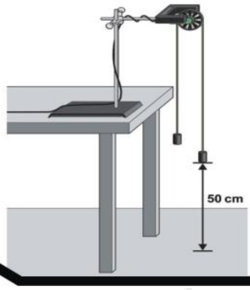


UNIT 3
DYNAMICS

3.1 FORCE, INERTIA AND MOMENTUM

3.1 SHORT QUESTIONS

Q.1 Define dynamics. ***(K.B)*** **(GRW 2015, 2017)**

Ans: **DYNAMICS**

Definition:

"The branch of mechanics that deals with the study of motion of an object and the cause of its motion is called dynamics".

Example:

- How the moon effect the ocean.
- Car on a banked road.

Q.2 Define force? Write its formula and unit. ***(K.B+U.B+A.B)*** **(GRW 2013, LHR 2017)**

Ans: **FORCE**

Definition:

"A force that moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body".

Formula:

$F = ma$

Quantity:

A force is a vector quantity.

Unit:

S.I unit of force is newton(N)

$1N = 1kg \times 1ms^{-2}$

Definition of newton:

"One newton is the force that produces an acceleration of $1ms^{-2}$ in a body of mass 1kg."

Examples:

- We can open the door either by pushing or pulling the door.
- A man pushes the cart. The push may move the cart or change the direction of its motion or may stop the moving cart.
- A batsman changes the direction of a moving ball by pushing it with his bat.

Figure: Functions of Force

Q.3 Define inertia. Explain it with examples. ***(K.B+A.B)*** **(LHR 2014, 2015, GRW 2017)**

Ans: **INERTIA**

Definition:

"Inertia of a body is its property due to which it resists any change in its state of rest or of motion".

Introduction:

Galileo observed that it is easy to move or to stop light objects than heavier ones. Heavier objects are difficult to move or if moving then difficult to stop. Later on Newton concluded that everybody resists to the change in its state of rest or of uniform motion in a straight line. He called this property of matter as inertia. He related the inertia of a body with its mass; greater is the mass of a body greater is its inertia.

Dependence:

It depends on the mass of the body. Greater the mass of the body greater will be the inertia. Therefore, we can say that mass is the direct measure of inertia.

Examples: **(GRW 2017)**

- Take a glass cover it with a piece of cardboard. Place a coin on the cardboard. Now flick the card horizontally with a jerk of your finger. The coin does not move with the cardboard due to inertia and falls in to the glass.

Figure: **The coin Falls into the Glass Due To Inertia as the Card Flicks Away**

- Cut a strip of paper. Place it on the table. Stack a few coins at its on end. Pull out the paper strip under the coins with a jerk. We will succeed in pulling out the paper strip under the stacked coin without letting them to fall due to inertia.

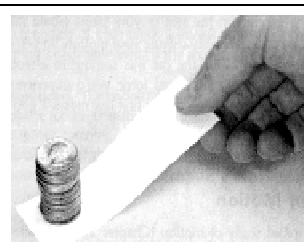


Figure: **Coins Stacked Over Remain Undisturbed on Pulling the Paper Strip Quickly**

Q.4 When a bus takes a sharp turn why do passengers fall in outward direction? *(K.B+U.B)* **(Do you know PTB Pg. # 60)**

Ans: **TAKING SHARP TURN**

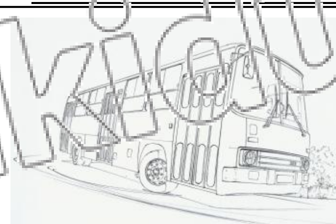


Figure: **Bus Taking Sharp Turn**

When a bus takes a sharp turn passengers fall in outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

Q.5 What is momentum? *(K.B)* **(LHR 2014)**

Ans: **MOMENTUM**

Definition:

"Momentum of a body is the quantity of motion it possesses due to its mass and velocity**"**.

Formula:

The momentum **'P'** of a body is given by the product of its mass **m** and velocity **v.** Thus

$P = m \times v$

Quantity:

Momentum is a vector quantity.

