

SECONDARY SCHOOL IMPROVEMENT PROGRAMME (SSIP) 2019



GRADE 12

SUBJECT: TECHNICAL SCIENCE

LEARNER GUIDE

SESSION	TOPIC	PAGE
1	Newton's laws and Newton's laws application	4 – 13
2	Momentum and Impulses	14 – 23
3	Consolidation Newton's law & Momentum and Impulses	24 – 29
4	Work, Energy and Power	30 - 37
5	Elasticity and Viscosity	38 - 46
6	Hydraulics.	47 - 57

SESSION NO: 1

▪ **TOPIC: NEWTON'S LAWS AND APPLICATION OF NEWTON'S LAWS**

LEARNING OBJECTIVES

The following concepts are very important. You must be able to **define** each of the following:

- Weight
- Normal Force
- Frictional Force
- Static Frictional Force
- Kinetic Frictional Force
- Tension

It is also important to distinguish between mass and weight

NEWTON'S First Law

- Define inertia
- Define mass
- State Newton's first law
- Give examples to illustrate Newton's first law

NEWTON'S SECOND LAW

Definitions and law

- State Newton's second law

Diagrams

Force diagrams, free-body diagrams

- Define a force diagram.
- Define a free-body diagram.
- Draw force diagrams.
- Draw free-body diagrams.
- Draw force diagrams and free-body diagrams for objects that are in equilibrium or accelerating.
- Determine the resultant or net force of two or more forces.

Calculations of Newton 2

Use the equation, $F_{\text{net}} = ma$ to solve problems involving force, mass and acceleration in the content of technology. (Do not include pulley problems and lift problems).

- Apply Newton's laws to a variety of equilibrium and non-equilibrium problems including:
 - A single object:

- Moving on a horizontal plane with or without friction.
- Moving in the vertical plane.
- Two-body systems (joined by a light inextensible string):
 - Both on a flat horizontal plane with and without friction.

NEWTON'S THIRD LAW

- State Newton's third law
- Identify and give examples of action-reaction pairs.
- List the properties of action-reaction pairs.

Example 1

A and B are two crates, each with a mass of 3 000 kg, made of different materials. They are connected with a strong, but light steel cable – the mass is relative light and not of a significant amount. The crates are pulled over a rough surface by a tractor with a normal force of 15 000 N, that acts precisely horizontally on crate B, as indicated in the diagram. The tension in the cable is 8 000 N. The acceleration of both crates is 2 m.s^{-2} . What is friction force each crate experiences?



Possible solutions

For A:

The force with which it is being pulled to the right = the tension force, T in the cable. The crate experiences a friction force of f_A to the left.

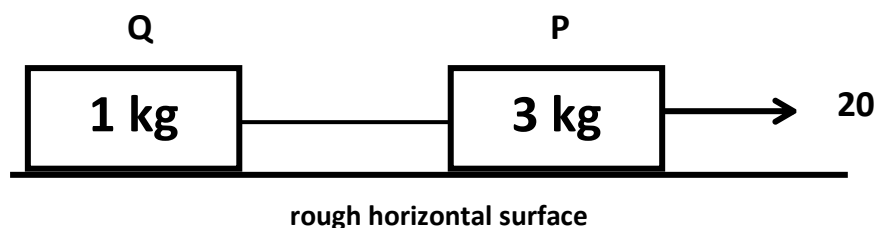
$$\begin{aligned}
 F_{\text{net}} &= ma \\
 T - f_A &= ma \\
 8\,000 - f_A &= (3\,000)(2) \\
 f_A &= 2\,000 \text{ N to the left}
 \end{aligned}$$

For B:

$$\begin{aligned}
 F_{\text{net}} &= ma \\
 F - (T + f_B) &= ma \\
 15\,000 - (8\,000 + f_B) &= (3\,000)(2) \\
 f_B &= 1\,000 \text{ N to the left}
 \end{aligned}$$

EXAMPLE 2

The diagram below shows a 3 kg block connected to a 1 kg block by a light inextensible string. A constant horizontal force of 20 N pulls the system along a rough horizontal surface.

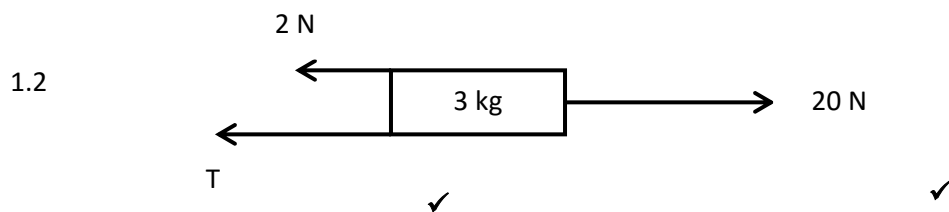


The frictional force between the blocks P and Q and the surface is 2 N and 1 N respectively.

- 1.1 State, in words, Newton's Second Law of Motion. (2)
- 1.2 Draw a labelled force diagram showing ALL the horizontal forces acting on the 3 kg block. (3)
- 1.3.1 Calculate the magnitude of the acceleration of the 3 kg block. (5)
- 1.3.2 Hence, determine the magnitude of the tension in the string. (2)

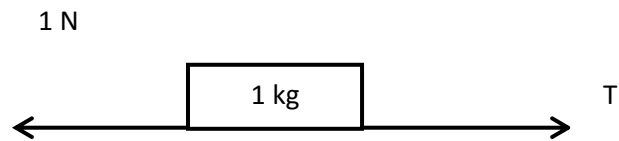
SOLUTION

- 1.1 When a net force is applied to an object, the object accelerates in the direction of the net force. The acceleration is directly proportional to the (net) force and inversely proportional to the mass of the object. ✓✓ //



(3)

1.3 1.3.1 Consider the 1 kg block:



$$F_{\text{net}} = ma = T + f$$

$$1a = T - 1$$

$$T = a + 1$$

..... equation 1

Consider the 3 kg block:

$$F_R = ma = F_{\text{applied}} + T + F_f$$

$$3a = 20 - T - 2$$

..... equation 2

Substituting for T:

$$3a = 20 - (a + 1) - 2$$

$$4a = 17$$

$$a = 4,25 \text{ m.s}^{-2}$$

(5)

OR/ OR

$$F_{\text{net}} = ma$$

$$(F - f) = (M + m) a$$

$$20 - (2 + 1) = 4a$$

$$a = 17/4 = 4,25 \text{ ms}^{-2}$$

(5)

$$1.3.2 \quad T = a + 1 = 4,25 + 1 = 5,25 \text{ N}$$

(2)

LEARNER ACTIVITY

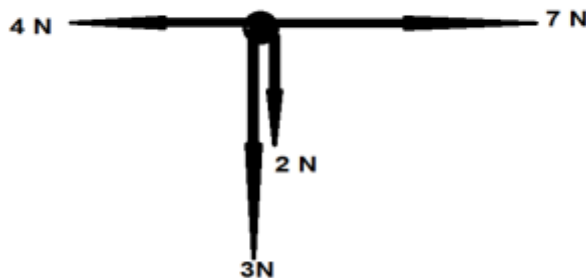
MULTIPLE CHOICE

Four options are provided as possible answers to the following questions. Each question has only **ONE** correct answer. Write only the letter (A-D) next to the question number (1.1-1.3) in the ANSWER BOOK, for example 1.6 D.

1.1. Net force is the measure of the

- A change in energy
- B rate of change in energy
- C change in momentum
- D rate of change in momentum (2)

1.2 Four forces act on a point, as indicated in the diagram.



The magnitudes of the resultant forces in the horizontal (F_x) and vertical (F_y) plane, are...

- A. $F_x = 3\text{ N}$ and $F_y = 5\text{ N}$
- B. $F_x = 8\text{ N}$ and $F_y = 1\text{ N}$
- C. $F_x = 3\text{ N}$ and $F_y = 1\text{ N}$
- D. $F_x = 8\text{ N}$ and $F_y = 5\text{ N}$ (2)

1.3 Which ONE of the following forces always acts perpendicular to the surface on which a body is placed?

- A Normal force

- B Frictional force
- C Gravitational force
- D Tension force

1.4 Thabiso lifts a mass of 200kg, with uniform velocity, through a certain height in 2s. What is the magnitude of the force that he exerts on the mass?

- A 4000N
- B 1960 N
- C 1000 N
- D 400 N

1.5 A learner is sitting on a chair. According to Newton's Third law, the reaction force to the learner's weight is:

- A the force of the learner on the chair
- B the force of the chair on the learner
- C the force of the earth on the learner
- C the force of the learner on the earth

QUESTION 2

A man, on frictionless roller-skates, is standing at rest on the back of a truck which is travelling at a constant velocity of $10 \text{ km} \cdot \text{h}^{-1}$, horizontally to the left.



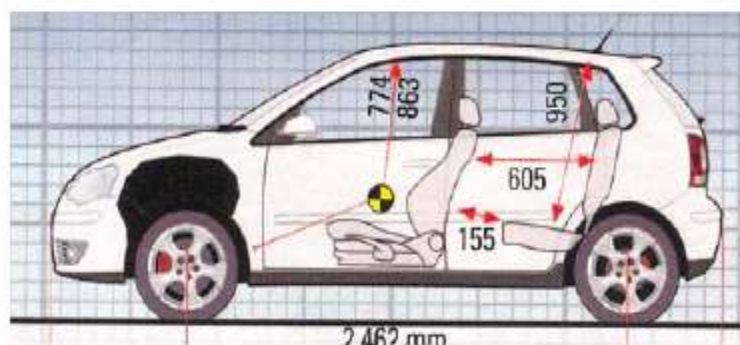
2.1 While the truck is moving, in which direction and with what speed must the man move, relative to the truck, in order to be stationary relative to the ground ? (2)

2.2 If the man is initially at rest on the truck, in which direction, relative to the truck, will the man be displaced (if at all) if the truck slows down? (1)

2.3 Name and describe, in words, the law used in Question 2.2 (2)

QUESTION 3

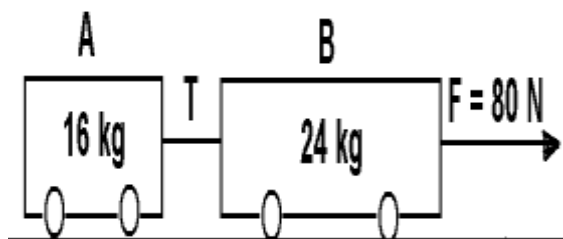
The diagram below shows the VW Polo that has a mass of 1 264 kg. The force of friction on each wheel is 700 N while the car is moving to the left (at constant velocity) and the normal reaction force on each wheel is 3 160 N.



- 3.1. Draw a force diagram (not to scale) of all the forces acting on the left front wheel. (3)
- 3.2. Calculate the co-efficient of kinetic friction. (3)
- 3.3. Describe the difference between the co-efficient of kinetic friction and the co-efficient of static friction. (2)
- 3.4. Modern motor cars are an example of the use of science to develop technology that has impacted on humans. Make separate lists of the positive impact and negative impact of cars on humans and the environment. (4)

QUESTION 4

A force of 80 N is exerted on two frictionless trolleys that are on a horizontal track, as indicated in the diagram. The trolleys are connected with a piece of rope (of negligible mass).

