inelastic.

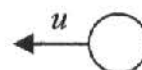


Examples that you must fully understand

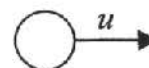
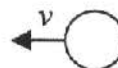
38. Two identical spheres are moving in opposite directions with speeds u and v (with $u > v$) respectively as shown. They make a head-on collision. Which of the following diagrams show(s) a possible situation of the spheres after collision?



(1)



(2)



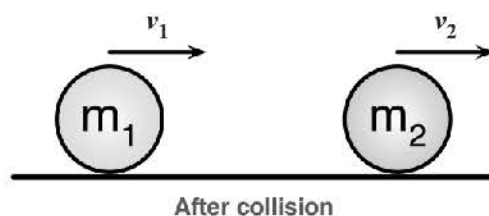
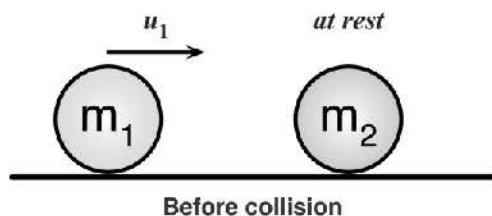
(3)





Examples that you must fully understand

39. A ball hits another identical ball which is initially at rest. Which of the following are the possible data?



$u / \text{m s}^{-1}$ $v_1 / \text{m s}^{-1}$ $v_2 / \text{m s}^{-1}$

(1) 10 5 5

(2) 8 6 2

(3) 7 2 6

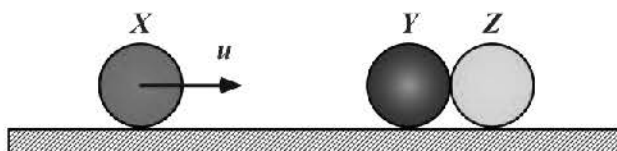
(4) 6 0 6

(5) 4 -2 6



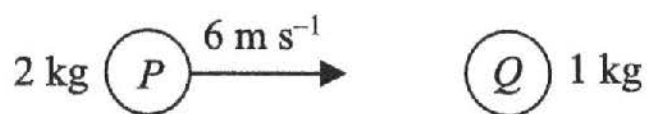
Examples that you must fully understand

40. X , Y and Z are three spheres of the same size but with masses m , m and $2m$ respectively, lying on a smooth horizontal track. X is moving to the right with velocity u and makes a head-on collision with Y . If all collisions are elastic, which of the following give(s) the possible velocities of the three spheres after all collisions? (Take to the right as positive)



	X	Y	Z	Momentum	Total KE	Situation
(1)	0	$u/3$	$u/3$			
(2)	0	$-u/3$	$2u/3$			
(3)	$-u/3$	0	$2u/3$			

41. A sphere P of mass 2 kg makes a head-on collision with another sphere Q of mass 1 kg which is initially at rest. The speed of P just before collision is 6 m s^{-1} .



If the two spheres move in the same direction after collision, which of the following could be the speed(s) of Q just after collision?

- (1) 2 m s^{-1}
 (2) 4 m s^{-1}
 (3) 6 m s^{-1}



Examples that you must fully understand

42. On a smooth horizontal surface, sphere X of mass m travels with speed 4 m s^{-1} . It collides head-on with another sphere Y of mass $2m$, which is at rest initially. Which of the following can be the speed of Y just after collision?



- (1) 1 m s^{-1}
 (2) 2 m s^{-1}
 (3) 3 m s^{-1}

43. On a smooth horizontal surface, a marble P moving with speed u collides head-on with another marble Q , which is at rest. After collision, P and Q move with different speeds. Which of the following statements about this collision is/are correct?

- (1) **During collision, the force acting on Q by P is equal and opposite to that acting on P by Q .**
 (2) **The total momentum of the two marbles is conserved only when the collision is perfectly elastic.**
 (3) **The kinetic energy lost by P must be equal to that gained by Q .**

44. Comment on the below statement:

"In a collision between 2 bodies which are free to move, momentum and kinetic energy must be conserved."

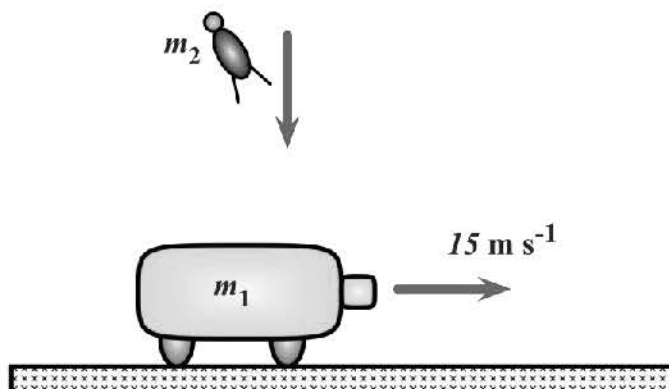


1. **Momentum**
 since there is
 2. **Kinetic energy**
 depending on



Examples that you must fully understand

45. A boy of mass 200 kg is dropped from a height of 20 m onto a vehicle of mass 1000 kg travelling at 15 m s^{-1} .



- (a) Calculate the velocity of the boy when it just touches the vehicle.
- (b) Find their common horizontal velocity after impact.
- (c) If the duration time of impact is 0.2 s, find the average horizontal force (with direction) acting on the car during the impact.
- (d) Albert claims that since there is no vertical motion after collision, the vertical momentum of the vehicle-boy system is not conserved. Comment on his claim.
- Albert is since there is an acting on the vehicle-boy system by the ground during collision. Therefore, the of the vehicle-boy system is .
- (e) If the duration time of impact is 0.2 s, find the average vertical force (with direction) acting on the car by the boy during the impact.



Examples that you must fully understand

46.



(a) Trolley *A* of mass 2 kg moves towards the right with a velocity of 3 m s^{-1} . Trolley *B* of mass 3 kg moving with 5 m s^{-1} towards the left. A pin is attached to trolley *A* and a cork is attached to trolley *B* to ensure the collision is inelastic. What is the loss of total kinetic energy after collision?

(b) A trolley of mass 3 kg is moving towards the right with a velocity of 6 m s^{-1} . A plasticine of mass 2 kg falls from a negligible height and sticks onto the trolley.

(i) Which of the following statements is / are correct?

- (1) The momentum of the trolley is conserved.
- (2) The total momentum of the trolley and the plasticine is conserved.
- (3) The speed of the loaded trolley is lower than that of the unloaded trolley.
- (4) The kinetic energy of the loaded trolley is lower than that of the unloaded trolley.

(ii) What is the loss of total KE after collision? (Neglect the initial kinetic energy of the plasticine.)

(iii) Explain why there is loss of kinetic energy during the collision.

There is loss of KE since the collision is .

or There is loss of KE since some KE is changed to or during the collision.



Examples that you must fully understand

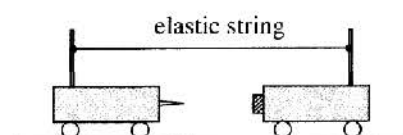
47. A basketball falls freely from rest and hits the ground. It then rebounds to $\frac{1}{4}$ of its original height. Neglecting air resistance, which of the following statements about the basketball is / are correct?