Unit:

SI unit of momentum is **kg ms^{-1}** or **Ns.**

Dependence:

Momentum or quantity of the motion of a body depends on two quantities.

- Mass of the body
- Velocity of the body

Q.6 What are the effects of a force. (*C.B*)

Ans: Force do not only affect motion. If two or more forces acts on something, they will change its shape or volume (or both). The effect is slight with hard objects, but can be very noticeable with flexible bodies.

3.1 MULTIPLE CHOICE QUESTIONS

1. The direct measure of inertia is: *(K.B)*
(A) Mass (B) Energy
(C) Momentum (D) All of above

2. The characteristic of a body due to which it tends to retain its state of rest or of uniform motion is known as: *(K.B)*
(A) Weight (B) Force
(C) Inertia (D) Momentum

3. The agency which changes or tends to change the state of rest or of uniform motion of a body: *(K.B)*
(A) Weight (B) Force
(C) Inertia (D) Momentum

4. SI unit of force is: *(K.B)*
(A) Kilogram (B) Dynes
(C) newton (D) Pound

5. 1 N = ? *(U.B)* **(GRW 2014)**
(A) $kgms^{-2}$ (B) $kgms^{-1}$
(C) kgm^2s^{-1} (D) kg^2ms^{-2}

6. Quantity of motion in a body is known as: *(K.B)*
(A) Mass (B) Momentum
(C) Velocity (D) Acceleration

7. Product of mass and velocity is known as: *(K.B)*
(A) Force (B) Speed
(C) Momentum (D) Acceleration

8. $Kgms^{-1}$ = ? *(U.B)*
(A) N (B) J
(C) Ns (D) W

3.2 NEWTON'S LAWS OF MOTION

LONG QUESTIONS

3.2 Q.1 State and Explain Newton's First law of motion. ***(K.B+A.B+U.B)*** **(GRW 2011, 2012, 2014, LHR 2021)**

Ans: **NEWTON'S FIRST LAW OF MOTION**

Introduction:

First law of motion deals with bodies which are either at rest or moving with uniform speed in a straight line. It means no net force acts on them.

Statement:

Newton's First Law of Motion states that:

"A body continues in its state of rest or of uniform motion in a straight line provided no net force acts on it**"**.

Explanation For Rest:

Newton's first law of motion deals with bodies which are either at rest or moving with uniform speed in straight line. According to first law of motion, a body at rest remains at rest provided no net force acts on it. This part of the law is true as we observe that objects do not move by themselves unless someone moves them.

Example:

A book lying on a table remains at rest as long as no net force acts on it.

Explanation For Motion:

Similarly, a moving object does not stop moving by itself. A ball rolled on a rough ground stops earlier than that rolled on smooth ground. It is because rough surface offer greater friction. If there would be no force to oppose the motion of the body would never stop.

Example:

When its engine of a car moving with uniform velocity is turned off it stops gradually because a net force of friction is acting in the opposite direction causes to stop it.

Law of Inertia:

Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as **law of inertia.**

Example:

Passengers standing in a bus fall forward when its driver applies brakes suddenly. It is because the upper parts of the bodies tend to continue their motion, lower parts of their bodies are in contact with the bus stop with it. Hence, they fall forward. Similarly, when a moving bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

3.2 Q.2 State and Explain Newton's Second law of motion. ***(K.B+U.B+A.B)***

(GRW 2011, LHR 2012, 2013)

Ans: **NEWTON'S SECOND LAW OF MOTION**

Introduction:

Newton's Second Law of Motion deals with the situation where a net force acts on the body.

Statement:

Newton's Second Law of Motion states that:

"When a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on the body and inversely proportional to its mass.**"**

Mathematical Form:

If the force **'F'** is acting on the body of mass **'m'** then we can write this in the mathematical form as,

$$a \propto F \quad \ldots\ldots\ldots\ldots\ldots (1)$$

and $$a \propto \frac{1}{m} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

From relation (1) and (2), we have

$$a \propto \frac{F}{m}$$

$$F \propto ma$$

Changing the sign of proportionality into the sign of equality

$$F = (\text{constant})\, ma$$

Putting k as proportionality constant, we get

$$F = kma$$

In above equation, according to international system of units k = 1

$$F = (1)\, ma$$

$$F = ma$$

This is the mathematical form of Newton's Second law of motion.