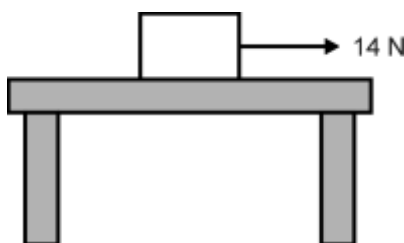


- 4.1 State Newton's Second Law of motion (2)
4.2 Draw two force diagrams, one for each trolley. Indicate and name all the forces exerted on both trolleys. (7)
4.3 Calculate the acceleration of the two trolleys. (4)

[13]

QUESTION 5

You pull a block along a rough horizontal table with a force of 14 N and a constant velocity. When you increase the pulling force to 31 N, the block accelerates at $8,5 \text{ m} \cdot \text{s}^{-2}$.



Calculate the following.

- 5.1 the frictional force between the block and the table (2)
5.2 the mass of the block (4)
5.3 the coefficient of kinetic friction, μ_k , between the block and the table (4)

[10]

QUESTION 6

In your workbook, redraw the following table and fill in the missing information.

	Net force (N)	Mass (kg)	Acceleration (m·s⁻²)
1.	100	50	
2.	50	50	
3.	50	25	
4.		100	2

(4)

6.1 Which law of motion did you use to complete the table? (2)

6.2 How does the acceleration change if the force is halved and the mass is kept constant? (2)

6.3 How does the acceleration change if the mass is doubled and the force is kept constant? (2)

6.4 What is the mathematical relationship between force and acceleration (constant mass)? (2)

6.5 What is the mathematical relationship between mass and acceleration (constant force)? (2)

[14]

QUESTION 7

A pencil lies on the dashboard of a car

7.1 What happens to the pencil when the car suddenly stops? (2)

7.2 What happens to the pencil when the car suddenly accelerates? (2)

7.3 Name the law that describes the behaviour of the pencil (2)

7.4 Name the property of the pencil that causes its behaviour (2)

QUESTION 8

A man pushes against a box of mass 2000 kg standing on the floor, with a force of 980N. If the frictional force with the floor remains at a constant 588N

8.1.1 State Newton 's second Law (2)

8.1.2 Define Acceleration (2)

8.1.3 Calculate the acceleration of the crate (4)

8.2 What happens to the acceleration of an object if:

8.2.1 the mass and net force both decreases by a factor of 4? (1)

8.2.2 the mass and net force both increases by a factor of 4? (1)

8.2.3 the mass increases by a factor of 4, but the net force decreases by the same factor? (2)

8.2.4 the mass decreases by a factor of 4, and the net force is zero (1)

[11]

QUESTION 9

A boy pulls an object, mass 5 kg, over a carpet. The light, inextensible rope is parallel to the floor.



The boy exerts a constant horizontal force of 3 N on the rope and the object moves with a constant acceleration of $0,5 \text{ m}\cdot\text{s}^{-2}$.

9.1 Draw a sketch and by means of labelled arrows, show all the forces acting on the object. (4)

9.2 Name each of the forces clearly and determine the magnitude of each. (4)

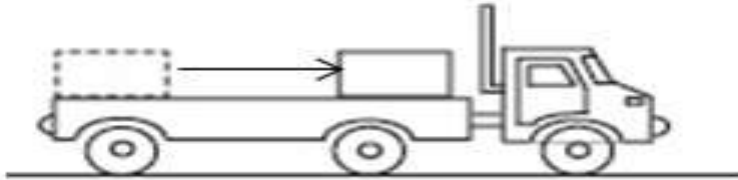
9.3 Keeping the force on the object a constant 3 N, the angle between the rope and the horizontal is increased from 0° to 20° . Without doing any calculation state HOW each of the forces indicated in your sketch is influenced by this. Use only the words LARGER, SMALLER or UNCHANGED to say what has happened to each of the forces.

(4)

[12]

QUESTION 10

During a journey, a truck is travelling at a speed of $6 \text{ m}\cdot\text{s}^{-1}$ when it collides with a concrete wall and decelerates at $11,25 \text{ m}\cdot\text{s}^{-2}$ as it comes to rest. The box on the back of the truck slides forward through a distance of $1,6 \text{ m}$ on the back of the truck before coming to rest.



10.1 Name, and explain in words, the property of the box that causes it to slide forward on the back of the truck. (3)

10.2 Calculate the magnitude and direction of the average frictional force which brings the box to rest. (4)
[7]

SESSION NO: 2

TOPIC: MOMENTUM AND IMPULSE

LEARNING OBJECTIVES

The following concepts are very important. You must be able to **define** each of the following:

Momentum

Change in momentum

Impulse

Net force

Isolated system

- **State** the following:

Principle of conservation of momentum.

Newton's second law in terms of Momentum

- Explain the relationship between the net force and the change in Momentum for a variety of motions.
- Express the principle of conservation of momentum as an equation in all situations, explosion or collision using $\sum p_i = \sum p_f$
- Draw vector diagrams to illustrate the relationship between the initial momentum, final momentum and the change in Momentum
- Do calculations on:
 - Momentum of a moving object using $p = mv$.
 - Change in momentum using $\Delta p = m\Delta v$.
 - All types of collisions (Elastic and inelastic collisions) using the following equations:
 - $m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$
 - $m_1v_{i1} + m_2v_{i2} = (m_1 + m_2)v_f$
 - $(m_1 + m_2)v_{fi} = m_1v_{f1} + m_2v_{f2}$
 - Impulse using $F_{net}\Delta t = \Delta p = m(v_f - v_i)$
 - Proving that collisions are elastic or inelastic by comparing the total kinetic energy of the system before and after collision by using:

$$\frac{1}{2}mv_i^2 + \frac{1}{2}mv_i^2 \text{ for the two objects}$$

$$\frac{1}{2}mv_i^2 + \frac{1}{2}mv_f^2 \text{ for the two objects}$$

If the energies are the same then the collision is elastic BUT if not then the collision is inelastic

- Solve impulse problems based on a graph.

MOMENTUM AND IMPULSE PROBLEM SOLVING STRATEGY

- 1 Read the problem as many time as you need, draw a sketch or diagram of the situation described if not provided.
 - 2 From the reading collect the data and write it in symbolic form (not only numbers are part of the data)
 - 3 Draw a free body diagram for each object and clearly define the system you are going to work with.
 - If possible choose a system which is isolated ($\vec{F}_{net} = \vec{0}$) and closed ($m=\text{constant}$). If the interactions are sufficiently short and intense you can ignore external forces.
 - If it is not possible to choose an isolated system, try to divide the problem into parts (SCENARIOS).
 - 4 Select the law (principle), theorem, equation or formula that will answer your question.
 - If the mathematical representation is based in the law of conservation of momentum ($\sum \vec{p}_{initial} = \sum \vec{p}_{final}$). Write it in component form.
 - 5 Substitute the values into the equation or formula (the system of units must be homogeneous)
 - 6 Check your answer
 - Is the unit correct?
 - Is the value of the answer reasonable?
- : Check that your result has the correct units, is reasonable and answers the question.

WORKED EXAMPLES

Example 1

To improve the safety of motorists, modern cars are built so the front end crumples upon impact. A 1200 kg car is travelling at a constant velocity of $8.0 \text{ m}\cdot\text{s}^{-1}$. It hits an immovable wall and comes to a complete stop in 0.25 s.

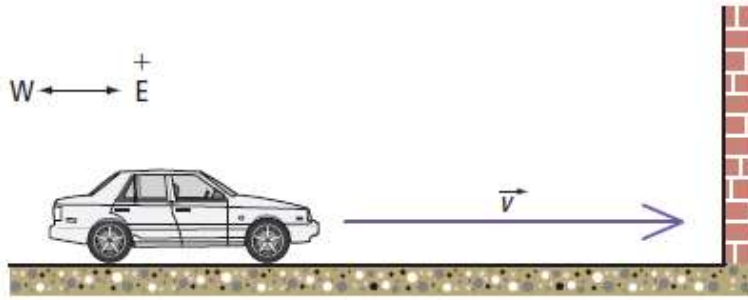


Figure 1

- 1.1 Calculate the impulse provided to the car.
- 1.2 What is the average net force exerted on the car?
- 1.3 For the same impulse, what would be the average net force exerted on the car if it had a rigid bumper and frame that stopped the car in 0.040 s?

Analysis and Solution

When the car hits the wall, the final velocity of the car is zero.

$$v_f = 0 \text{ m}\cdot\text{s}^{-1}$$

During each collision with the wall, the net force on the car is not constant, but the mass of the car remains constant.

Use the equation of impulse to calculate the impulse provided to the car.

$$\begin{aligned}
 1.1 \quad F_{\text{netave}} \Delta t &= m \Delta v \\
 &= m(v_f - v_i) \\
 &= (1200 \text{ kg})[0 - (8.0)] \\
 &= (1200)(-8.0) \\
 &= -9.6 \times 10^3 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1} \\
 \text{impulse} &= 9.6 \times 10^3 \text{ N}\cdot\text{s} \text{ [W]}
 \end{aligned}$$

$$F_{\text{netave}} \Delta t = 9.6 \times 10^3 \text{ N}\cdot\text{s}$$

$$F_{\text{netave}} = \frac{9.6 \times 10^3}{\Delta t}$$

$$F_{\text{netave}} = \frac{9.6 \times 10^3}{0.25}$$

$$= -3.8 \times 10^4 \text{ N}$$

$$= 3.8 \times 10^4 \text{ N [W]}$$

$$1.3 \quad F_{\text{netave}} = \frac{9.6 \times 10^3}{\Delta t}$$

$$F_{\text{netave}} = \frac{9,6 \times 10^3}{0,040}$$

$$= -2,4 \times 10^5 \text{ N}$$

$$= 2,4 \times 10^5 \text{ N [W]}$$

Example 2

Two billiard balls each with a mass of 150 g collide head-on in an elastic collision. Ball 1 was travelling at a speed of $2 \text{ m} \cdot \text{s}^{-1}$ and ball 2 at a speed of $1,5 \text{ m} \cdot \text{s}^{-1}$. After the collision, ball 1 travels away from ball 2 at a velocity of $1,5 \text{ m} \cdot \text{s}^{-1}$.

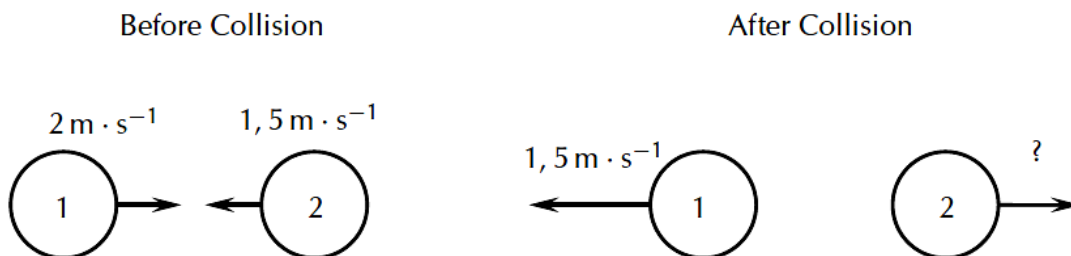
- 1.1 Calculate the velocity of ball 2 after the collision.
- 1.2 Prove that the collision was elastic. Show by calculations.

Solution

Step 1: Choose a frame of reference

Choose to the right as positive.

Step 2: Draw a rough sketch of the situation



Step 3: Decide how to approach the problem.

Since momentum is conserved in all kinds of collisions, we can use conservation of momentum to solve for the velocity of ball 2 after the collision.