- (1) Its potential energy just before collision is four times its potential energy just after collision.**
- (2) Its kinetic energy just before collision is four times its kinetic energy just after collision.**
- (3) The speed just before collision is two times the speed just after collision.**

48. A basketball of mass m is projected up with a speed of v . After it hits the ground, it rebounds to the original height. Neglecting air resistance, which of the following statements about the basketball is / are correct?

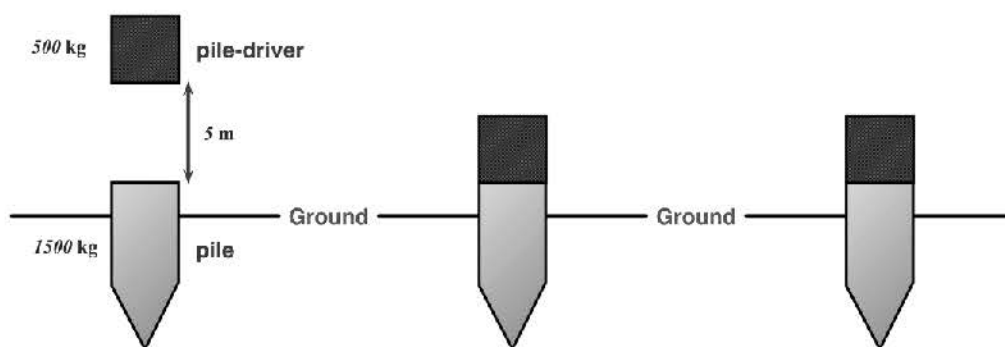
- (1) The collision with the ground is elastic.**
- (2) The lost in energy during collision is $0.5mv^2$.**

49. Two trolleys are linked by an elastic string. There is a long pin on one of the trolleys and a thick cork on the other as shown in the figure. The trolleys are pulled apart and then released. Which of the following statements is / are correct?



- (1) The trolleys stop moving after collision only if both of the trolleys have the same mass.**
- (2) The total momentum of the trolleys is always a constant.**
- (3) The total kinetic energy of the trolleys is conserved.**

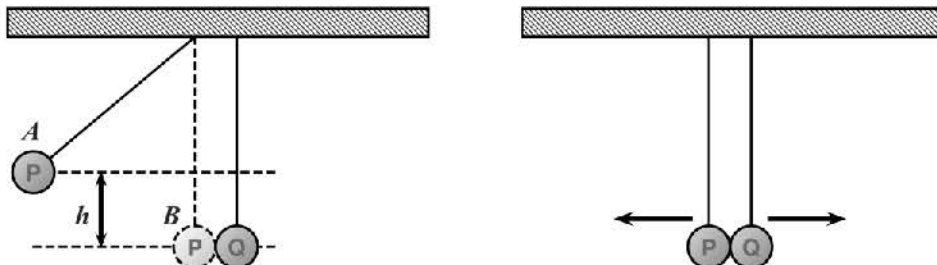
50. A pile-driver of mass 500 kg falls down from a height of 5 m hits a pile of mass 1500 kg. after collision, they move together and penetrate into the ground. If the average resistance force of the ground is 30,000 N, find the depth of penetration.





Examples that you must fully understand

51. Two metal balls P and Q are suspended by light inextensible strings. Ball P is pulled to point A which is at a height h above its initial position B and is then released. After colliding with Q , they move away in opposite directions.



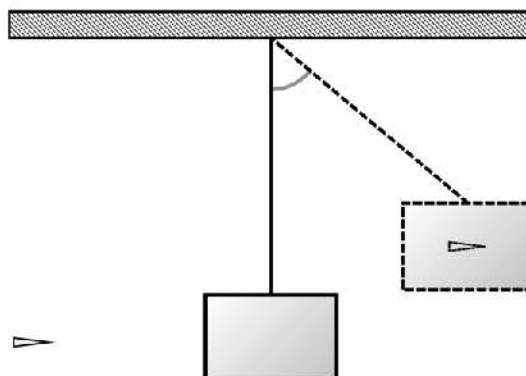
- (a) Draw the forces acting on P when it is at position A in the above diagram. Label the forces.
- (b) Describe the energy changes of the balls, from the moment P is released until the balls swing up to their maximum heights after the collision.
- When P swings from A to B , its P.E. is changed into K.E.*
- When P collides with Q , part of the K.E. of P is transferred to Q .*
- When P and Q swing upward after impact, their K.E. are changed into P.E.*
- (c) The mass of P is 0.4 kg and its speeds immediately before and after the collision are found to be 1.2 m s^{-1} and 0.75 m s^{-1} respectively.
- (i) Find h .
- (ii) Find the average force acting on P during the collision. Assume the time of contact is 0.03 s .
- (d) Consider the following set of data and show that the set of data obeys the law of conservation of momentum but the collision is not possible.

	P	Q
Mass / kg	0.4	0.6
Velocity before collision / m s^{-1}	1.2 (rightwards)	0
Velocity after collision / m s^{-1}	0.75 (leftwards)	1.3 (rightwards)



Examples that you must fully understand

52. A bullet of mass 20 g hits a wooden block of mass 2.48 kg as shown. The wooden block is attached to the ceiling by an inextensible string of length 2 m. After collision, the bullet is embedded into wooden block and the block then rises up to an angle of 20.6° with vertical.



- (a) Suggest a method to ensure that the bullet is embedded into the wooden block after collision.

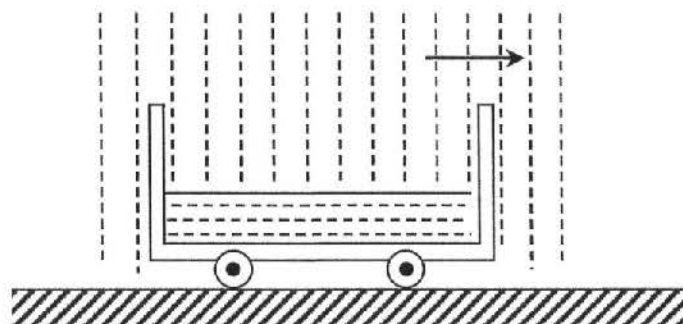
A piece of should be attached onto the bullet.

- (b) Calculate the velocity of the bullet just before hitting the wooden block.

- (c) Calculate the total kinetic energy of the system before and after collision. Account for the change of kinetic energy.

The of kinetic energy is changed into energy during collision.

53. The figure shows an open trolley moving an initial speed on a smooth horizontal surface. Rain water falls continuously onto the trolley and accumulates there. What are the effects on the speed, horizontal momentum and kinetic energy of the trolley together with the rain? (Ignore the initial kinetic energy of the rain water.)



Speed:

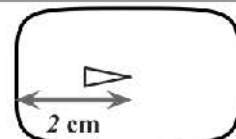
Momentum:

KE:

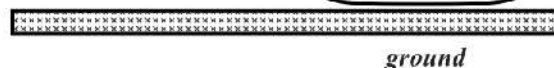


Examples that you must fully understand

54. A large block of mass 2 kg is fixed to the ground as shown. A bullet of mass 10 g and velocity 500 m s^{-1} travels towards it and embeds inside.



- (a) Find the average force acting on the bullet during impact.