Unit of Force:

In the System International, the unit of force is newton, which is represented by the symbol **'N'**.

Definition of newton:

"One newton **(1N)** is the force that produces an acceleration of **1ms^{-2}** in a body of mass **1kg."**

Thus, a force of one newton can be expressed as

$$1\ N = 1\ kg \times 1\ ms^{-2}$$

or $$\mathbf{1\ N = 1\ Kgms^{-2}}$$

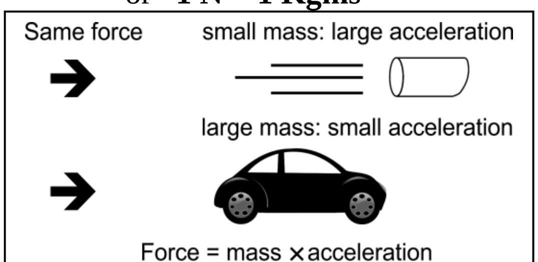


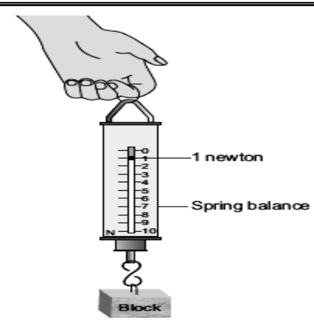
Figure: Newton's Second Law

3.2 Q.3 Differentiate between Mass and Weight. ***(K.B)*** **(GRW 2011, 2012, LHR 2014, 2015)**

Ans: **DIFFERENTIATION**

Mass and weight can be differentiated as:

Mass	Weight
Definition	
• Mass of a body is the quantity of matter possessed by the body.	• The weight of an object is the force acting on the object due to gravity.
Quantity	
• It is a base and scalar quantity.	• It is a derived and vector quantity. It is always directed toward the center of the earth.
Variations	

• It remains same everywhere and does not change with change of place.	• It does not remain same at all places and varies with the value of 'g', acceleration due to gravity.
Unit	
• Unit of mass is kilogram (Kg).	• Unit of weight is newton (N).
Formula	
• It can be calculated by using the formula F = ma	• It can be calculated by using the formula w = mg
Zero Value	
• Mass of a body can never be zero	• Weight of body can be zero
Measurement	
• It is measured by comparison with standard masses using a physical balance (beam balance or electronic balance etc.	• It is measured by spring balance.
Measuring Instruments	
 **Figure:** <u>A Spring Balance</u>	 **Figure:** <u>A Physical Balance</u>

3.2 Q.4 State and Explain Newton's Third law of motion. ***(K.B+A.B+U.B)*** **(LHR 2011, GRW 2013)**

Ans: **NEWTON'S THIRD LAW OF MOTION**

Introduction:

Newton's Third Law of Motion deals with the situation where action and reaction forces act on the bodies.

Statement:

Newton's Third Law of Motion states that:

"To every action there is always an equal but opposite reaction**".**

Explanation:

According to this law, action is always accompanied by a reaction force and the two forces must always be equal and opposite. Note that action and reaction forces act on different bodies due to this reason they do not cancel each other.

- **Action Force:** The applied force by a body is called action.
- **Reaction Force:** The responsive force to action is called reaction force

Newton's third law of motion deals with the reaction of a body when a force acts on it. Let a body A exerts a force on another body B, the body B reacts against this force and exerts a force on body A. The force exerted by body A on B is the **action force** whereas the force exerted by B on A is called the **reaction force.**

Examples:

- Consider a book lying on a table as shown in figure. The weight of the book is acting on the table in the downward direction. This is the action. The reaction of the table acts on the book in the upward direction.