Step 4: Solve problem

$$\begin{aligned}\Sigma \vec{F}_{\text{ext}} &= \vec{0} \\ \Delta \vec{p}_{\text{net}} &= \vec{0} \\ \vec{p}_{Tf} - \vec{p}_{Ti} &= \vec{0} \\ \vec{p}_{Ti} &= \vec{p}_{Tf} \\ \vec{p}_{i1} + \vec{p}_{i2} &= \vec{p}_{f1} + \vec{p}_{f2} \\ m_1 \vec{v}_{i1} + m_2 \vec{v}_{i2} &= m_1 \vec{v}_{f1} + m_2 \vec{v}_{f2} \\ (0,15)(2) + (0,15)(-1,5) &= (0,15)(-1,5) + 0,15 \vec{v}_{f2} \\ 0,3 - 0,225 &= -0,225 + 0,15 \vec{v}_{f2}\end{aligned}$$

$$\vec{v}_{f2} = 3 \text{ m} \cdot \text{s}^{-1} \text{ to the right.}$$

Step 5: Elastic collisions

The fact that characterises an elastic collision is that the total kinetic energy of the particles before the collision is the same as the total kinetic energy of the particles after the collision. This means that if we can show that the initial kinetic energy is equal to the final kinetic energy, we have shown that the collision is elastic.

Step 6: Calculating the initial total kinetic energy.

$$E_{KTi} = \frac{m_1 v_{i1}^2}{2} + \frac{m_2 v_{i2}^2}{2} = \frac{(0,15)(2)^2}{2} + \frac{(0,15)(-1,5)^2}{2} = 0,469 \text{ J}$$

Step 7: Calculating the final total kinetic energy

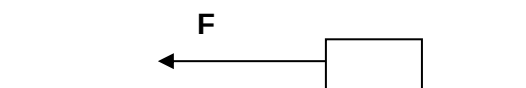
$$E_{KTf} = \frac{m_1 v_{f1}^2}{2} + \frac{m_2 v_{f2}^2}{2} = \frac{(0,15)(-1,5)^2}{2} + \frac{(0,15)(2)^2}{2} = 0,469 \text{ J}$$

So $E_{KTi} = E_{KTf}$ and hence the collision is elastic.

LEARNER ACTIVITY

QUESTION 1 : MULTIPLE CHOICE

- 1.1 When an airbag inflates in a car during a collision, the chances of serious injury to a passenger is reduced because the
- A passenger is brought to rest in a shorter distance
 - B net force acting on the passenger is reduced
 - C passenger's change in momentum is reduced
 - D passenger's change in momentum is increased
- 1.2 A truck of mass $2m$ collides with a car of mass m . If the truck exerts a force of magnitude F on the car during the collision, then the magnitude of the force that the car exerts on the truck is...
- A 0
 - B $\frac{1}{2} F$
 - C F
 - D $2F$
- 1.3 A block, being pulled by a force F , and moving to the left on a rough horizontal surface, is slowing down.



The directions of the resultant force and the acceleration are ...

	DIRECTION OF RESULTANT FORCE	DIRECTION OF ACCELERATION
A	to the right	to the left
B	to the right	to the right
C	to the left	to the left
D	to the left	to the right

1.4

The magnitude of the impulse on a ball bouncing off a wall is equal to the ...

- A net force of the ball on the wall.
- B product of the net force on the ball and the time it acts.
- C change in velocity of the ball.
- D product of the mass and the acceleration of the ball.

1.5

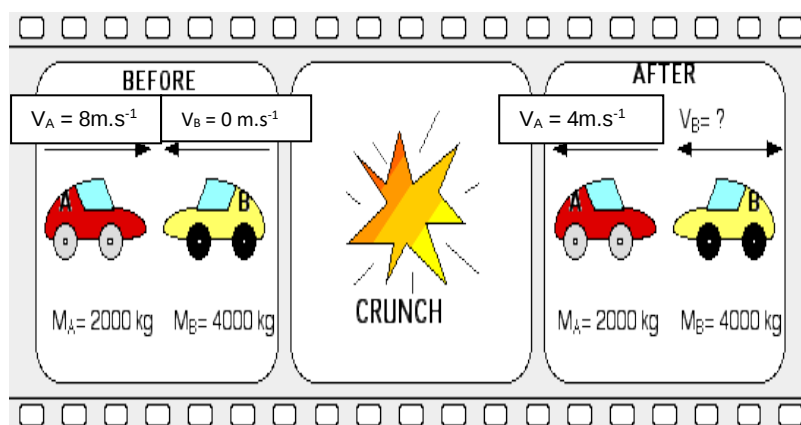
The front of a modern car is designed to crumble in case of a head-on collision. The chance of serious injuries to the passenger is reduced because the ...

- A net force acting on the passenger is reduced, since the contact time for the car to stop decreases.
- B net force acting on the passenger is reduced, since the rate of change in momentum decreases.
- C net force acting on the passenger is reduced, since the change in momentum is reduced.
- D net force acting on the passenger is reduced, since the change in momentum is increased.

STRUCTURED QUESTIONS

QUESTION 2

Car A of 2000 kg moving at 8 m.s^{-1} to the east collide with Car B of mass 4000 kg moving at 1 m.s^{-1} to the west.



2.1 State the principle of conservation of linear momentum

(2)

2.2 Calculate the change in momentum of the 2000 kg car.

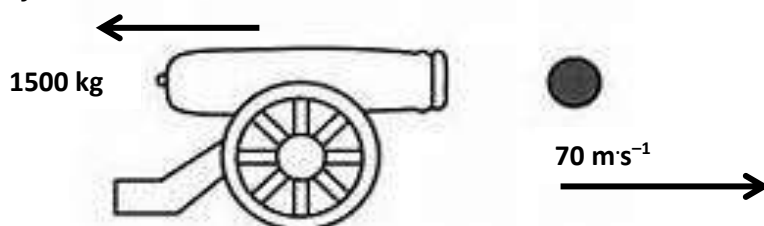
(3)

2.3 What will be the velocity of car B if car A moves with velocity of $4 \text{ m}\cdot\text{s}^{-1}$ after collision? (5)

QUESTION 3

A cannon has a mass of $1\,500 \text{ kg}$ and is $1\,000$ times heavier than the cannon ball that

it fires during a routine training exercise. The cannon ball leaves the barrel at a horizontal velocity of $70 \text{ m}\cdot\text{s}^{-1}$.



The cannon comes to **rest** 1 second after being fired.

3.1 Define, in words, the term *impulse*. (2)

3.2 Calculate the:

3.2.1 Maximum velocity with which the cannon moves backwards (5)

3.2.2 Magnitude of the average net force that causes the cannon to come to rest (4)

QUESTION 4

4.1 A rubber ball with a mass of 800 g is dropped and hits the floor with an initial downward velocity of $6 \text{ m}\cdot\text{s}^{-1}$. The ball bounces back with a final velocity of $4 \text{ m}\cdot\text{s}^{-1}$. Calculate the change in momentum of the ball. (4)

4.2 Serena Williams hits a tennis ball of mass 400 g approaching her at a velocity of $10 \text{ m}\cdot\text{s}^{-1}$ east. The ball leaves his racket at a velocity of $15 \text{ m}\cdot\text{s}^{-1}$ west. Calculate

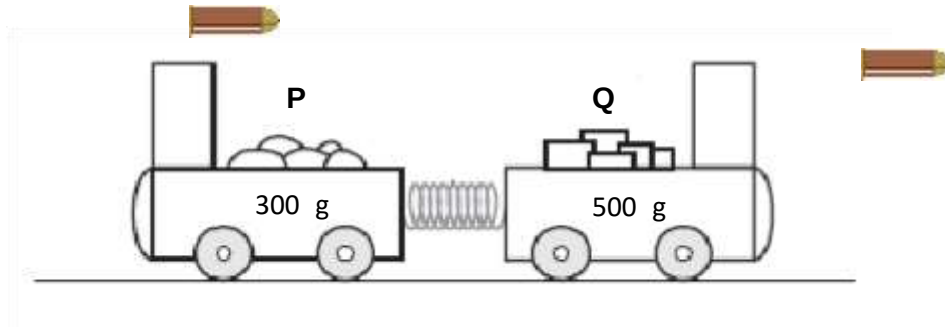
4.2.1 the impulse of the ball (3)

4.2.2 The force that the racket applies on the ball if the time of contact is 0.01 seconds. (3)

4.3 Explain the importance of the crumple zone (3)

QUESTION 5

The diagram below shows two trolleys, **P** and **Q**, held together by means of a compressed spring on a flat, frictionless horizontal track. The masses of **P** and **Q** are 300 g and 500 g respectively.



When the trolleys are released, it takes 0,5 s for the spring to unwind to its natural length. Trolley **Q** then moves to the right at $2 \text{ m}\cdot\text{s}^{-1}$.

5.1 State the *principle of conservation of linear momentum* in words. (2)

5.2 Calculate the:

5.2.1 Velocity of trolley **P** after the trolleys are released (4)

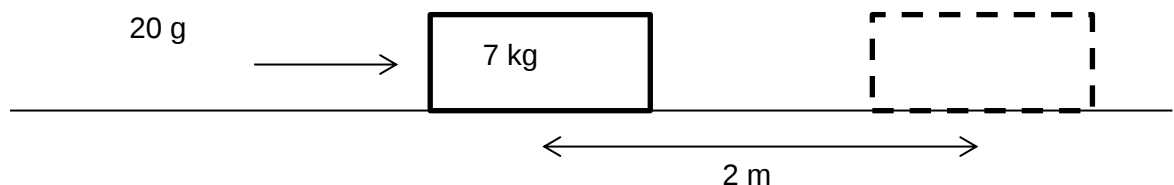
5.2.2 Magnitude of the average force exerted by the spring on trolley **Q** (4)

5.3 Is this an elastic or Inelastic collision? (1)

[11]

QUESTION 6

The diagram below shows a bullet of mass 20g that is travelling horizontally. The bullet strikes a stationary 7kg block and becomes embedded in it. The bullet and block together travel on a rough horizontal surface a distance of 2m before coming to a stop



At the moment of impact the bullet and the block begin to move with a velocity of $2,39 \text{ m}\cdot\text{s}^{-1}$.

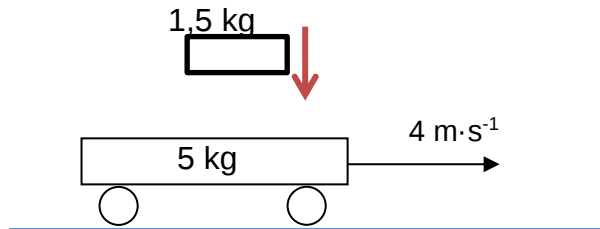
6.1 State the *principle of conservation of linear momentum* in words. (2)

6.2 Calculate the magnitude of the velocity with which the bullet hits the block. (4)

QUESTION 7

A trolley, mass 5 kg, moves at $4 \text{ m}\cdot\text{s}^{-1}$ east across a frictionless horizontal surface.

A brick of mass 1,5 kg is dropped onto the trolley.