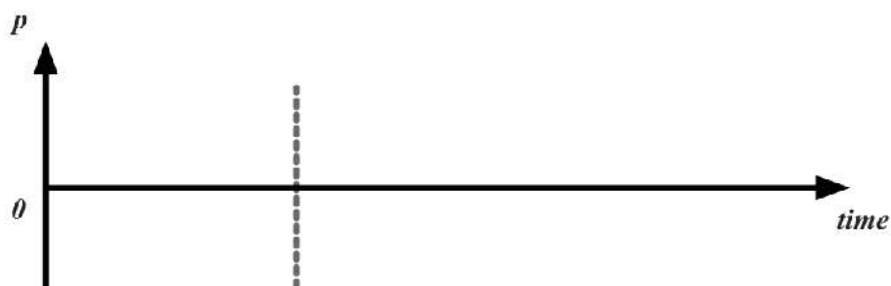
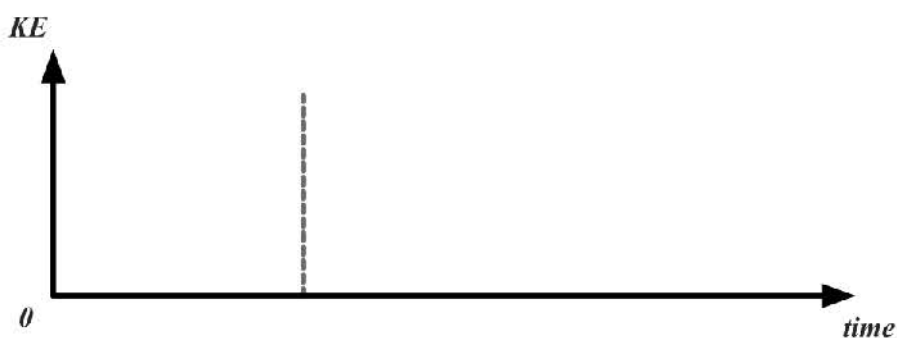
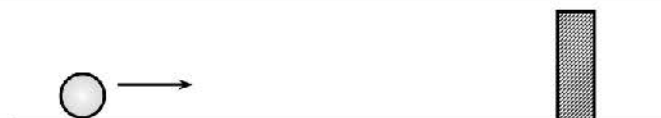


- (b) Is the total momentum of the bullet and the block conserved? Explain briefly.

- (c) During the impact, for which system is the momentum conserved?

- (d) If the block can move freely, find the common velocity of the bullet and the block after impact.

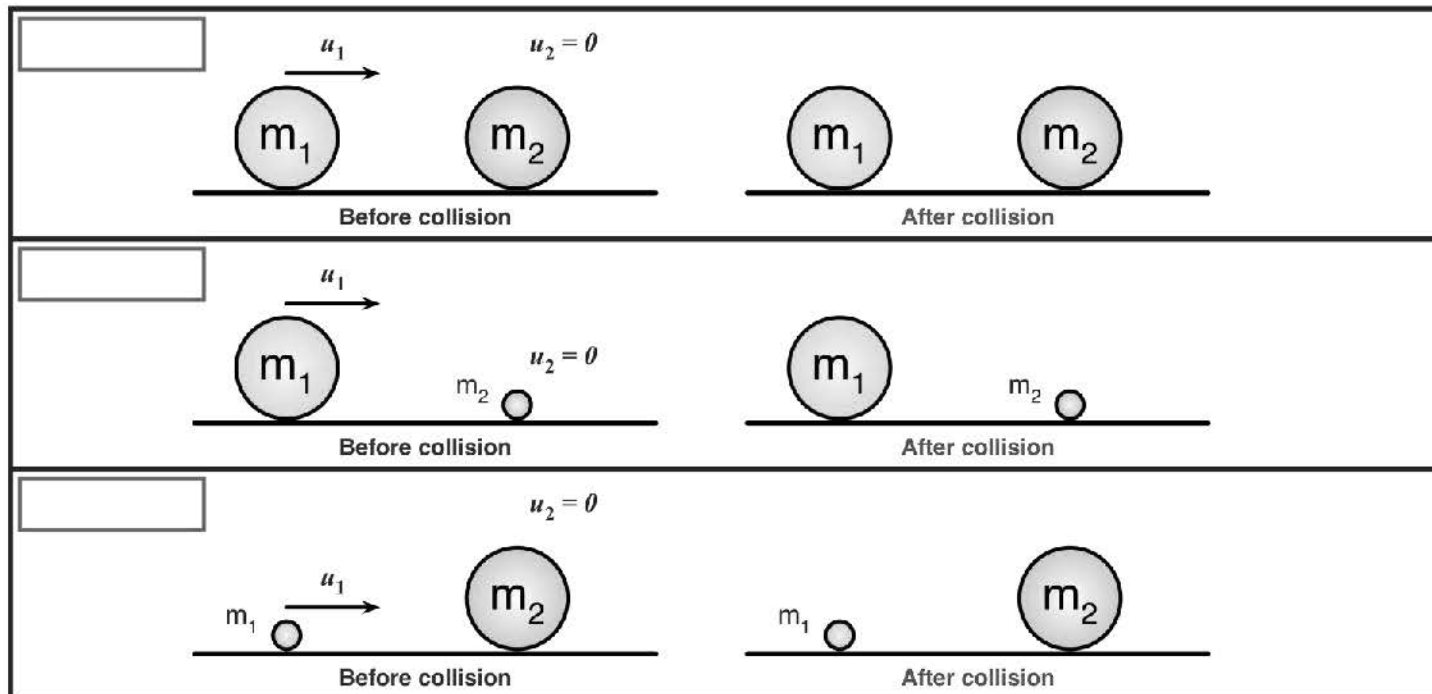
55. A ball moves along a horizontal smooth surface with a uniform speed. It then hits a vertical wall and rebounds backward with a smaller speed as shown. Sketch the variation of the KE and momentum of the ball with time.





(2) Head-on elastic collision of two bodies

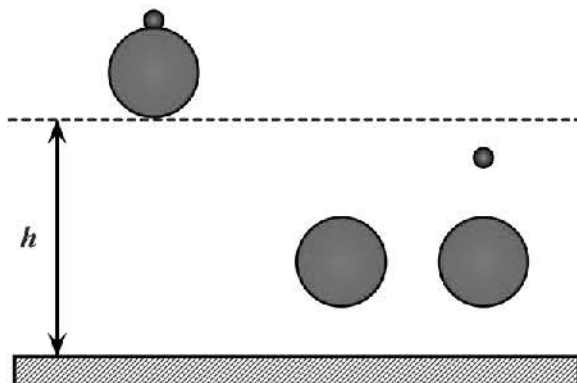
- Results of a ball m_1 hitting three balls of m_2 which are initially at rest:

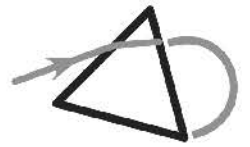


Examples that you must fully understand

56. In this question, you may assume all of the collisions are perfectly elastic. If the tennis ball is being put on top of the basketball this time and the whole system falls onto the ground again at a height of h , predict the maximum height of the balls that can reach after the rebound from the ground.