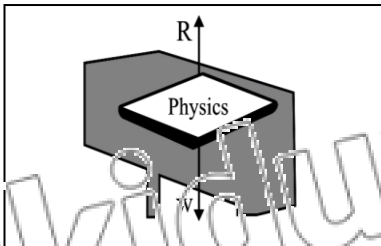


Figure: Action and Reaction on a Book Placed at Table

- Take an air - filled balloon. When the balloon is set free, the air inside it rushes out and the balloon moves forward. In this example, the action is by the balloon that pushes the air out of it when set free. The reaction of the air which escapes out from the balloon acts on the balloon. It is due to this reaction of the escaping air that moves the balloon forward.

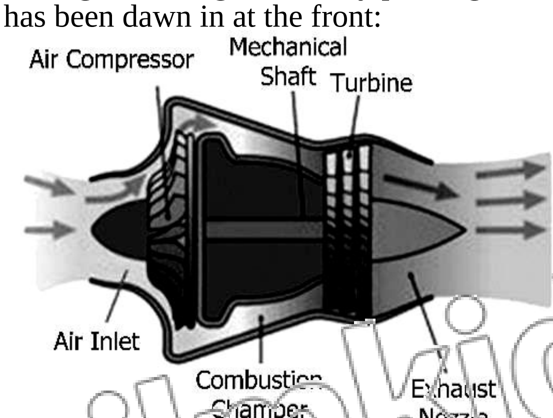
Figure: Action and Reaction on Rocket Taking Off

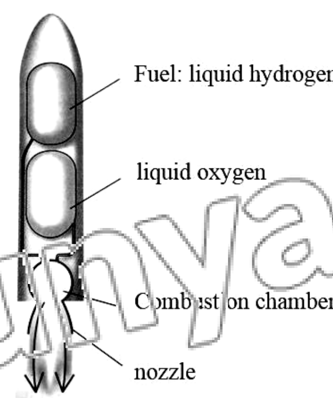
Q. 5 Rockets and Jets: Interesting Information

Rockets use the action-reaction principle. A rocket engine gets thrust in one direction by pushing out a huge mass of gas very quickly in the opposite direction. The gas is produced by burning fuel and oxygen. These are either stored as cold liquids, or the fuel may be stored in chemical compounds which have been compressed into solid pellets.

How can a rocket accelerate through space if there is nothing for it to push against? It does have something to push against – the huge mass of gas from its burning fuel and oxygen. Fuel and oxygen make up over 90% of the mass of a fully loaded rocket.

Jet engines also get thrust by pushing out a huge mas of gas. But the gas is mostly air that has been dawn in at the front:





Jet Engine:

A jet engine: the big fan at the front pushes out a huge mass of air. However, some of the air doesn't come straight out. It is compressed and used to burn fuel in a combustion chamber. As the hot exhaust gas expands, it rushes out of the engine pushing round a turbine as it goes. The spinning turbine drives the fan and the compressor.

Rocket Engine:

A rocket engine. In the combustion chamber, a huge mas of hot has expand and rushes out of the nozzle. The gas is produced by burning fuel and oxygen.

3.2 SHORT QUESTIONS

Q.1 **State Law of Inertia.** ***(K.B)***
OR **What is the Law of Inertia?** **(Ex. 3.4)**
Ans: *Given on Page # 94*
Q.2 **Why Newton's First law of motion is also called law of inertia?** ***(K.B)***
Ans: *Given on Page # 94*
Q.3 **State Newton's Second law of motion.** ***(K.B)*** **(LHR 2012, GRW 2013)**
Ans: *Given on Page # 94*
Q.4 **What is the unit of force? Define it.** ***(K.B)*** **(GRW 2013, LHR 2017)**
Ans: *Given on Page # 95*
Q.5 **Define the working of jet engine.** ***(Conceptual Base)***
Ans: *Given on Page # 97*
Q.6 **Define the working of rocket engine.** ***(Conceptual Base)***
Ans: *Given on Page # 97*
Q.7 **Define net Force.** ***(K.B)***
Ans:

NET FORCE

Definition:

"The resultant of all the forces acting on the body is called Net Force."