7.1 Define in words the *Law of Conservation of Momentum*. (2)

7.2 State the condition for an elastic collision. (1)

7.3 Calculate the change in momentum of the 5 kg trolley. (5)

[8]

QUESTION 8

8.1 A 65-kg girl is driving a 535 kg snowmobile at a constant velocity of $11.5 \text{ m}\cdot\text{s}^{-1}$ [60N of E]. Calculate the momentum of the girl-snowmobile system. (3)

8.2 The combined mass of a bobsled and two riders is 390 kg. The sled-rider system has a constant momentum of $4.68 \times 10^3 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}$ [W]. Calculate the velocity of the sled. (4)

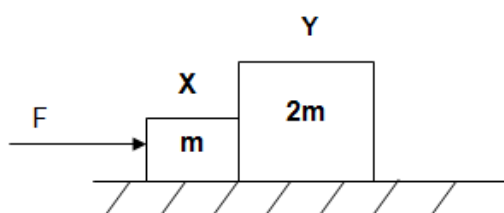
[7]

SESSION 3

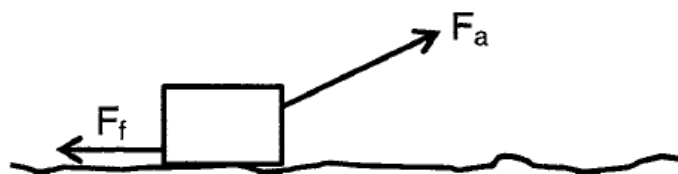
CONSOLIDATION NEWTON'S LAW, MOMENTUM & IMPULSE

QUESTION 1 : MULTIPLE CHOICE

- 1.1 Two blocks, X and Y, masses m and $2m$ respectively, are in contact with each other. The blocks are accelerated by a horizontal force F along a frictionless, horizontal surface. What is the magnitude of the force that Y exerts on X?

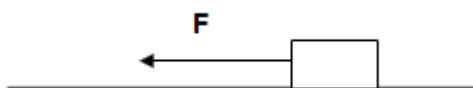


- A $2F$
B F
C $\frac{2}{3}F$
D $\frac{1}{3}F$
- 1.2 A constant force F_a acts on an object, causing it to move at a **constant speed** over a rough horizontally surface as shown in the diagram below.



How does the force of friction F_f compare to F_a ?

- A $F_f = F_a$
B $F_f > F_a$
C $F_f < F_a$
D $F_f = 0$
- 1.3 A block, being pulled by a force F , and moving to the left on a rough horizontal surface, is slowing down.

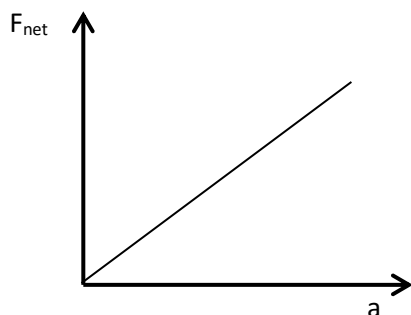


The directions of the resultant force and the acceleration are ...

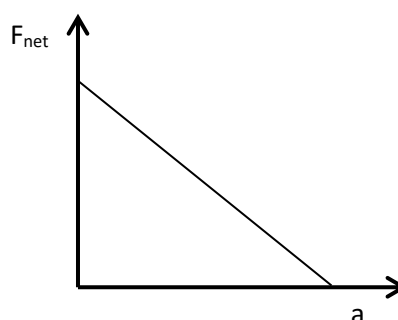
	DIRECTION OF RESULTANT FORCE	DIRECTION OF ACCELERATION
A	to the right	to the left
B	to the right	to the right
C	to the left	to the left
D	to the left	to the right

- 1.4 A 1 kg mass has a constant acceleration. Which ONE of the following sketch graphs correctly shows the relationship between the net force, F_{net} and acceleration, a ?

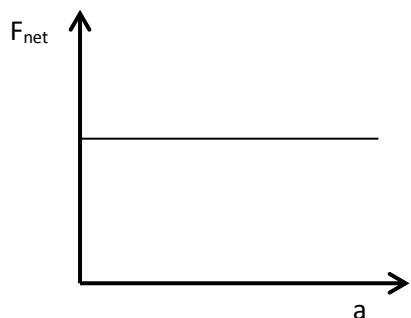
A



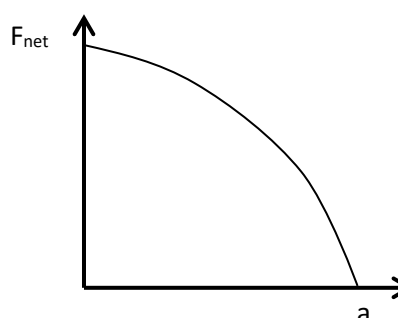
B



C



D



- 1.5 When a spaceship moves at constant velocity, it means that the resultant force acting on the body is zero. This phenomenon is best explained by

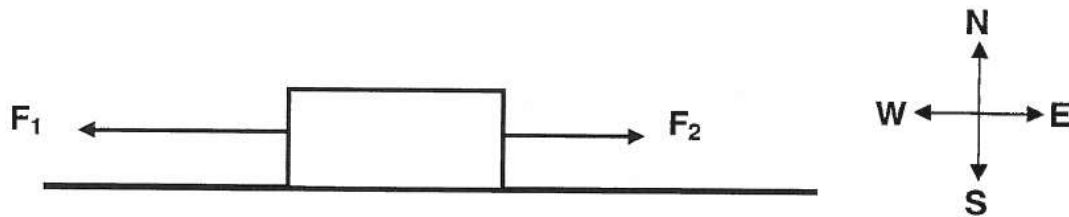
- A Newton's First Law
- B Newton's Second Law
- C Newton's Third Law
- D Newton's Universal Gravitational Law

- 1.6 Which ONE of the following forces always acts perpendicular to the surface on which a body is placed?

- A Normal force
- B Frictional force
- C Gravitational force

D Tension force

- 1.7 Two forces, F_1 and F_2 , are applied on a crate lying on a frictionless, horizontal surface, as shown in the diagram below.



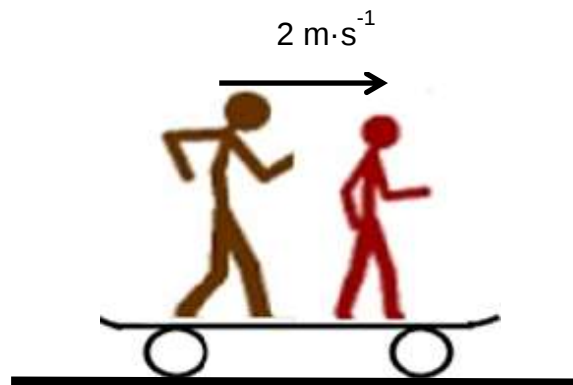
The magnitude of force F_1 is greater than that of force F_2 .

The crate will...

- A accelerate towards the east.
- B accelerate towards the west.
- C move at a constant speed towards the east.
- D move at a constant speed towards the west.

QUESTION 2

Peter and John are standing on a trolley, which is moving to the right at $2 \text{ m} \cdot \text{s}^{-1}$ as shown below. Peter has a mass of 70 kg and John a mass of 60 kg. The total mass of the trolley and both boys is 160 kg.

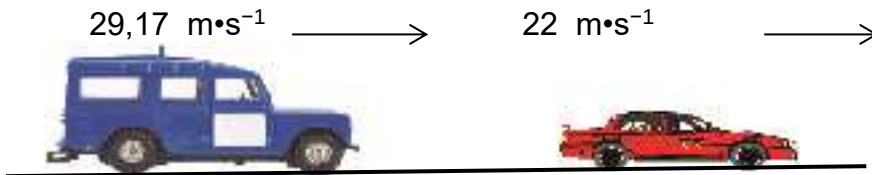


John jumps off the trolley at $2,5 \text{ m} \cdot \text{s}^{-1}$ in the direction of the motion of the trolley. When he lands on the ground he falls forward.

- 2.1 Name the principle (law) of Physics which explains why he falls forward after landing on the ground. (1)
 - 2.2 State the principle of conservation of linear momentum in words. (2)
 - 2.3 Calculate the magnitude and the direction of the velocity of the combination of Peter and the trolley immediately after John has jumped off. (5)
- [8]

QUESTION 3

A truck of mass 3 000 kg is travelling at $29,17 \text{ m}\cdot\text{s}^{-1}$ to the right. At the same time a car of mass 1 000 kg is travelling at $22 \text{ m}\cdot\text{s}^{-1}$ in the same direction ahead of the truck



Ignore the effects of friction.

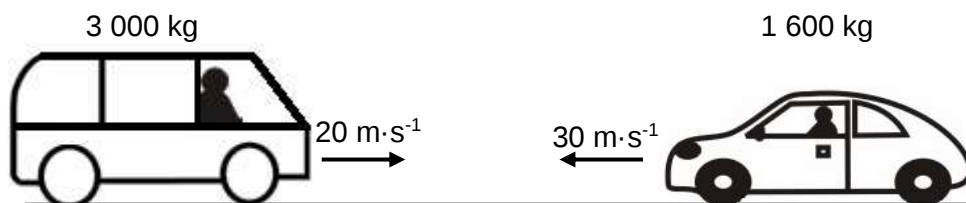
The truck collides with the car and they stick together after the collision.

- 3.1 State the *principle of conservation of linear momentum* in words. (2)
- 3.2 Calculate the velocity of the truck-car system immediately after the collision. (5)
- 3.3 Is the collision between the truck and the car elastic or inelastic? (1)
- 3.4 On impact the truck exerts a force of magnitude F on the car and the car experiences an acceleration of magnitude a .
 - 3.4.1 Will the magnitude of the force that the car exerts on the truck, on impact, be GREATER THAN, LESS THAN or EQUAL TO, F . (1)
 - 3.4.2 Name and state the Law of motion that explains the answer to question 3.4.1 (3)

[8]

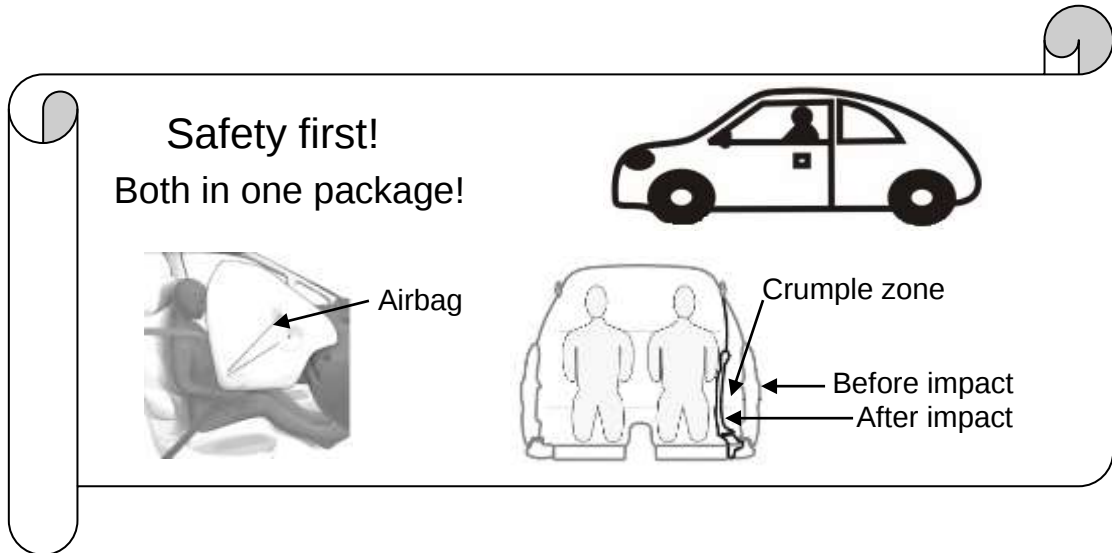
QUESTION 4

Collisions happen on the roads in our country daily. In one of these collisions, a car of mass 1 600 kg, travelling at a speed of $30 \text{ m}\cdot\text{s}^{-1}$ to the left, collides head-on with a minibus of mass 3 000 kg, travelling at $20 \text{ m}\cdot\text{s}^{-1}$ to the right. The two vehicles move together as a unit in a straight line after the collision.