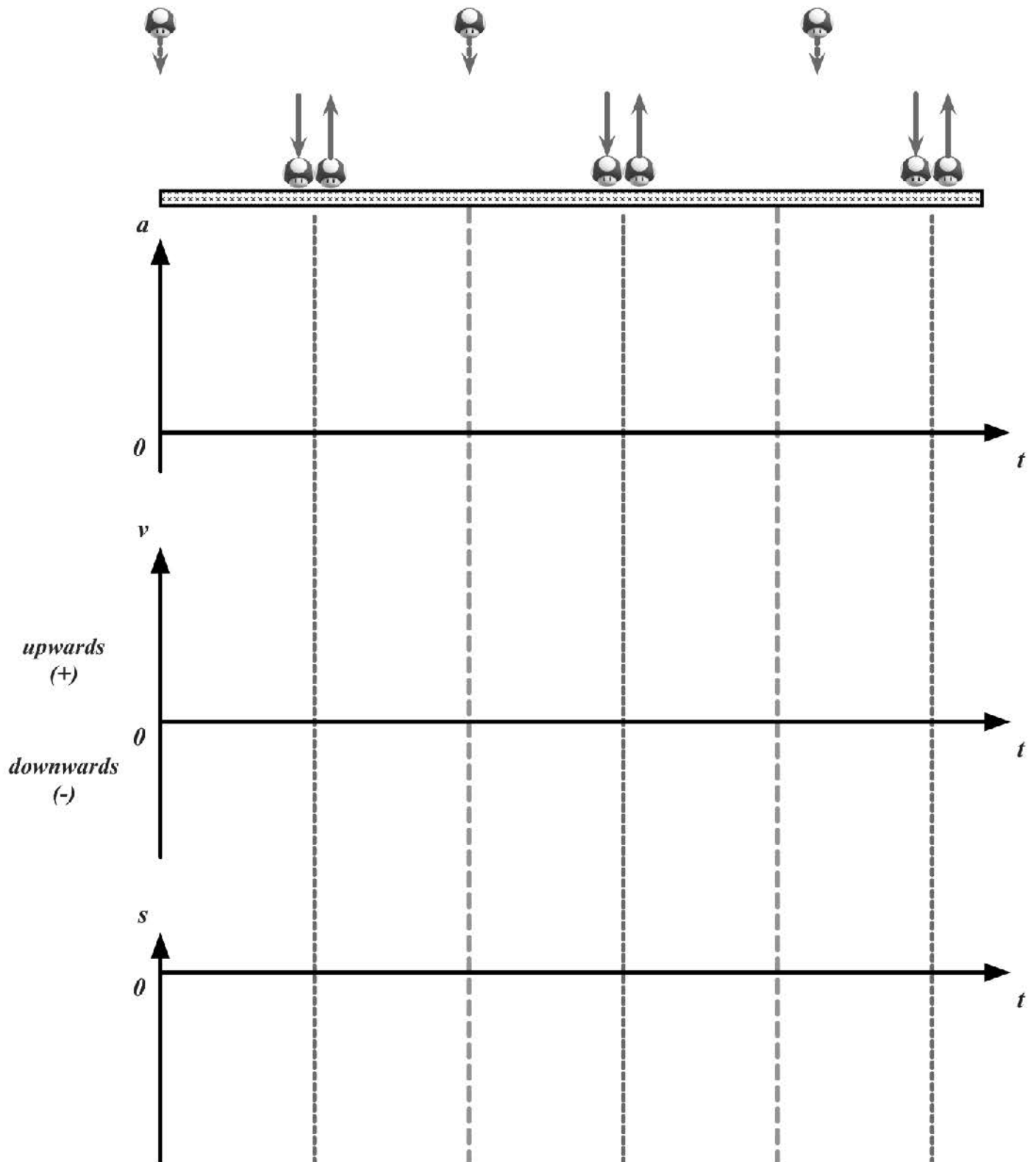
(Tips: You may assume that the mass of the table tennis is so much smaller than that of the basketball while the mass of the basketball is on the other hand much smaller than that of the Earth.)





(3) Motion of a ball rebounding from the ground

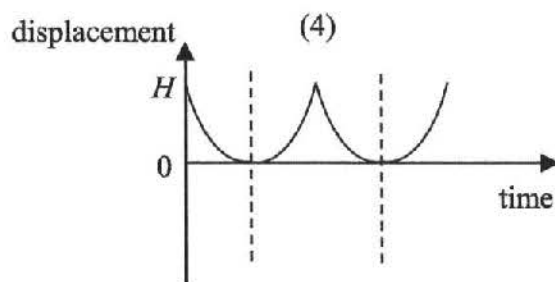
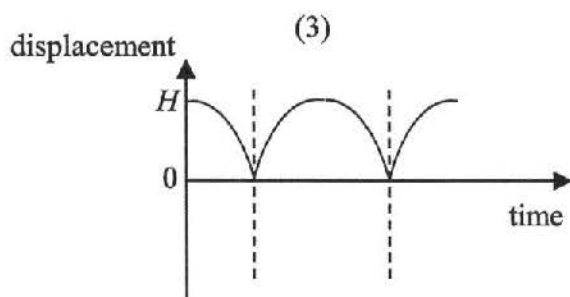
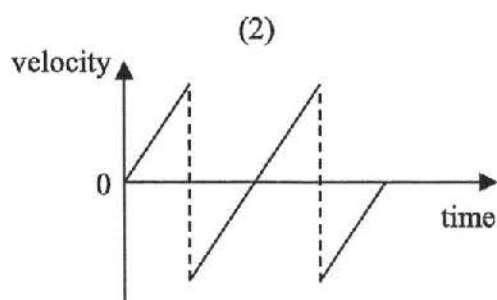
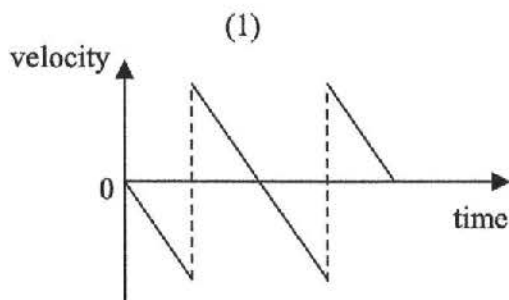
- Suppose a ball is released from rest at a certain height. It then falls to the ground, hits the ground and then rebounds from the ground. Assume all of the collisions are **perfectly elastic**.





Examples that you must fully understand

57. Which of the following graphs (velocity-time and displacement-time) best represent the motion of a ball falling from rest under gravity at a height H and bouncing back from the ground two times? Assume that the collision with the ground is perfectly elastic and neglect air resistance. (Downward measurement is taken to be negative.)



