2.4 MOMENTUM AND IMPULSE *HW/Study Packet*

SL/HL	
Required: READ Hamper pp 37-55 Tsokos, pp 87-98	Supplemental: Cutnell and Johnson, pp 195-208

REMEMBER TO….

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

UNIT OUTLINE

I. MOMENTUM AND IMPULSE

A. NEWTON'S 2nd LAW REVISITED
B. IMPULSE AND MOMENTUM
C. CONSERVATION OF MOMENTUM
D. FORCE-TIME GRAPHS

FROM THE IB DATA BOOKLET

$$p = mv$$

$$F = \frac{\Delta p}{\Delta t}$$

$$E_K = \frac{p^2}{2m}$$

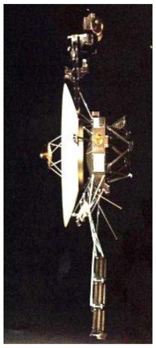
$$\text{Impulse} = F\Delta t = \Delta p$$

WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC

- □ Demonstrate the validity of Newton's 2nd Law in terms of momentum where mass is constant.
- □ Use Newton's 2nd Law quantitatively and in situations where mass is not constant.
- □ Define momentum and recognize that it is a vector quantity.
- □ Derive the Law of Conservation of Momentum using Newton's Laws and identify situations in which momentum is conserved.
- □ Understand how average net force is really the rate of change of momentum.
- □ State the definition of impulse and recognize it as the area under a force-time graph.
- □ Apply the conservation of momentum in simple isolated systems such as collisions and explosions.
- □ Qualitatively and quantitatively compare situations involving elastic collisions, inelastic collisions, and explosions.

HOMEWORK PROBLEMS:

1. A ball of mass *m*, travelling in a direction at right angles to a vertical wall, strikes the wall with a speed v_1. It rebounds at right angles to the wall with a speed v_2. The ball is in contact with the wall for a time Δt. Write an expression for the magnitude of the force that the ball exerts on the wall in terms of these given variables. **[** $\frac{m(v_1 + v_2)}{\Delta t}$ **]**



2. The Voyager 1 spacecraft was launched on September 5, 1977 from Cape Canaveral, Florida, USA. Its dry mass (with no fuel) was measured as 721.9 kg. During its journey through the solar system, it explored all of the outer giant planets, 48 of their moons, and various rings and magnetic fields. Voyager 1 crossed into the final frontier of the solar system, and into interstellar deep space, around August 1, 2002 at a speed of 21.725 km/s. Its fuel was exhausted decades ago but to this day it continues to fly through the vacuum of deep space. Scientists hope to maintain radio contact with the spacecraft until the year 2020.

a) Assuming that no external forces act upon this spaceship, predict how fast it will be going in 100 years. Explain your answer using Newton's Laws as appropriate. **[21.725 kms^{-1}]**

b) Speculate on at least 2 possible (and credible) sources of external forces that could act on the spaceship, causing it to change its motion according to Newton's First Law.

c) Determine the force necessary to bring Voyager 1 to a complete stop in exactly 1 hour. **[4357 N]**

3. A compact car, with a mass of 725 kg, is moving at +100.0 km hr^{-1}. At what velocity is the momentum of a larger car (mass 2175 kg) equal to that of the smaller car? **[33.3 km hr^{-1}]**

4. A snowmobile has a mass of 2.50 × 10^{2} kg. A constant force is exerted on it for 60.0 s. the snowmobile's initial velocity is 6.00 ms^{-1} and its final velocity is 28.0 ms^{-1}.

a) What is the snowmobile's change in momentum? **[5500 kgms^{-1}]**

b) What is the magnitude of the force exerted on it? **[91.7 N]**

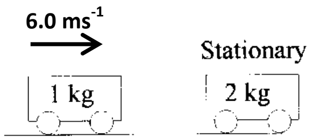
5. A 0.105 kg hockey puck moving at 48 ms^{-1} is caught by a 75 kg goalie at rest on a frictionless ice surface. After impact, with what speed does the goalie slide backwards on the ice? **[0.67 ms^{-1}]**