- 4.1 Calculate the velocity of the two vehicles after the collision. (6)

- 4.2 Do the necessary calculations to show that the collision was inelastic. (6)
- 4.3 The billboard below advertises a car from a certain manufacturer.

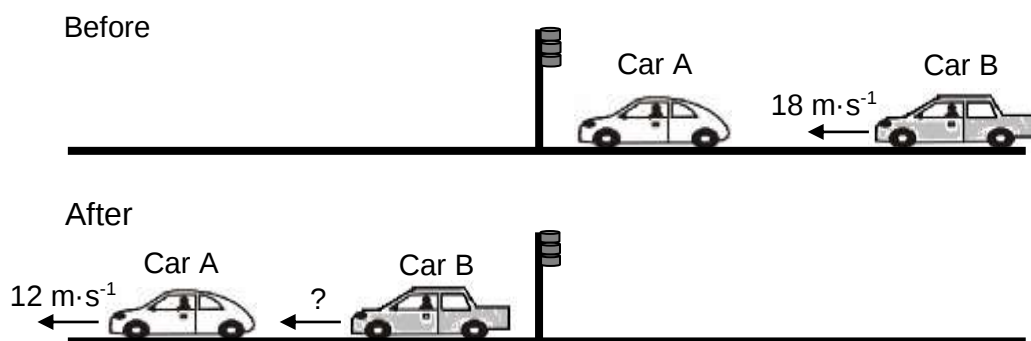


Use your knowledge of momentum and impulse to justify how the safety features mentioned in the advertisement contribute to the safety of passengers.

(3)
[15]

QUESTION 5

The most common reasons for rear-end collisions are too short a following distance, speeding and failing brakes. The sketch below represents one such collision. Car A of mass $1\,000\text{ kg}$, stationary at a traffic light, is hit from behind by Car B of mass $1\,200\text{ kg}$, travelling at $18\text{ m}\cdot\text{s}^{-1}$. Immediately after the collision Car A moves forward at $12\text{ m}\cdot\text{s}^{-1}$.



- 5.1 Assume that linear momentum is conserved during this collision. Calculate the speed of Car B immediately after the collision. (4)
- 5.2 Modern cars are designed to crumple partially on impact. Explain why the assumption made in QUESTION 4.1 may NOT be valid in this case. (2)
- 5.3 A traffic officer appears at the scene of the accident and mentions the dangers of a head-on collision. He mentions that for cars involved in a head-on collision, the risk of injury for passengers in a heavier car would be less than for passengers in a lighter car. Use principles of Physics to explain why the statement made by the traffic officer is correct. (3)
- [9]**

QUESTION 6

6.1 A ball of mass 450 g collides with a wall at a horizontal velocity of $12\text{m}\cdot\text{s}^{-1}$. The ball bounces back at a horizontal speed of $8\text{m}\cdot\text{s}^{-1}$.

6.1.1 Calculate the change in momentum of the ball (4)

6.1.2 Calculate the impulse of the ball (1)

6.1.3 Calculate the force that the wall applies on the ball if the time of contact between the wall and the ball is 0.02 s. (3)

6.2 Why do you bend your knees as you land when you jump off a low wall? (3)

6.3 Why do golf players follow through on their swing with a golf club? (3)

6.4 Why are airbags built into cars as a safety device? (3)

6.5 Are there any similarities between crumple zone of cars and the foam rubber mattresses used by high jumpers? If you think there are, explain similarities. (3)

[20]

SESSION 4

TOPIC: WORK, ENERGY AND POWER

WORK

Definition

Work is the product of the product of the force applied on the object and the displacement in the direction of the force.

Work is measured in **Joules**.

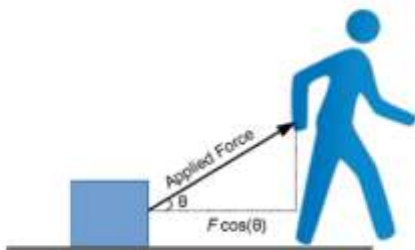
Work is a scalar quantity.

1J = 1N.m

For work to be done: $W = F \cdot \Delta x \cdot \cos \theta$

When is work done on an object?

- The force doing work on the object and the displacement are in the same direction. $\theta = 0^\circ$
- If the force is perpendicular to direction of the displacement, no work is done on the object.
 $\theta = 90^\circ$



The main steps involved in problem-solving :

- identify the force(s) acting on the object,
- draw the free-body diagram,
- and then use the equation ($W = F \cdot \Delta x \cdot \cos \vartheta$).

EXAMPLES

- 1 In which one of the following case(s) is/are work done?
 - 1.1 A man is pushing a ridge on a flat surface in the kitchen.
 - 1.2 A teacher is walking across the class holding a briefcase.
 - 1.3 Thabo is supporting a huge box preventing it from falling.
 - 1.4 Paramedics are lifting an injured player on a stretcher.
- 2 Themba pushes a crate by applying a constant a force of 400N towards a wall 1,8m away.

Calculate the work done on the box.

Solutions

- 1.1 Work is done on the fridge.
 - 1.2 Work is not done on the briefcase. The force exerted on the briefcase is perpendicular to the displacement.
 - 1.3 Work is not done on the box. There is zero displacement.
 - 1.4 Work is done.
- 2 $W = F\Delta x \cos \Theta$
- $$W = 400(1,8)\cos 0^\circ$$
- $$W = 720\text{J}$$

ENERGY

Definition:

Energy is the ability to do work.

The two main forms of energy are kinetic and gravitational potential energy.

$$E_p = mgh \quad KE = \frac{1}{2}mv^2$$

An object in a state of motion **possesses kinetic energy** whereas an object at some height above the ground possesses **gravitational potential energy**.

Energy is a scalar quantity.

SI unit is the Joule (J)

When doing calculations, necessary conversion of units needs to be done.

EXAMPLES

A worker at a construction site accidentally drops concrete block of mass 8kg from a scaffold which is 10m above the ground. Ignore the effects of air resistance.

1. Calculate the mechanical energy of the block.
2. Calculate much gravitational potential energy does the block possess when it is has fallen half the distance.
3. Calculate the speed of the block when it reaches the ground.

Solutions

When the block drops, it starts from rest, that is, its speed is 0m/s, therefore its kinetic energy just before it falls, is zero:

1. $ME = mgh + \frac{1}{2}mv^2$
 $ME = 8(9,8)10 + 0$
 $ME = 784\text{J}$

$$2. \quad E_p = mgh$$

$$E_p = 8(9,8)5$$

$$E_p = 392 \text{ J}$$

$$3. \quad ME = mgh + \frac{1}{2}mv^2$$

$$784 = 0 + \frac{1}{2}(8)v^2$$

$$V = 14\text{m.s}^{-1}$$

CONSERVATION OF MECHANICAL ENERGY

Definition

Mechanical energy of an object is the sum or total of its gravitational potential and kinetic energy.

Principle of conservation of mechanical energy:

The total mechanical energy of an object in an isolated system remains constant.

Mechanical energy of an object

Mechanical energy : $M_E = E_k + E_p$

An object is said to have potential energy if it has the ability to do work by way of its position or state and the same object will possess kinetic energy due to its state of motion.

Kinetic energy is a form of energy associated with the motion of a particle, single body, or system of objects moving together.

$$E_p = mgh \quad \text{and} \quad KE = \frac{1}{2}mv^2$$

$$\text{Thus, } M_E = mgh + \frac{1}{2}mv^2$$

Relationship between object's mass, potential energy and height.

- $E_p \propto h$ (For a constant mass)
- $E_p \propto m$ (From the same height above the ground)

Relationship between object's mass, kinetic energy and velocity :

- $E_k \propto v^2$
- $E_k \propto m$

Between any two points, mechanical energy of an object **remains constant**

$$E_{mi} = E_{mf}$$

POWER

Definition

Power is the rate at which work is done.

Power can be also thought of as the rate at which energy is transferred or amount of work done per unit time.

$$P = \frac{W}{\Delta t} \quad \text{or} \quad P = \frac{\Delta E}{\Delta t}$$

SI unit of power is the Watt (**W**)

$$1 \text{ Watt} = 1 \text{ J.s}^{-1}$$

When an object travels at a constant velocity,

$$P = F.v$$

Practical units of power in Technology are:

$$1 \text{ kW} = 1000 \text{ W}$$

$$1 \text{ Horse power (hp)} = 726 \text{ W}$$

Because work is energy transfer, power is also the **rate at which energy is expended**.

A 100-W light bulb, for example, expends 60 J of energy per second.

Great power means a large amount of work or energy developed in a short time. For example, when a powerful car accelerates rapidly, it does a large amount of work and consumes a large amount of fuel in a short time.

EXAMPLES

1. If a motor is rated at 5.60 kW, how much work can it do in 20 min?
2. A tow-truck is pulling a trailer up a steep-hill. If it has a 5hp engine, how much work does the truck do in 1 minute?

SOLUTIONS

$$1. \quad P = \frac{W}{\Delta t}$$

$$5,6 \times 1000 = \frac{W}{20 \times 60}$$

$$W = 6720000$$

$$W = 6720 \text{ kJ}$$

$$2. \quad P = \frac{W}{\Delta t}$$

$$5 \times 746 = \frac{W}{60}$$

$$W = 223,8 \text{ kJ}$$

LEARNER ACTIVITY

Question 1: MULTIPLE CHOICE

1.1 In which one of the following cases is work NOT done on the object?

- A. A crane lifts a pile of tiles from the floor to the roof
- B. A boy drags a loaded suitcase along the floor
- C. An fruit falls from a tree
- D. A man applies a force on a fridge, preventing it from falling.

(2)

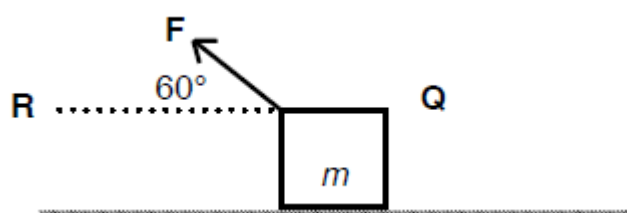
1.2 Which one of the following is equivalent to the SI unit of energy?

- A. A mass of 1 kg falls down for 1 m.
- B. A force of 1 N moves an object for 1 m in its direction.
- C. A Joule of work is done per second.
- D. An applied force of 1 N acts on a stationary object

(2)

The figure below shows an applied force F that acts on an object of mass m , at an angle of 60° . The object moves horizontally to the left on a rough surface.

Refer to the figure, to answer Questions (1.3 and 1.4)



1.3 Which one of the following about the magnitude and direction of **the horizontal component** of force **F** is **CORRECT**?

- A. $F \sin 60^\circ$ to the right.
- B. $F \sin 60^\circ$ to the left.
- C. $F \cos 60^\circ$ to the right.
- D. $F \cos 60^\circ$ to the left.