- A. (1) and (3) only
 B. (1) and (4) only
 C. (2) and (3) only
 D. (2) and (4) only

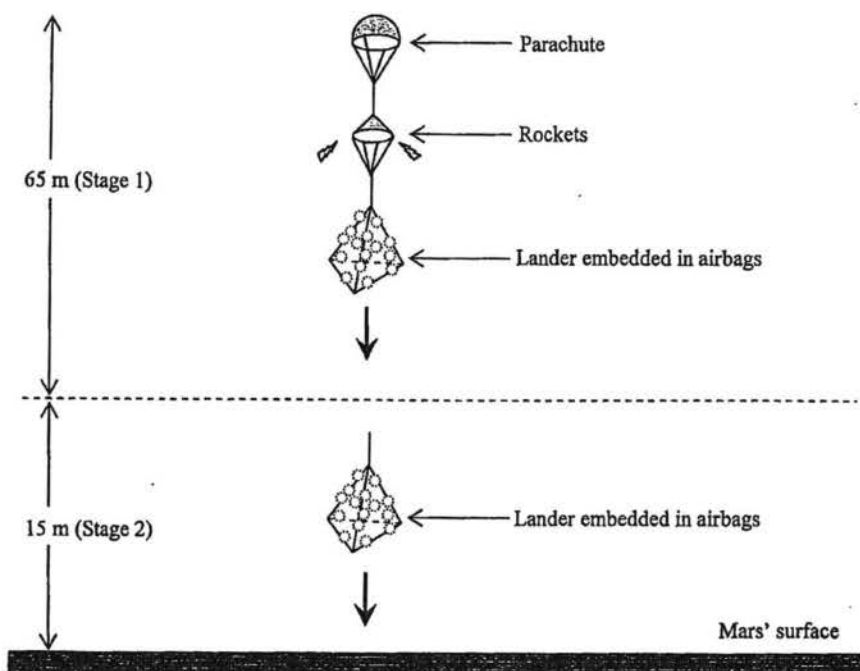
58. In 4 January, 2004, the lander "Spirit" landed on the surface of Mars. The spacecraft includes the lander embedded in some airbags, a parachute and decelerating rockets.

A teacher presents the simplified information about the last two stages of the landing process as follows:

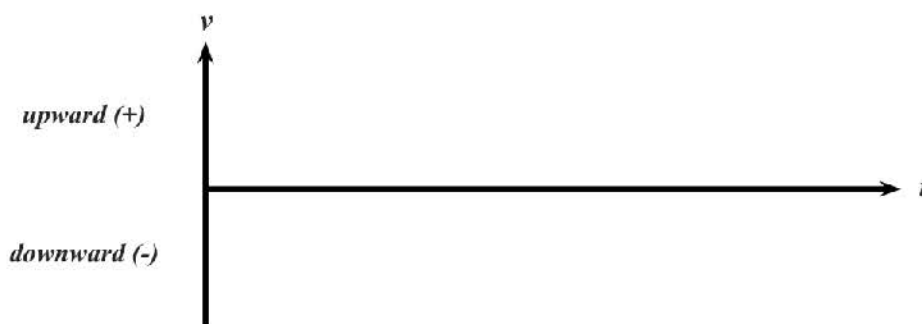
Stage 1: When the spacecraft was at a height of 80 m above Mars' surface, it was falling with a speed of 75 m s^{-1} . At this instant, the rockets were fired. The parachute and rockets exerted a total upward force of 16,900 N on the lander and brought it to an instantaneous rest at a height of 15 m above the surface.

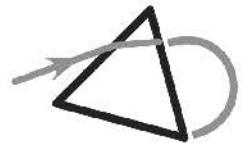
Stage 2: At the instant when the lander was 15 m above the surface, the parachute and rockets were separated from it. The lander then fell from rest to the surface under the action of the gravity of Mars.

You may assume that the lander descended vertically and the resistance exerted by the atmosphere on the lander was negligible.



- (a) The mass of the lander was 360 kg. Estimate the acceleration due to gravity on Mars' surface.
- (b) Find the speed of the lander when it just reached the surface.
- (c) Explain how the airbags helped the lander to land on the surface safely.
 The airbags are which can the impact time and the during the landing.
- (d) The lander bounced a few times on the surface before coming to rest. Sketch the time variation of the velocity.

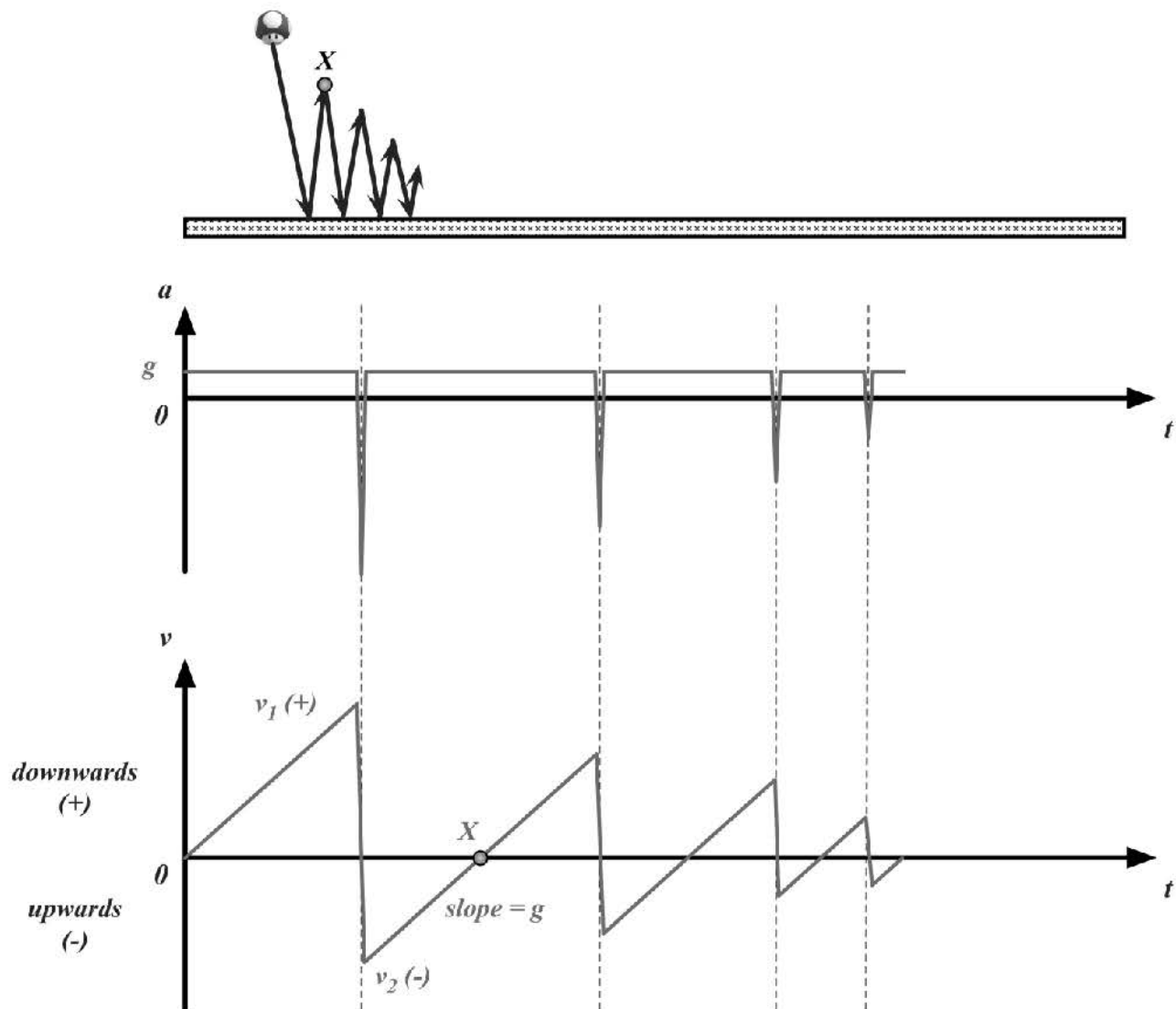




Examples that you must fully understand

59. A boy releases a basketball from rest at a certain height. The ball then bounces a few times on the ground before coming to rest.