6. A 35.0 g bullet moving at 475 ms^{-1} strikes a 2.5 kg wooden block. The bullet passes through the block, leaving at 275 ms^{-1}. The block was at rest when the bullet hit. How fast is it moving when the bullet leaves? **[2.8 ms^{-1}]**

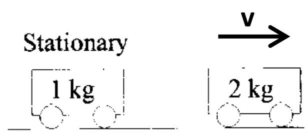
7. A 0.50 kg ball traveling at +6.0 ms^{-1}collides head-on with a 1.00 kg ball moving in the opposite direction at a velocity of -12.0 m s^{-1}. The 0.50 kg ball moves away at -14.0 m s^{-1}after the collision. Find the velocity of the second ball after the collision. **[-2.0 ms^{-1}]**

8. Two carts are rolling along a frictionless track. One cart has mass $m_1 = 1.0$ kg, the other $m_2 = 2.0$ kg $= 2m_1$. For each scenario, state the type of collision, and determine the unknown velocity **v**. For each collision, find out how much kinetic energy is lost. *Vectors drawn are not necessarily to scale.*

a)



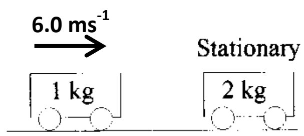
Before collision



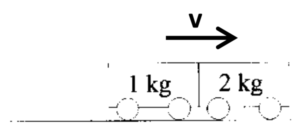
After collision

[v = +3.0 ms^{-1}, 9.0 J lost]

b)



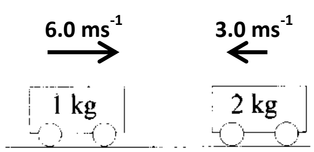
Before collision



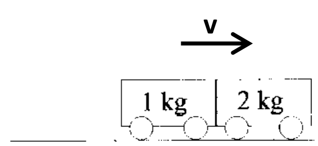
After collision

[v = +2.0 ms^{-1}, 12 J lost]

c)



Before collision

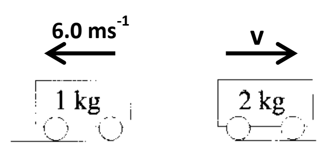


After collision

[v = 0 ms^{-1}, 27 J lost]

d)

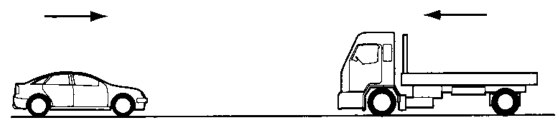
Before explosion



After explosion

[v = +3.0 ms^{-1}, 0 J lost]

9. A car and a truck are both travelling at the speed limit of 60.0 kmh^{-1} but in opposite directions as shown. The truck has twice the mass of the car. The vehicles collide head-on and become entangled together.



a) During the collision, how does the force exerted by the car on the truck compare with the force exerted by the truck on the car? Explain.

b) In what direction will the entangled vehicles move after the collision, or will they be stationary? Explain.

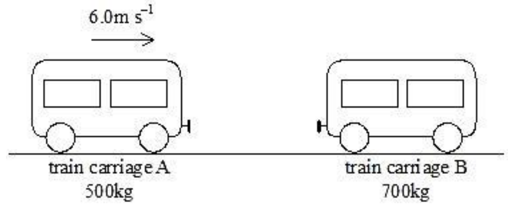
c) Determine the speed of the combined wreck immediately after the collision. **[-20.0 ms^{-1}]**