(2)

1.4 Which one of the combinations of forces listed below does **work** on this object in motion?

- A. Weight, friction.
- B. Normal force, friction
- C. Friction, horizontal component of force F
- D. Force due to gravity, vertical component of force F

(2)

1.5 Which one of the following is equivalent to a **horse power**?

- A. 1 kW
- B. $1 \text{ J} \cdot \text{s}^{-1}$
- C. 1 N.m
- D. $746 \text{ J} \cdot \text{s}^{-1}$

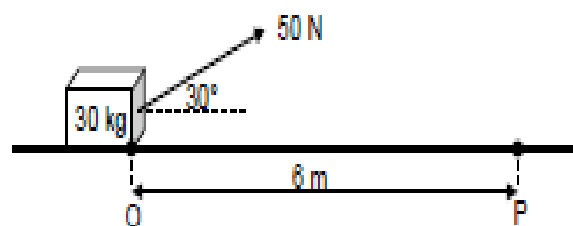
(2)

[10]

SECTION B

Question 2

A worker pulls a crate of mass 30 kg from rest along a horizontal floor by applying a constant force of magnitude 50 N at an angle of 30° to the horizontal. A frictional force of magnitude 20 N acts on the crate whilst moving along the floor.



2.1 Define the term **work**.

(2)

2.2 Draw a labelled free-body diagram showing all the forces that act on the block.

(4)

2.3 Calculate the

2.3.1 magnitude of the horizontal component of the applied force.

(3)

2.3.2 work done by the horizontal component of the applied force.

(3)

2.3.3 work done due to the frictional force acting on the box.

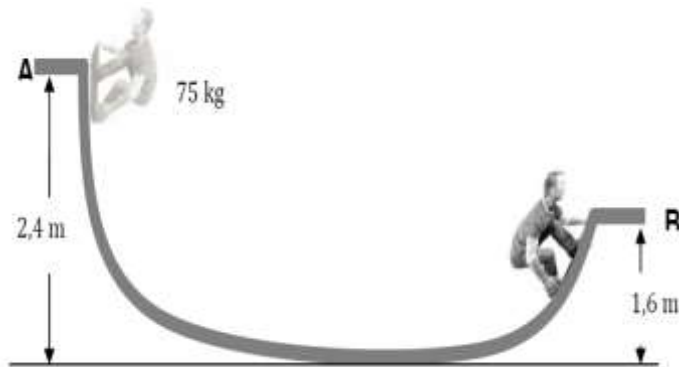
(3)

2.4 Briefly explain why the normal force does no work on the box.

(2)

Question 3

The figure below shows a boy who skates from **rest** at point A to point B on an uneven **frictionless** surface. The combined mass of the boy and the skateboard is 75 kg. Ignore the effects of air resistance.



3.1 State the **principle of conservation of mechanical energy**, in words.

(2)

3.2 Calculate the magnitude of gravitational potential energy of the boy and the skateboard at point A.

(3)

3.3 It is observed that the boy moves at the highest speed while he moves past the lowest point of the track. **Using energy principles**, briefly explain this observation.

(3)

3.4 Calculate the speed of the boy and the skateboard when he reaches point B.

(4)

Question 4

A lift of mass 800 kg has a maximum load of 600 kg. In full capacity, the lift cable pulls it 30 m up, at a constant speed of 5 m/s. **Ignore air resistance.**



4.1 Define the term **power**. (2)

4.2 The weight of the lift is doing negative work on the lift. Briefly explain. (2)

4.3 Calculate the average power of the motor as it lifts the elevator 30 m upwards. (4)

Question 5

A racing motorbike has a mass of 450 *kg*, at most it has a maximum power output of 3 *hp*.

5.1 Convert the power output of the motorbike to Watts. (2)

5.2 Calculate the work done by the engine if the motorbike moves for 5 seconds at maximum power output. (3)

SESSION 5

ELASTICITY

Definitions

A deforming force is a force that changes the **shape and size** of the object

A restoring force develops inside the body and tries to bring back the original **shape and size** of the object

Elasticity of a body is the property of the body by virtue of which the body regains its original **shape and size** when the deforming force is removed.

The internal restoring **force per unit area** of body is called stress.

Strain is the **ratio** of change in dimension to the original dimension.

Hooke's law states that, within the limit of elasticity, stress is directly proportional to strain.

Young's modulus: is a measure of the forces between the particles of the material. These forces resist a tensile force.

A spring constant is a measure of the force exerted by a spring as it tries to return to its equilibrium position.

The restoring force can be calculated using :

$$\vec{F} = -k\vec{x}$$

During deformation, two forces act on an object simultaneously – deforming force and restoring force

Deforming force and restoring force have equal magnitudes and opposite direction.

Deforming force is directly proportional to the restoring force

Perfectly plastic body:

A body which does not show a tendency to regain its original shape and size when the deforming force is removed is a perfectly plastic body.

Stress

To calculate stress in a material, we use the equation:

$$\sigma = \frac{F}{A}$$

SI unit of stress is the **Pascal**

$$1 \text{ Pa} = 1 \text{ N.m}^{-2}$$

Examples

A 15 m marble column of cross sectional area 3 m^2 support a mass of 15 000 kg. The column measures 14,7 m after the load is applied. Calculate the stress within the column.

$$\sigma = \frac{F}{A}$$

$$F = mg$$

$$F = 15\,000 \times 9,8$$

$$F = 147\,000 \text{ N}$$

$$\sigma = \frac{147\,000}{3}$$

$$\sigma = 49\,000 \text{ Pa}$$

$$\sigma = 49\,000 \text{ N} \cdot \text{m}^{-2}$$

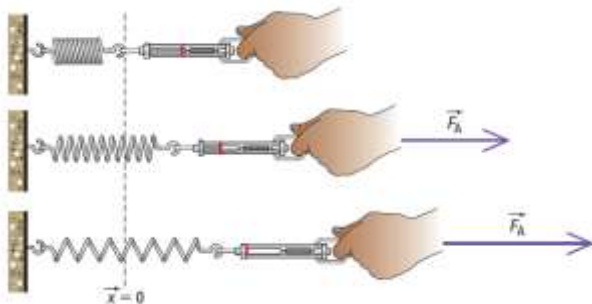
Strain

$$\text{Strain} = \frac{\text{change in length}}{\text{original length}}$$

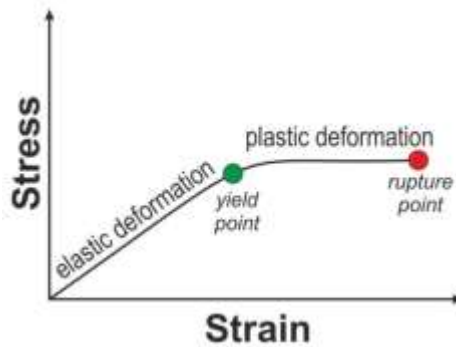
The equation

$$\epsilon = \frac{\Delta l}{L_0} \quad , \text{ is used to calculate strain}$$

strain has **no units**, since it is a ratio of two same dimensions.



The graph below shows the relationship that exists between the restoring force of an object that is subjected to some degree of deformation.



The demonstration of a ruler can be used to explain the following observations:

- As the size of the deforming force increases, so does the size of the force that opposes deformation (stress).
- It is exactly when the ruler experiences elastic deformation.
- As the magnitude of the deforming force reaches the yield point, the size of the restoring force remains more or less constant until the ruler snaps (rupture point)
- Beyond the yield point, it is important to note that the ruler is now experiencing an irreversible form of deformation (plastic deformation).

Hooke's law is given by:

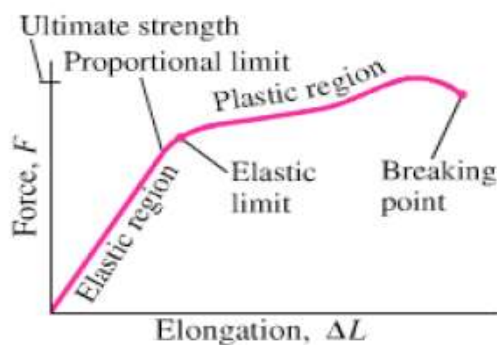
$$F = k\Delta L$$

Rearranging this to:

$$\Delta L = \frac{F}{K}$$

, makes it clear that the **deformation (ΔL) is proportional to the applied force (F)**. Hooke's law is applicable to most solids from iron to bone but is only valid up to a certain point.

The graph below shows a region where Hooke's law is obeyed and where it is not obeyed:



Youngs modulus, $Y = \frac{\text{tensile stress}}{\text{tensile strain}}$ represented mathematically as

$$K = \frac{\sigma}{\varepsilon} \quad \text{OR} \quad Y = \frac{\sigma}{\varepsilon}$$

Unit: $1 \text{ N}\cdot\text{m}^{-2}$ or 1 Pa

Examples

A vertical steel beam in a building support a load of $6,0 \times 10^4 \text{ kg}$. The length of the beam is $4,0 \text{ m}$ and its cross sectional area is $8,0 \times 10^{-3} \text{ m}^2$. The elastic (young's) modulus is $2,0 \times 10^{11} \text{ Pa}$ and the ultimate stress of steel is $5,0 \times 10^8 \text{ Pa}$.

1.1 Calculate the amount of compression in the beam.

1.2 Find the maximum load the beam can support.

Solution

$$1.1 \quad \sigma = Y\varepsilon$$

$$\frac{F}{A} = Y \frac{\Delta l}{L_0}$$

$$\frac{6,0 \times 10^4}{8,0 \times 10^{-3}} = 2,0 \times 10^{11} \left(\frac{\Delta l}{4,0} \right)$$

$$\Delta l = 1,5 \times 10^{-4} \text{ m}$$

1.2 Set the compressive stress equal to the ultimate compressive strength.

$$\frac{F}{A} = \frac{F}{8,0 \times 10^{-3}} = 5,0 \times 10^8.$$

$$F = 4,0 \times 10^6 \text{ N}$$

Example on Hookes law

A $1,5 \text{ m}$ long steel piano wire has a diameter of $0,2 \text{ cm}$. It is stretched $0,2 \text{ m}$ when tightened.

1.1 State Hooke's law in words.

1.2 Calculate the tension in the wire.

Solutions

1.1 Hooke's law states that, within a limit of elasticity, stress is directly proportional to strain.

1.2

$$radius = \frac{diameter}{2}$$

$$radius = \frac{0,2 \times 10^{-2}}{2}$$

$$= 0,001 \text{ m}$$

$$A = \pi r^2$$

$$A = 3,14(0,001)^2$$

$$A = 3,1 \times 10^{-6} \text{ m}^2$$

$$\sigma = Y\varepsilon$$

$$\frac{F}{A} = Y \frac{\Delta l}{L_0}$$

$$\frac{F}{3,1 \times 10^{-6}} = 2,0 \times 10^{11} \left(\frac{0,2}{1,5} \right)$$

$$F = 8,27 \times 10^4 \text{ N}$$

LEARNER ACTIVITY

Question 1: MULTIPLE CHOICE

1.1 Which one of the following is the correct regarding a deforming force?

- A. Changes the volume of object.
- B. Changes the mass of the object.
- C. Changes the size and shape of the object.
- D. Size and shape remain constant.