(a) Take downward direction as positive, sketch the variation of the velocity and acceleration of the basketball with time in the figures below.



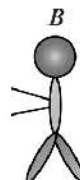
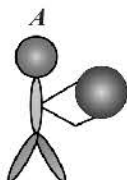
(b) If the maximum height reached by the basketball after the first rebound is 1.2 m, what is the speed of the ball when it just leaves the ground after the first rebound?



5. System with three bodies

Examples that you must fully understand

60. Two astronauts *A* of mass 60 kg and *B* of mass 70 kg float in the cabin of a space shuttle orbiting round the Earth. Astronaut *A* is at rest and he carries a toolbox of mass 20 kg. Astronaut *B* moves towards *A* with a speed of 2 m s⁻¹ as shown below.



- (a) In order to avoid head-on collision with astronaut *B*, *A* throws the toolbox to *B* and *B* grasps the toolbox once it reaches him. How can a collision be avoided by doing so?

Since some of *A* is to *B*, the of *A* and *B* can then be to avoid the occurrence of a collision.

- (b) Suppose astronaut *A* throws the toolbox with a speed of 7.5 m s⁻¹ to *B*.

(i) Find the velocity of astronaut *A* after throwing the toolbox.

(ii) Find the work done by astronaut *A* on the load during the throwing process.

- (c) Astronaut *B* then receives the load and grasps it once the toolbox reaches him.

(i) What is the common velocity of astronaut *B* and the toolbox after *B* grasps it?

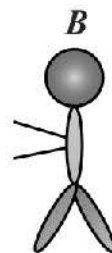
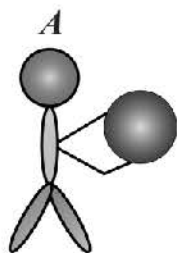
(ii) What is the loss of kinetic energy when astronaut *B* grasps the toolbox?

- (d) Which of the following statements is / are correct in the above throwing and receiving processes?

- (1) The momentum of the toolbox is conserved.
- (2) The total momentum of the two astronauts and the toolbox is conserved.
- (3) The total mechanical energy is conserved.
- (4) The total energy is conserved.



(e) Now suppose the two astronauts are approaching each other with the same speed of 1.5 m s^{-1} initially.



(i) Calculate the **MINIMUM** speed that the toolbox should have when it reaches *B* in order to avoid a collision.

(ii) Use the result in (e)(i) to find the corresponding work that is done on the toolbox by *A*.

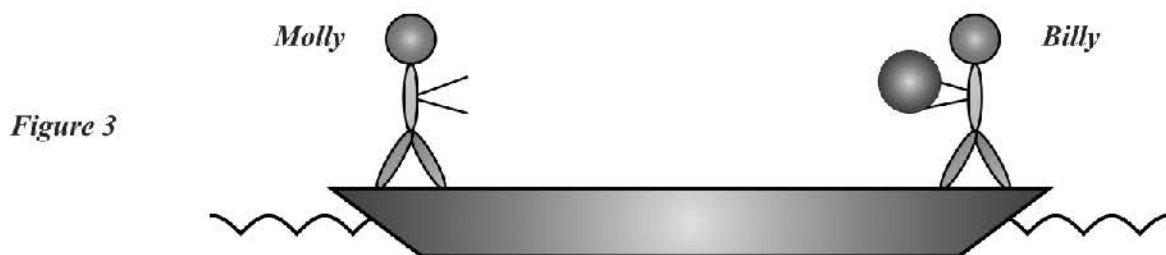
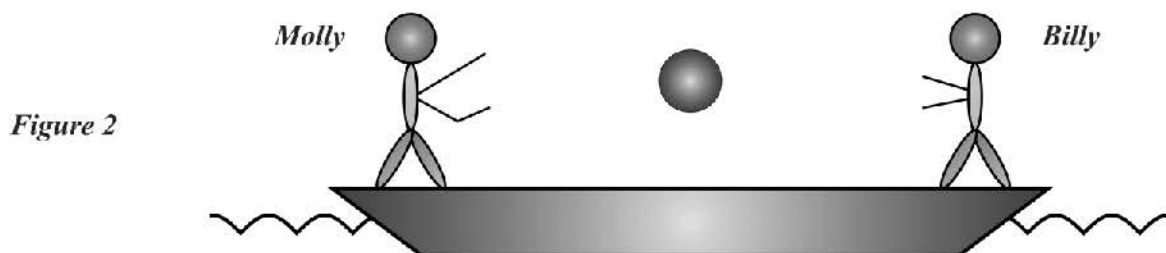
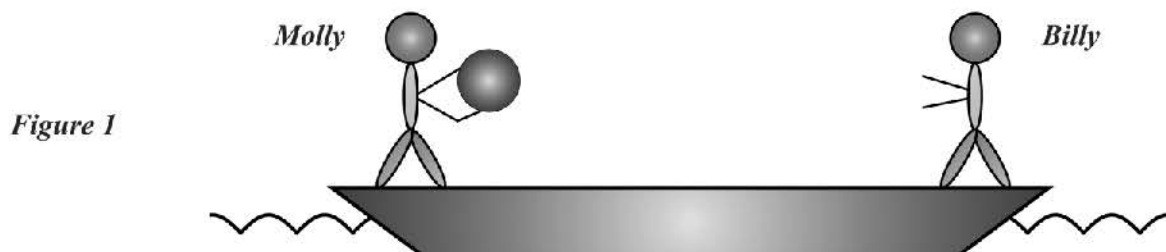
61. Judy (20 kg) and Kevin (38 kg) wear roller blades and stand on a smooth ground. Both of them are initially at rest. Judy holds a basketball of mass 2 kg and she throws the ball to Kevin. If Judy moves backwards with a speed of 1.5 m s^{-1} , what is the common velocity of Kevin and the ball after he catches the ball?

62. David and Candy standing on light skateboards with frictionless rollers are moving towards each other. Both of them have the same mass of 30 kg and move at a speed of 1.2 m s^{-1} . Initially David holds a ball of mass 1.0 kg. He then throws the ball straight towards Candy. After David has thrown the ball, he moves at 0.74 m s^{-1} along the original direction. Determine the velocity of Candy after she catches the ball.



Examples that you must fully understand

63. Molly and Billy are standing on a small boat floating on the sea. The boat is initially at rest. Figure 1 shows that Molly is holding a heavy ball. She then throws the ball towards Billy in figure 2 and Billy then catches the ball in figure 3. Which of the following statements is / are correct?