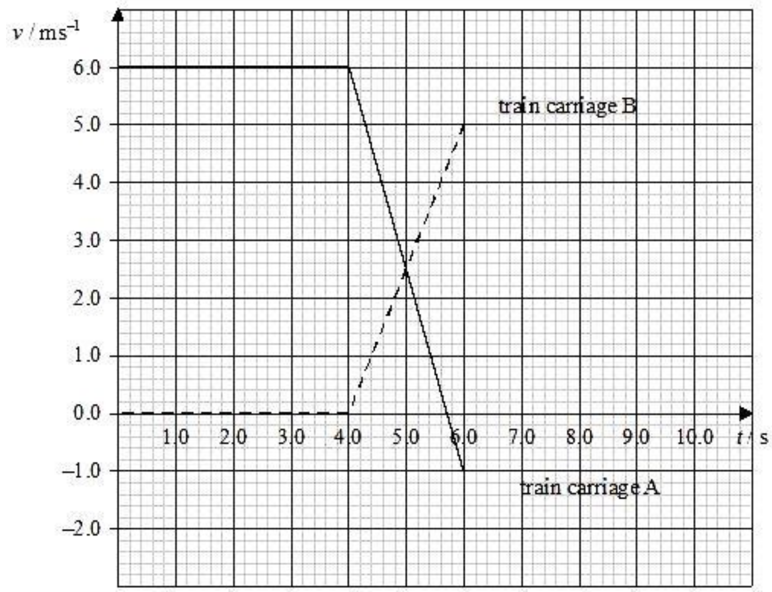
d) How does the acceleration of the car compare with the acceleration of the truck during the collision? Explain. **[car has twice the acceleration]**

e) Both the car and truck drivers are wearing seat belts. Which driver if more likely to be severely jolted in the collision? Explain.

f) The total kinetic energy of the system decreases as a result of the collision. Is the principle of conservation of energy violated? Explain.

10. A train carriage A of mass 500 kg is moving horizontally at 6.0 m s^{-1}. It collides with another train carriage B of mass 700 kg that is initially at rest, as shown in the diagram. The graph shows the variation with time t of the velocities of the two train carriages before, during and after the collision.





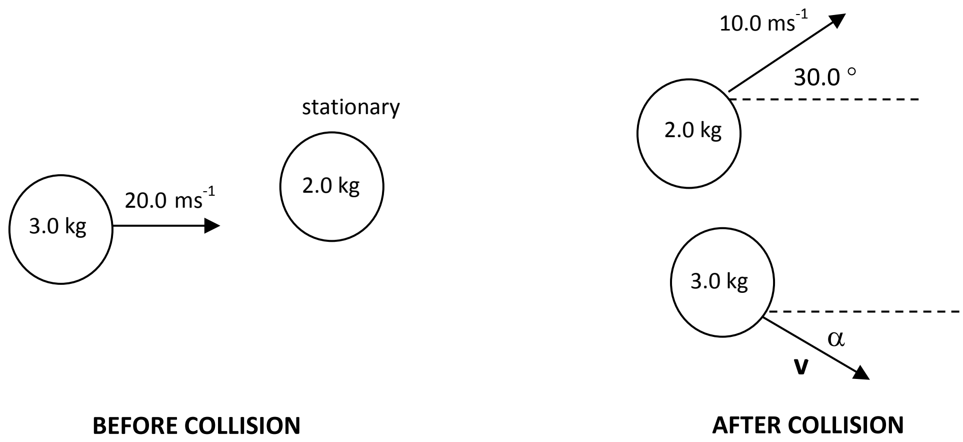
a) Use the graph to deduce that the total momentum of the system is conserved in the collision.

b) Use the graph to deduce that the collision is elastic.

c) Calculate the magnitude of the average force experienced by train carriage B. **[1800 N]**

11. Two balls collide as shown. Determine the angle α and the velocity **v** of the 3.0 kg ball.

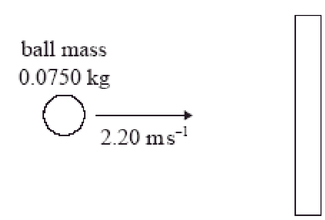
[v = 15 ms^{-1}, α = 13°]