(2)

1.2 Which one of the following is an example of a perfectly plastic body?

- A. Aluminium can
- B. Foam rubber
- C. Glass
- D. Tennis ball

(2)

1.3 The SI unit of stress is equivalent to

- A. 1 kg.m.s^{-1}
- B. 1 N.m^{-2}
- C. 1 J.s
- D. 1 W

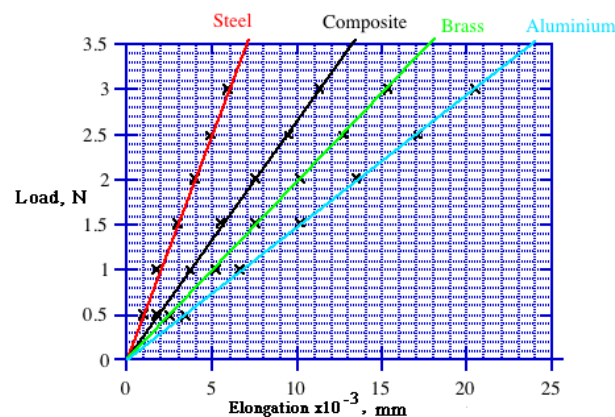
(2)

1.4 A force of 2 kN is exerted on a cubicle object, the stress experienced by the object is 500Pa. The area on which the force acts is:

- A. 340 m^2
- B. $3,4 \text{ m}^2$
- C. $0,29 \text{ m}^2$
- D. 29 m^2

(2)

1.5 Consider the graph below showing the stress-strain for different materials :



Which one of the following materials has the greatest modulus of elasticity?

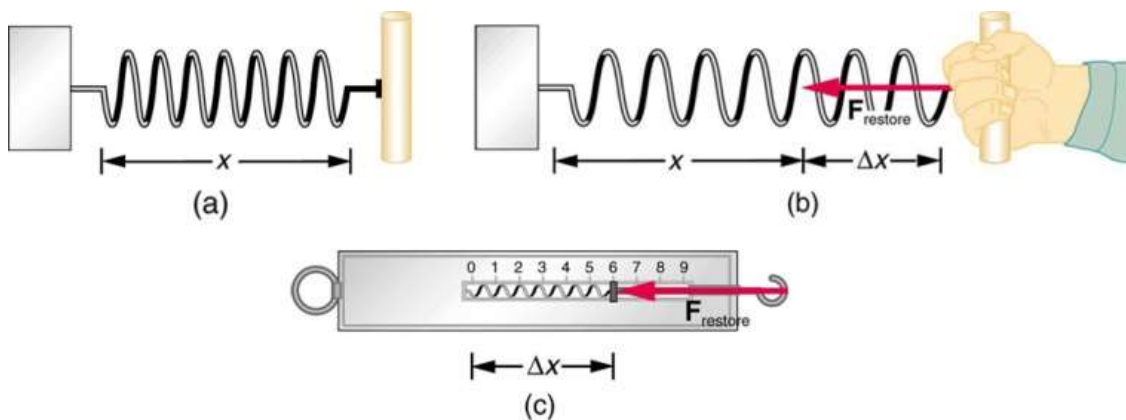
- A. Aluminium
- B. Brass
- C. Composite
- D. Steel

(2)

[10]

Question 2

Consider the situation below wherein a learner applies a force on a spring. The force meter measures the force applied



2.1 define the following terms

2.1.1 deforming force

(2)

2.1.2 restoring force

(2)

2.2 What is the reading on the force meter which measures the applied force? (1)

2.3 How does the magnitude and direction of the applied force compare to that of the restoring force? Write down only LESS THAN, EQUAL TO or GREATER THAN. Explain briefly

(3)

2.4.1 In another demonstration, a learner applies a deforming force on a string with a constant of 40N.m^{-1} for a distance of 20cm.

Calculate the magnitude of the restoring force?

(3)

2.4.2 If the force applied to deform the spring is doubled, what will be the new restoring force.

(2)

Question 3

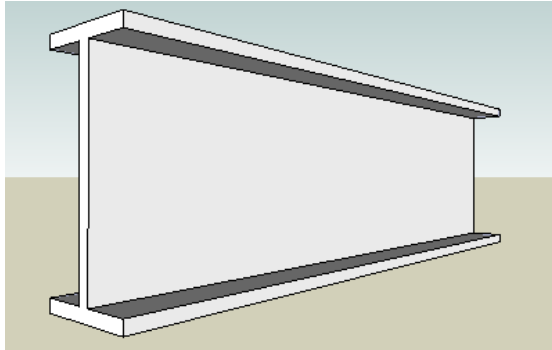
A metal strip has a diameter of 25 cm and is 2m long. A force of 12 N is applied on the circular cross sectional area.

3.1 Assume that the material is elastic. Calculate the stress within the metal strip. (3)

3.2 A rectangular concrete beam carries a load of mass 400kg. The rectangular cross-sectional area of the beam has dimensions, 1,5 m x 2,5 m. Assume that the concrete is elastic. Determine the magnitude of stress in the beam.

(4)

- 3.3 How much force would create a stress of 750 Pa on a cubic rubber material with a length of 200 mm? (4)
- 3.4 In most real-life applications, beams are usually I-shaped.



Give **TWO** reasons for this. (2)

Question 4

A metal strip has a diameter of 40mm and is 3 m long. A constant force acts on the strip and stretches it by 5mm.

- 4.1 Determine the strain in the strip (3)
- 4.2 A steel bar is 10 mm in diameter and 2 m long. It is stretched by a force of 20 kN and extends to 2,03 m. Calculate the strain of the bar (3)
- 4.3 A rod is 0,5 m long and 5 mm in diameter. The rod is stretched 0,06 mm by a force of 3 kN. Calculate the strain. (3)

Question 5

- 5.1 What is the magnitude of required to stretch a 20 cm long spring with a spring constant of 100 N/m to a length of 21 cm? (3)
- 5.2 What is the spring constant of a spring that needs a force of 3 N to be compressed from 40 cm to 35 cm? (3)
- 5.3 A spring stretches 5 cm when a load of 20 N is hung on it. If instead, we put a load of 30 N, how much will the spring stretch? What is the spring constant? (3)
- 5.4 A spring has a spring constant that is equal to 3.5. What force (in kilograms) will make it stretch 4 cm? (4)

Question 6

A steel wire 10m long and 2mm in diameter is attached to the ceiling and a 200N weight is attached to its end.

- 6.1 What is the magnitude of the applied stress? (3)

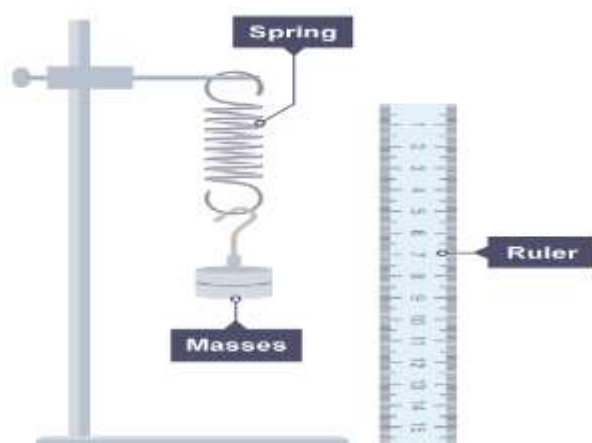
6.2 It is noted that the wire stretches 3,08 mm due to the 200N load. Calculate the strain on the wire. (3)

6.3 The elastic limit of the steel wire is $2,48 \times 10^8$ Pa. Determine the maximum weight that can be supported without exceeding the elastic limit of the wire. (3)

6.4 Calculate the modulus of elasticity of the wire (3)

Question 7

The diagram below shows a setup of apparatus done by the teacher.



Different masses are suspended and the corresponding elongations are obtained.

Table of results

Mass (g)	0	200	400	600	800	1000	1200
X (cm)	0	1	2	3	4	5	8
W (N)							

7.1 Copy and complete the table of results. (7)

7.2 What NAME is given to the force causing the spring to elongate? (1)

7.3 Using a graph paper, plot a graph of weight (N) versus elongation (cm). (6)

7.4 Briefly explain why the pattern changes from the fifth reading (2).

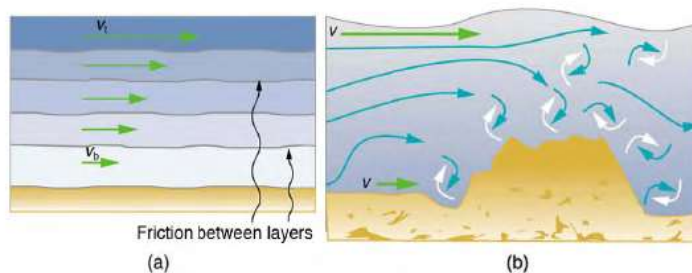
SESSION 6

VISCOCITY

Definition

viscosity is the property of the fluid to oppose relative motion between two adjacent layers.

In figure below:



- Laminar flow occurs in layers without mixing. Notice that viscosity causes drag between layers as well as with the fixed surface.
- An obstruction in the vessel produces turbulence. Turbulent flow mixes the fluid.

There is more interaction, greater heating, and more resistance than in laminar flow.

Viscosity is the property of the fluid to oppose relative motion between the two adjacent layers, thus a fluid with high viscosity will tend to have the greatest resistance to flow

Viscosity varies from one fluid to another by several orders of magnitude.



Effect of temperature on viscosity:

- As you might expect, the viscosities of gases are much less than those of liquids and these viscosities are often temperature dependent.
- The viscosity of liquids decrease with increasing temperature, while that of gases increases with increasing temperature

Motor oil viscosity grades

Motor oil, engine oil, or **engine lubricant** is any of various substances that is used as a substance that reduces friction between moving parts of an internal combustion engines.

The main function of motor oil:

- To reduce wear and tear on moving parts.
- Prevent corrosion
- Cools the engine by carrying the heat away from the moving parts.

- Motor Oils are differentiated based upon viscosities.
- They have a number on them, the SAE number, which tells you the viscosity.
- The first part of the code (i.e. 10W and 5W) is the apparent viscosity of the motor oil when it is cold, as the W stands for "winter".
- The second part of the code (i.e. 30 and 40) is the apparent viscosity of the motor oil when it is hot.

HYDRAULICS

Definitions

Thrust is the normal force exerted by a liquid at rest on a given surface in contact with it.

Pressure at a point is the thrust force acting per unit area.

Pascal's Law states that, in a continuous liquid at equilibrium, the pressure applied at any point is transmitted equally to the other parts of the liquid.

Pressure (P) can be thought of as, the force divided by the area perpendicular to the force over which the force is applied. The mathematical expression of pressure is given by:

$$P = \frac{F}{A}$$

where F is a force applied to an area A that is perpendicular to the force.

Force must be in Newtons (**N**) and area in square metres (**m²**)

The SI unit for pressure is the **Pascal, P** where

$$1 \text{ Pa} = 1 \text{ N} \cdot \text{m}^{-2}.$$

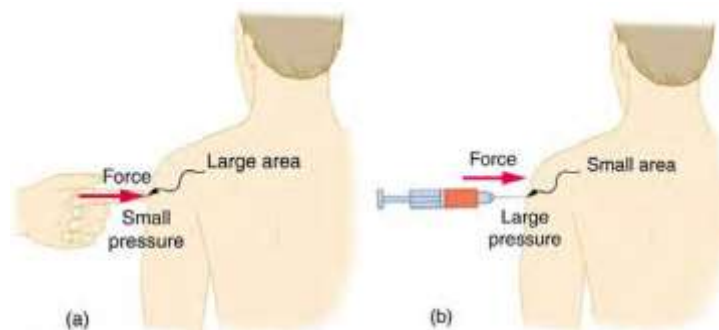
In addition to the Pascal, there are many other units for pressure that are in common use. In meteorology, atmospheric pressure is often described in units of millibar (mb), where

$$100 \text{ mb} = 1 \times 10^5 \text{ Pa} .$$

Other units used in technology are:

- 1 atmosphere (**atm**) = $1,0110^5 \text{ Pa}$
- 1 **bar** = 10^5 Pa
- 1 **torr** = 133 **Pa**

$P \propto \frac{1}{A}$, Pressure and area are inversely proportional.