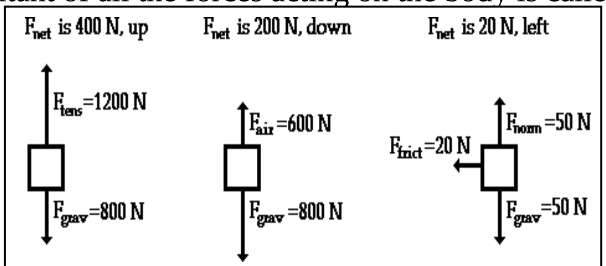


Figure: **Concept of Net Force**

Q.8 **State Newton's Third law of motion.** ***(K.B)*** **(LHR 2017)**
Ans: *Given on Page # 96*
Q.9 **If a moving body has no acceleration; does it mean that no force is acting on it?**
Ans:

ACCELERATION AND NET FORCE

According to Newton's second law of motion, we have

$$F = ma$$

When acceleration = a = 0, we get

$$F = m \times 0$$

So, $F = 0$

Q.10 **Action and reaction are always equal and opposite then why they don't cancel each other?** ***(U.B)***
OR **Action and reaction are always equal and opposite then how does a body move?** **(Ex. 3.9)**
Ans:

ACTION AND REACTION DO NOT CANCEL EACH OTHER

According to this law, action is always accompanied by a reaction force and the two forces must always be equal and opposite. Note that action and reaction forces act on different bodies due to this reason they do not cancel each other due to which the body will move.

Q.11 **Is it possible for a body to move without force?**
Ans: On Earth, unpowered vehicles soon come to rest because of friction. But with on friction, gravity, or other external force on it, a moving object will keep moving for ever – at a steady speed in a straight line. It doesn't need a force to keep it moving.

This idea is summed up a in a law first put forward by Sir Isaac Newton in 1687:

Q.12 Stretch out your palm and hold a book on it. ***(K.B+U.B)*** **(Quick Quiz PTB Pg. # 64)**

1. How much force you need to prevent the book from falling?

Ans: **PREVENTING BOOK FROM FALLING**

Force equal to the weight of the book is needed to prevent the book from falling.

2. Which is action?

Ans: **ACTION**

Weight of the book is action in this case.

3. Is there any reaction? If yes, then what is its direction?

Ans: **REACTION**

Yes there is a reaction offered by hand. The direction of reaction is opposite to the weight.

EXAMPLE 3.1 *(U.B+A.B)*

Find the acceleration that is produced by a 20N force in a mass of 8kg.

Solution:

Given Data:

Force acting on body = F = 20N

Mass of the body = m = 8kg

To Find:

Acceleration = a = ?

Calculations:

We know according to 2nd Law of Motion

$F = ma$

$a = F/m$

Putting values

$a = 20\text{ N} / 8\text{ kg}$

$a = 2.5\text{ms}^{-2}$

Result:

Hence the acceleration produced will be 2.5ms^{-2}.

EXAMPLE 3.2 *(U.B+A.B)*

A force acting on a body of mass 5 kg produces an acceleration of 10 ms^{-2}. What acceleration the same force will produce in a body of mass 8 kg?

Solution:

Given Data:

Mass of First Body = m_1 = 5 kg

Mass of Second Body = m_2 = 8 kg

Acceleration in First body = $a_1 = 10\text{ms}^{-2}$

To Find:

Acceleration in Second body = $a_2 = ?$

Calculations:

As the same force is acting on both bodies so

$m_1a_1 = m_2a_2$

$m_1a_1/m_2 = a_2$

$a_2 = m_1a_1/m_2$

Putting values

$a_2 = (5)(10)/8$

$a_2 = 6.25\text{ms}^{-2}$

Result:

Hence, the acceleration produced in second body will be 6.25ms^{-2}.

EXAMPLE 3.3 *(U.B+A.B)*

A cyclist of mass 40 kg exerts a force of 200 N to move his bicycle with an acceleration of 3 ms^{-2}. How much is the force of friction between the road and the tyres?