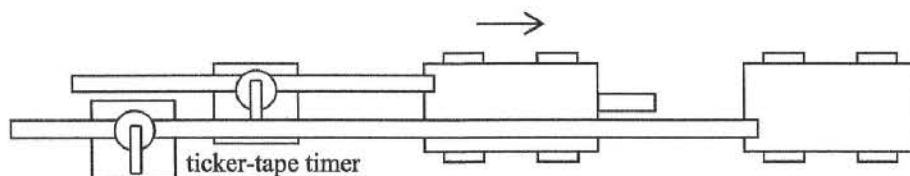
- (1) The total momentum of the boat, Molly, Billy and the ball is conserved in the above cases.
- (2) The boat will remain at rest in the above cases.
- (3) In figure 2, the momentum of the ball is equal in magnitude to the total momentum of the boat, Molly and Billy.
- (4) The total kinetic energy of the ball and Billy remains unchanged in the above cases.



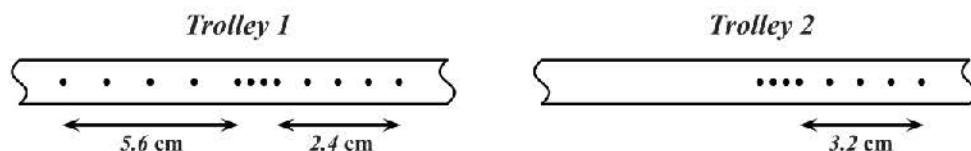
6. Experimental methods

Examples that you must fully understand

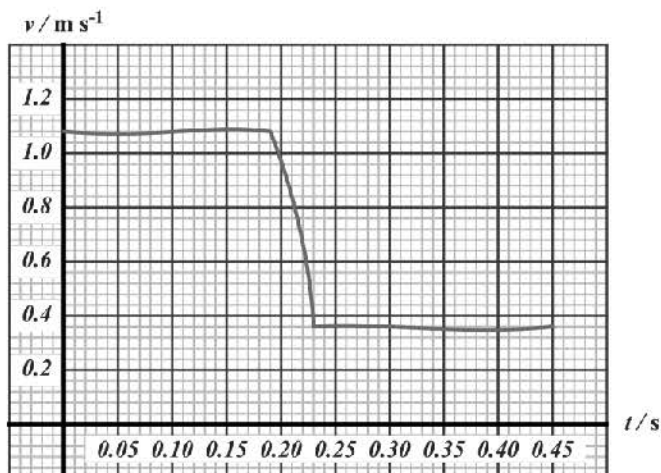
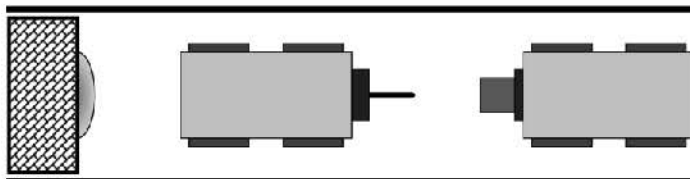
64. A trolley of mass m moving with an initial velocity collides with another identical trolley initially at rest as shown in the figure.



The tapes attached to the two trolleys are shown below. The frequency of the ticker tape time is 50 Hz. Verify the Principle of Conservation of Momentum from the result.



65. Two trolleys X and Y have masses m_1 and m_2 respectively. Trolley X is given an initial velocity and moves towards the trolley Y . A motion sensor is attached at the left of the trolley X . A pin and a cork are attached to the two trolleys. The velocity-time graph displayed by the computer is as shown below.



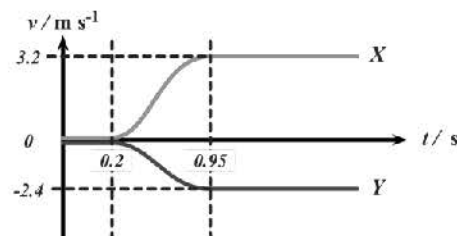
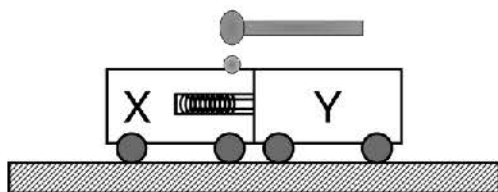
(a) Find the mass ratio of the two trolleys.

(b) If mass of m_1 is 1.2 kg, find the force acting on m_1 .



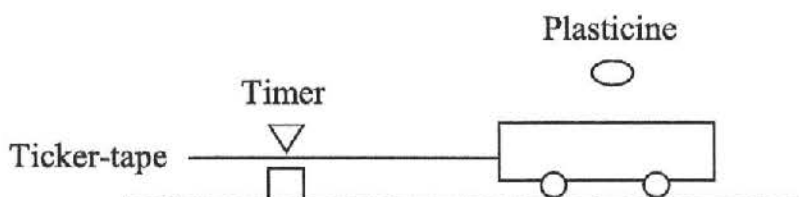
Examples that you must fully understand

66. Two trolleys *X* and *Y* are triggered off to separate from each other as shown below. The graph shows the variation of the velocity of the two trolleys before and after the explosion.



- (a) If the mass of trolley *X* is 1.5 kg, find the mass of trolley *Y*.
- (b) What is the average force acting on *Y* during the explosion?
- (c) Estimate the potential energy stored in the compressed spring.

67. A trolley moves with constant speed along a horizontal surface. A lump of plasticine having the same mass as the trolley is dropped onto the trolley and sticks to it. Which one of the following ticker-tape best represents the motion of the trolley?



A. start

B. start

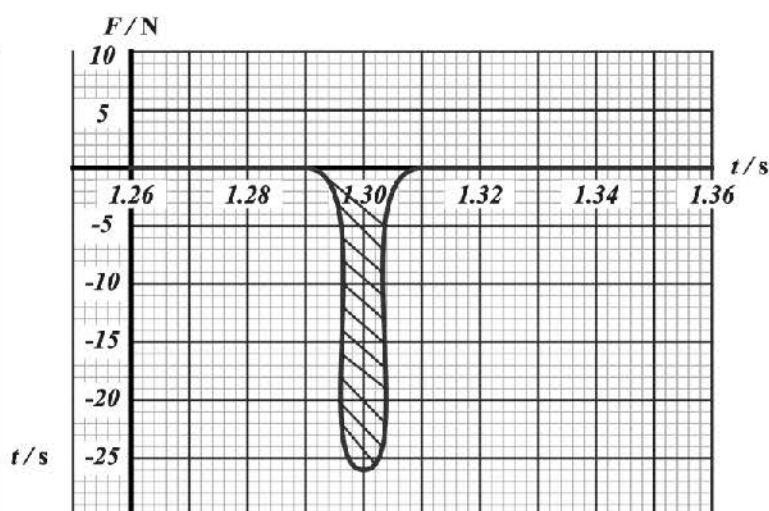
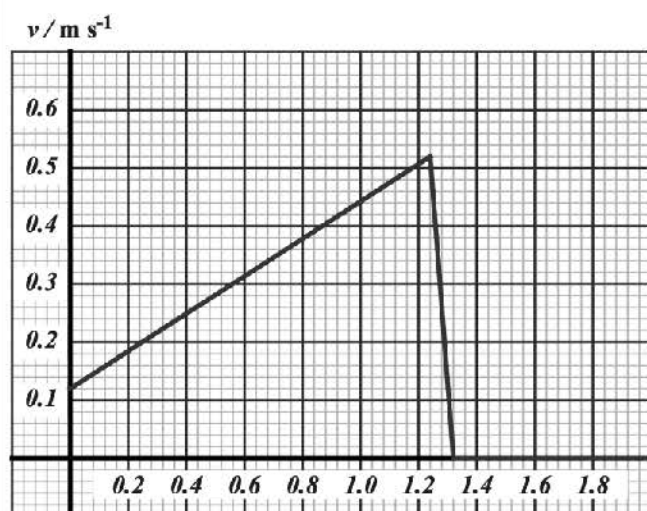
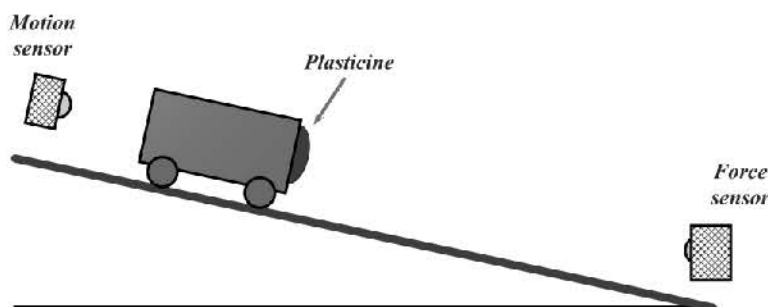
C. start