- While the person being poked with the finger might be irritated, the force has little lasting effect.
- In contrast, the same force applied to an area the size of the sharp end of a needle is great enough to break the skin.

General properties of liquids:

- Liquid substances are generally incompressible
- Pressure of a liquid increases with depth
- The fluid pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid and the acceleration due to gravity.
- Fluid pressure does not depend upon the total mass or total volume of the liquid.

Fluid pressure is calculated by the following equation:

$$P = \rho gh$$

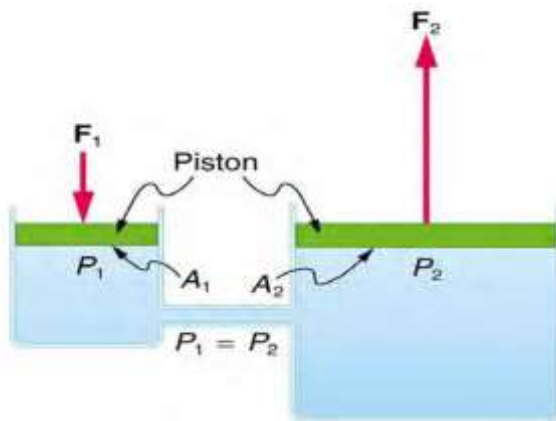
, where **ρ** is the symbol for density, **g** is the gravitational acceleration , and **h** is the average depth of the liquid

Pascal's law

The equation :

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

is used to calculate force and area in hydraulic systems such as lifts, jacks, etc.



A typical hydraulic system with two fluid-filled cylinders, capped with pistons and connected by a tube called a hydraulic line.

A downward force F_1 on the left piston creates a pressure that is transmitted undiminished to all parts of the enclosed fluid.

This results in an upward force F_2 on the right piston that is larger than F_1 because the right piston has a larger area.

Relationship Between Forces in a Hydraulic System

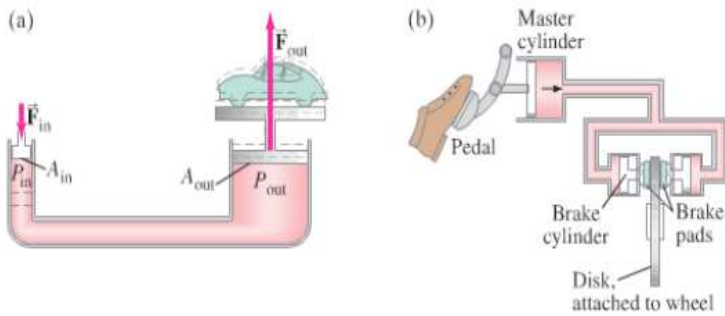
$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \text{Where} \quad A_2 > A_1$$

Hydraulic lift

Hydraulic lift is used to lift heavy loads.

Examples:

- (a) Car lifts and jacks
- (b) Hydraulic brakes



Example 1

The surface of a water in a storage tank is 30 m above a water faucet in the kitchen of a house. Calculate the pressure of the water on the faucet.

Solution

Water is practically incompressible, so ρ is constant. For water $\rho = 1,0 \times 10^3 \text{ kg} \cdot \text{m}^{-3}$.

$$P = \rho gh$$

$$P = (1,0 \times 10^3)(9,8)(30)$$

$$P = 2,9 \times 10^5 \text{ Pa}$$

OR

$$P = 2,9 \times 10^5 \text{ N} \cdot \text{m}^{-2}$$

Example 2

The dam is 500 m wide, and the water is 80.0 m deep at the dam.

2.1 What is the average pressure on the dam due to the water?

2.2 Calculate the force exerted against the dam and compare it with the weight of water in the dam (previously found to be $1.96 \times 10^{13} \text{ N}$).

Solution

2.1 The average pressure due to the weight of a fluid is

$$P = \rho gh.$$

$$\begin{aligned} P &= (10^3) (40.0) 9.8) \\ &= 3.92 \times 10^5 \text{ Nm}^2 = 392 \text{ kPa.} \end{aligned}$$

2.3 The force exerted on the dam by the water is the average pressure times the area of contact:

$$F = P \cdot A$$

We have already calculated the value for P . The area of the dam is $A = 80.0 \text{ m} \times 500 \text{ m}$

$$A = 4.00 \times 10^4 \text{ m}^2, \text{ so that}$$

$$F = P \cdot A$$

$$\begin{aligned} F &= (3.92 \times 10^5) (4.00 \times 10^4) \\ &= 1.57 \times 10^{10} \text{ N.} \end{aligned}$$

Example 3

A force of 100 N is applied to the brake pedal, which acts on the cylinder—called the master—through a lever. A force of 500 N is exerted on the master cylinder. Pressure created in the master cylinder is transmitted to four so-called slave cylinders. The master cylinder has a diameter of 0.500 cm, and each slave cylinder has a diameter of 2.50 cm. Calculate the force F_2 created at each of the slave cylinders.

Solution

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$ can be used to find the force F_2 .

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_1}{\pi r^2} = \frac{F_2}{\pi r^2}$$

$$\frac{500}{0,250^2} = \frac{F_2}{1,25^2}$$

$$F_2 = 1.25 \times 10^4 \text{ N.}$$

Example 4

In a car lift use in service station, compressed air exerts a force on a small piston of circular cross section having a radius of 5,0 cm. This pressure is transmitted by an incompressible liquid to a second piston of radius 15,0 cm. What force must the compressed air exert on the small piston in order to lift a car weighing 13 300 N?

Solution

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

The area of the piston are unknown, but $A = \pi r^2$

$$\frac{F_1}{\pi r_1^2} = \frac{F_2}{\pi r_2^2}$$

$$\frac{F_1}{(3,14)(5.0 \times 10^{-2})^2} = \frac{13\,300}{(3,14)(15.0 \times 10^{-2})^2}$$

$$F_1 = 1,48 \times 10^3 \text{ N}$$

LEARNER ACTIVITY

1.1 A liquid with a **high viscosity**:

- A. Has a definite volume.
- B. Flows faster.
- C. Flows slowly.
- D. Fills the container.

(2)

1.2 The _____ is responsible for **resistance to flow**.

- A. Tension force.
- B. Gravitational force.
- C. Pressure.
- D. Intermolecular forces.

(2)

1.3 Which one of the following quantities or property is used in application of hydraulic lifts?

- A. Thermal conductivity.
- B. Pressure of fluids.
- C. Viscosity of fluids.
- D. Stiffness of material.

(2)

1.4 Which one of the following statements is **INCORRECT**?

- A. All liquids are generally incompressible.
- B. Pressure of a liquid increases with depth
- C. The fluid pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid and the acceleration due to gravity.
- D. Fluid pressure does depends upon the total mass or total volume of the liquid.

(2)

1.5 The correct **SI unit** of fluid pressure is :

- A. 1 bar
- B. 1 atm
- C. 1 Pa
- D. 1 kPa

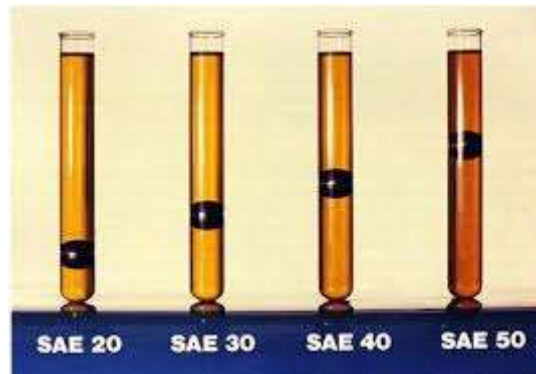
(2)

[10]

Question 2

Grade 12 learners are performing an experiment to compare the rate of flow of three different fluids as show in the figure below.

Study the figure carefully and answer the questions that follow.



- 2.1 Which **property of fluids** are the learners comparing between the three substances?(1)
2.2 Why is it important that learners keep track of time during the experiment? (2)
2.3 Identify any **THREE** apparatus used in this experiment. (3)

In a separate experiment compare the rate of flow of milk, motor engine oil and honey, the following results were obtained:

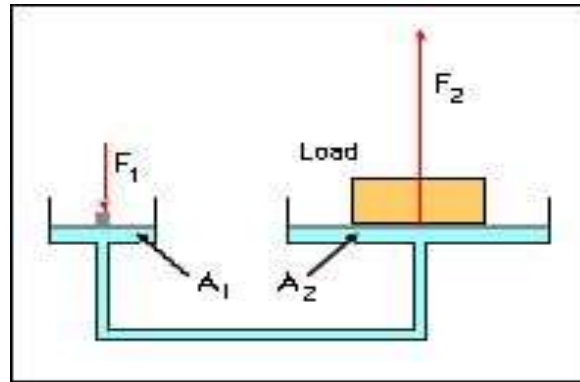
Table of results

Type of Fluid	Time taken to reach 100ml mark (s)
Milk	142
Motor engine oil	267
Honey	276

- 2.4 Identify the substance with:
2.4.1 the **highest** rate of flow (1)
2.4.2 **greatest** resistance to flow (1)
2.5 What conclusion(s) can be drawn for this experiment? (2)

Question 3

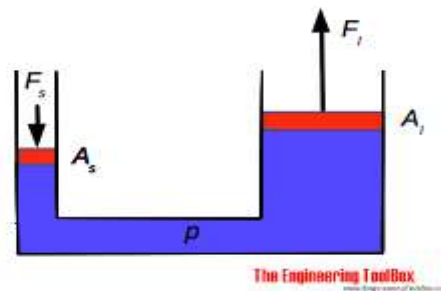
Study the figure below is a simplified illustration of a hydraulic lift. A_1 has an area of $0,25 \text{ m}^2$ and A_2 is $1,75 \text{ m}^2$.



- 3.1 State **Pascal's law**, in words. (2)
- 3.2 Which property of fluids allows them to be used in hydraulics to lift heavy loads? (1)
- 3.3 If a mass of 5 kg is placed on F_2 , calculate the output force F_2 (3)
- 3.4 What mass must be placed on A_1 so that the output force F_2 is double the force calculated in (3.3)? (3)
- 3.5 List and three uses of hydraulic lifts in technology. (3)

Question 4

The figure below shows a simple hydraulic lift. Study the diagram carefully and answer the questions that follow.



- 4.1 **NAME** and **STATE** the principle on which this hydraulic lift operates. (3)
- 4.2 If an external force of 10 N is applied on the smaller piston of diameter 2 cm, determine the maximum weight that can be lifted on the larger piston of diameter 12 cm. (3)
- 4.3 What **property of fluids** makes it possible for the hydraulic lift to operate? (1)

Question 5

Different motor oils are used for lubrication purposes and temperature has an effect on the viscosity of motor oil. Study the figure below and answer the questions that follow.



- 5.1 Define the term ***viscosity***. (2)
- 5.2 Briefly explain the meaning of the code “**10W-40**” as shown in the figure above. (2)
- 5.3 At a temperature above 40 degrees Celcius, how will the viscosity of this motor oil be affected? (2)