Solution:

Given Data:

Mass of cyclist = m = 40 kg

Force exerted = F = 200N

Putting values

$F = (40)(3)$

$F = 120\text{N}$

We know

Acceleration = a = $3ms^{-2}$

To Find:

Force of friction = f = ?

Calculations:

Before finding force of friction we have to find net force first

So F = ma

Net force = Applied Force – Force of friction

120N = 200N – f

f = 200N-120N

f = 80N

Result:

Hence, the force of friction between the road and the tyres will be 80N.

3.2 MULTIPLE CHOICE QUESTIONS

1. **Laws of motion were presented by: *(K.B)***
(A) Einstein (B) Newton
(C) Galileo (D) Archimedes

2. **Isaac Newton described the laws of motion in his famous book: *(K.B)***
(A) Qanoon-ul-Masoodi (B) Principia Mathematica
(C) Kitab-ul-Astralab (D) Al-Manazir

3. **The laws of motion established the relationship between motion and: *(K.B)***
(A) Force (B) Torque
(C) Acceleration (D) Momentum

4. **First law of motion is also known as law of: *(K.B)***
(A) Torque (B) Acceleration
(C) Inertia (D) None of these

5. **Law of inertia is actually the which law of motion? *(K.B)***
(A) First (B) Second
(C) Third (D) Fourth

6. **When a net force is applied on the body, what is produced in the body? *(K.B)***
(A) Weight (B) Acceleration
(C) Energy (D) None of the above

7. **The acceleration produced in a moving body is always in the direction of applied: *(K.B)***
(A) Velocity (B) Force
(C) Speed (D) Momentum

8. **If mass of the body is doubled while keeping the force constant, then acceleration will be: *(U.B)***
(A) One half (B) Doubled
(C) One fourth (D) Four times

9. **If force applied on the body is doubled while keeping the mass constant, then acceleration will be: *(U.B)***
(A) One half (B) Doubled
(C) One fourth (D) Four times

10. **SI unit of force is: *(K.B)***
(A) Kilogram (B) Dynes
(C) Newton (D) Pound

11. **When a force of 8 newton is applied on a body of mass 2 kg, then the acceleration produced will be: *(A.B)***
(A) 16 ms^{-2} (B) 4 ms^{-2}
(C) 0.4 ms^{-2} (D) 160 ms^{-2}

12. **1 N = ? *(K.B)*** **(GRW 2014)**
(A) $kgms^{-2}$ (B) $kgms^{-1}$
(C) kgm^2s^{-1} (D) kg^2ms^{-2}

13. **Action and reaction are equal in magnitude but opposite in direction is known as: *(K.B)***
(A) First law of motion (B) Second law of motion
(C) Third law of motion (D) Fourth law of motion

14. **Walking on road is an example of which law of motion? *(K.B)***
(A) First (B) Second
(C) Third (D) Fourth

15. **When a block is lying on a smooth surface, its weight is balanced by: *(K.B)***
(A) Mass (B) Momentum
(C) Inertia (D) Normal Reaction

16. **The weight of a body of mass 10 kg on earth will: *(U.B)***
(A) 10 N (B) 1 N
(C) 100 N (D) 1000 N

17. **Always acting towards the center of the earth: *(K.B)***
(A) Mass of the body (B) Force of the body
(C) Velocity of the body (D) Weight of the body

18. **Quantity of matter in a body: *(K.B)***
(A) Mass (B) Force
(C) Velocity (D) Weight

19. **The Force with which earth attracts a body towards its centre is known as: *(K.B)***
(A) Mass (B) Force
(C) Weight (D) Inertia

20. **The characteristic of a body which determines the magnitude of acceleration produced when a certain force acts upon it: *(K.B)***
(A) Mass (B) Force
(C) Inertia (D) Weight

21. **Mass of the body is measured by: *(K.B)***
(A) Free Fall Apparatus (B) Physical balance
(C) Spring balance (D) All of above

22. **Weight of the body is measured by: *(K.B)***
(A) Free Fall Apparatus (B) Physical balance
(C) Spring balance (D) All of above