12. Fill in the following table, given typical masses and speeds of the following objects:

OBJECT	MASS (kg)	SPEED (ms^{-1})	MOMENTUM ($kgms^{-1}$)	FORCE TO STOP IN 60s (N)	ACCELERATION (ms^{-2})
electron	9.1×10^{-31}	3.0×10^{8}			
oil tanker	5.5×10^{8}	1.5×10^{-2}			
rain drop	6.0×10^{-4}	1.0×10^{1}			
snail	4.7×10^{-2}	2.1×10^{-4}			
satellite	7.0×10^{0}	8.5×10^{4}			
human runner	7.3×10^{1}	3.9×10^{0}			

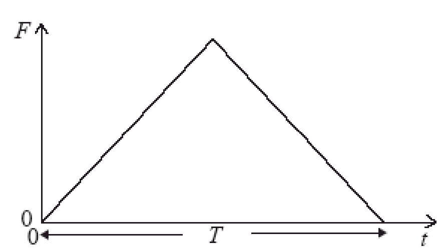
13. A ball of mass 0.0750 kg is travelling horizontally with a speed of 2.20 m s^{-1}. It strikes a vertical wall and rebounds horizontally. Due to the collision with the wall, 20 % of the ball's initial kinetic energy is dissipated.



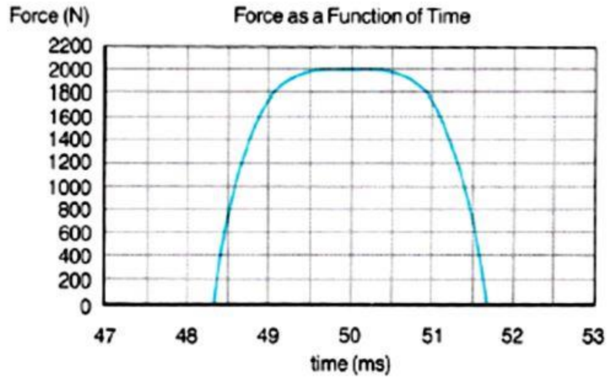
a) Determine the speed with which the ball rebounds from the wall. **[1.97 m s^{-1}]**

b) Determine the impulse given to the ball by the wall. **[0.313 N s]**

c) The sketch graph shows how the force *F* that the wall exerts on the ball is assumed to vary with time *t*. The time *T* is measured electronically to equal 0.0894 s. Determine the average value of *F*. **[3.50 N]**



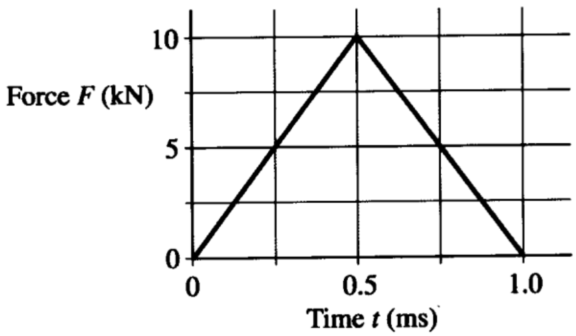
14. The graph shows the force applied against time during a collision. The collision involved one ball hitting another ball initially at rest.



a) Find the impulse given to the ball at rest by the moving ball. **[≈ 52 Ns]**

b) If the second ball had a mass of 2.4 kg, what was its speed after the collision? **[22 ms^{-1}]**

15. A 2.0 kg frictionless cart is moving at a constant speed of 3.0 ms^{-1} to the right on a horizontal surface, as shown, when it collides with a second cart of undetermined mass *m* that is initially at rest. The force *F* of the collision as a function of time t is shown in the graph below, where $t = 0$ is the instant of initial contact. As a result of the collision, the second cart acquires a speed of 1.6 ms^{-1} to the right. Assume that friction is negligible before, during, and after the collision.



a) Calculate the magnitude and direction of the velocity of the 2.0 cart after the collision. **[+0.52 ms^{-1}]**

b) Calculate the mass m of the second cart. **[3.1 kg]**