D. start



Examples that you must fully understand

68. The figure below shows a data-logging experimental set-up to investigate impacts. A trolley with a lamp of plasticine attached to its front is held on an inclined runway and a motion sensor is mounted on the top of the runway to record the velocity of the trolley. A force sensor is fixed at the bottom end of the runway. The trolley is released from rest so that it runs downwards along the plane and makes an impact with the force sensor. The velocity-time graph captured by the motion and the force-time graph recorded by the force sensor are shown in the figures below.



Assume that the collision between the trolley and the force sensor is inelastic. The area of the shaded region in the force-time graph is recorded to be 0.3 N s .

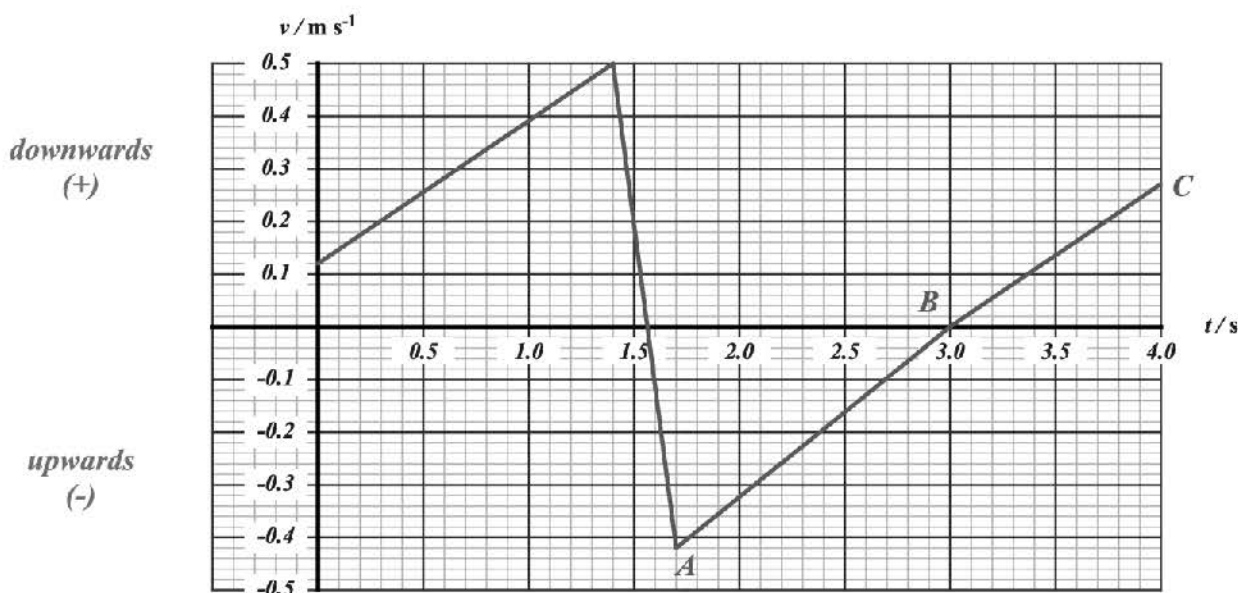
(a) State the physical meaning of the shaded area in the force-time graph.

The area represents the of the trolley.

(b) Using the two graphs, estimate the mass of the trolley.



- (c) The student uses the set-up to investigate the effect of using air bags as a safety device in cars. He replaces the plasticine attached to the trolley with a small inflated balloon and repeats the experiment. The velocity-time graph of the trolley captured by the motion sensor is shown in the figure below.



- (i) Describe the motion of the trolley after its impact with the force sensor as recorded in the above figure.

- (ii) Estimate average resultant force acting on the trolley during the impact.

- (iii) Comment on a student's statement: "Air bags can reduce the change of momentum of a driver and hence reduce the average force by increasing the impact time."

The student is . The air bags can reduce the average force by increasing the
, but the is the same.

- (iv) Explain why the slopes of the portions of the graph AB and BC in the above figure are different. The slope represents the .

When the trolley moves upwards in AB , both and the friction points ,
 giving a and , thus the slope is greater.

When the trolley moves downwards in BC , is downwards but the friction is ,
 giving a and , thus the slope is smaller.

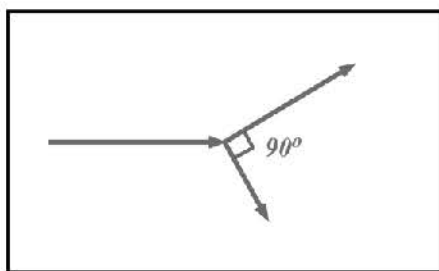
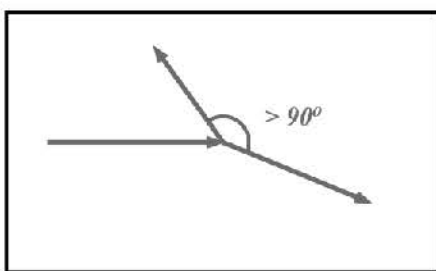
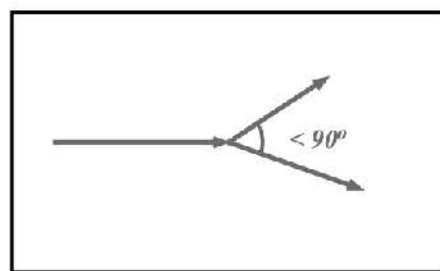


7. Collision of alpha-particles with helium atoms

- Consider a ball of mass m_1 moving with velocity u makes an oblique collision with another ball of mass m_2 which is initially at rest.



- Angle of separation for different masses:

Case 1: $m_1 = m_2$ Case 2: $m_1 < m_2$ Case 3: $m_1 > m_2$ 

- The tracks of alpha-particles can be observed in a diffusion cloud chamber.
- If a trace amount of helium gas is introduced into the cloud chamber, a right-angled fork track may sometimes be observed.
- The fork track is thought to be produced when an alpha-particle hits the helium nucleus.
- The fork track gives evidence that the mass of an alpha-particle is identical to a helium nucleus and thus confirms that alpha is a helium nucleus.