23. **Unit of weight is: *(K.B)***
(A) kg (B) ms^{-1}
(C) Nm (D) N

24. **Remains same everywhere: *(K.B)***
(A) Weight (B) Acceleration
(C) Velocity (D) Mass

25. **Does not remain same everywhere: *(K.B)***
(A) Weight (B) Inertia
(C) Mass (D) All of above

26. **The value of weight of a body of constant mass depends on: *(K.B)***
(A) Inertia (B) Momentum
(C) Force (D) 'g'

27. **Mass is a quantity: *(K.B)***
(A) Scalar (B) Vector
(C) Derived (D) Negative

28. **Weight is a quantity: *(K.B)***
(A) Scalar (B) Vector
(C) Unit less (D) Negative

TENSION AND ACCELERATION IN STRING

LONG QUESTIONS

Q.1 Find Acceleration in bodies and tension in the string when both the Bodies Move vertically using Atwood machine. *(K.B+A.B+U.B)* **(LHR 2013, GRW 2015)**

Ans:

TENSION IN STRING CASE # 1

Suppose two bodies **A** and **B** having masses m_1 and m_2 respectively are attached to two ends of an inextensible string which passes over a frictionless pulley. Let m_1 is greater than m_2, then the body **A** will move downward and the body **B** will move upward. The body **A** being heavier must be moving downwards with some acceleration. Let this acceleration be **a**. Since the string is inextensible therefore the body **B** attached to the other end of the string moves up with the same acceleration **a**. as the pulley is frictionless, hence tension will be the same throughout the string. Let the tension in the string be **T.**

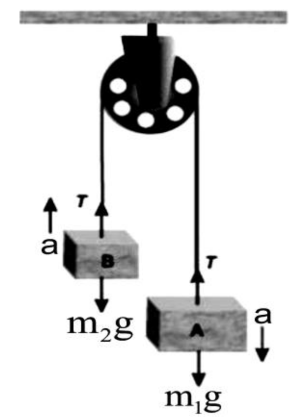


Figure: Atwood Machine Arrangements

Forces Acting on Body A:

There are two forces acting on body A

- Weight of the body $w_1=m_1g$ vertically downward
- Tension in the string **T** vertically upward

As the body **A** is moving downward, It means $w_1=m_1g$ is greater in magnitude so the resultant force acting on body **A** is downward due to which acceleration a is produced in it.

Net force acting on body A = $m_1g - T$

$$F_1 = m_1g - T$$

According to Newton's second law of motion:

$$m_1a = m_1g - T \quad \ldots\ldots\ldots\ldots\ (1)$$

Forces acting on body B:

There are two forces acting on body B

- Weight of the body $w_2=m_2g$ vertically downward
- Tension in the string **T** vertically upward

As the body **B** is moving upward, it means **T** force is greater in magnitude so the resultant force acting on body **B** is upward due to which acceleration **a** is produced in it.

Net force acting on body B = $T - m_2g$

$$F_2 = T - m_2g$$

According to Newton's second law of motion:

$$m_2a = T - m_2g \quad \ldots\ldots\ldots\ldots\ (2)$$

Calculation of Acceleration:

In order to find acceleration in bodies we will add equation (1) and equation (2)

$$m_1a + m_2a = m_1g - T + T - m_2g$$

$$m_1a + m_2a = m_1g - m_2g$$

$$(m_1 + m_2)a = (m_1 - m_2)g$$

$$a = \frac{m_1 - m_2}{m_1 + m_2}g$$

Calculation of Tension:

In order to find Tension in bodies we will divide equation (2) by equation (1)

$$\frac{T - m_2g}{m_1g - T} = \frac{m_2a}{m_1a}$$

$$\frac{T - m_2g}{m_1g - T} = \frac{m_2}{m_1}$$

$$m_1(T - m_2g) = m_2(m_1g - T)$$

$$m_1T - m_1m_2g = m_1m_2g - m_2T$$

$$m_1T + m_2T = m_1m_2g + m_1m_2g$$

$$(m_1 + m_2)T = 2m_1m_2g$$

$$\mathbf{T = \frac{2m_1m_2}{m_1 + m_2}g}$$

Atwood Machine:

The above arrangements are also known as Atwood machine. Atwood machine is an arrangement of two objects of unequal masses. Both the objects are attached to the ends of a string. The string passes over frictionless pulley. This arrangement is sometimes used to find the acceleration due to gravity by equation as

$$\mathbf{g = \frac{m_1 + m_2}{m_1 - m_2}a}$$

Result:

By using Atwood machine we can find following expressions:

$$a = \frac{m_1 - m_2}{m_1 + m_2}g$$

$$T = \frac{2m_1m_2}{m_1 + m_2}g$$

$$g = \frac{m_1 + m_2}{m_1 - m_2}a$$

Q.2 Find Acceleration in bodies and tension in the string, when one body moves vertically and other moves horizontally. ***(K.B+A.B+U.B)***

OR Describe motion of two bodies attached to the ends of a string that passes over a frictionless pulley such that one body moves vertically and the other moves on smooth horizontal surface.

Ans:

TENSION IN STRING CASE # 2

Consider two bodies **A** and **B** having masses $\mathbf{m_1}$ and $\mathbf{m_2}$ respectively are attached to an inextensible string which passes over the pulley as shown in figure. The body **A** moves vertically downward with an acceleration **a** since the string is inextensible therefore the body **B** moves on the horizontal smooth surface towards the pulley with the same acceleration **a.** As the pulley is frictionless, hence tension **T** will be the same throughout the string.

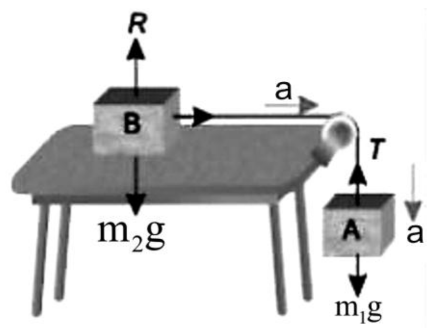


Figure: **Tension in string When One Body Moves Vertically and Other Moves Horizontally**

Forces Acting on Body A:

There are two forces acting on body A

- Weight of the body $\mathbf{w_1=m_1g}$ vertically downward
- Tension in the string **T** vertically upward

As the body **A** is moving downward, It means $\mathbf{w_1=m_1g}$ is greater in magnitude so the resultant force acting on body **A** is downward due to which acceleration **a** is produced in it.

Net force acting on body A = $\mathbf{m_1g - T}$

$$F_1 = m_1g - T$$

According to Newton's second law of motion:

$$m_1a = m_1g - T \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Forces Acting on body B:

There are three forces acting on body B

- Weight of the body $\mathbf{w_2=m_2g}$ vertically downward
- Normal reaction of the surface vertically upward
- Tension in the string **T** along the string pulling the body in the horizontal direction over the smooth surface.

As the body **B** is not moving vertically, therefore, vertical forces cancel each other and their resultant is zero. The only remaining force **T** due to which the body **B** is moving in the horizontal direction with acceleration **'a'**.

Hence according to Newton's second law of motion,

$$m_2a = T \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Calculation of Acceleration:

In order to find acceleration in bodies we will add equation (1) and equation (2)

$$m_1a + m_2a = m_1g - T + T$$

$$m_1a + m_2a = m_1g$$

$$(m_1 + m_2)a = m_1g$$

We get equation (3) as:

$$a = \frac{m_1g}{m_1 + m_2}$$

Calculation of Tension:

In order to find the value of T, put the value of a in equation (2), we have

$$T = m_2 \times \frac{m_1g}{m_1 + m_2}$$

$$T = \frac{m_1m_2g}{m_1 + m_2} \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

Result:

By using above arrangements we can find following expressions:

$$a = \frac{m_1g}{m_1 + m_2}$$

$$T = \frac{m_1m_2g}{m_1 + m_2}$$

SHORT QUESTIONS

Q.1 Define Tension in the string. ***(K.B)***

Ans:

TENSION IN THE STRING

Definition:

"The force which is exerted by the string on the body when it is subjected to a pull is called the tension in the string.**"**

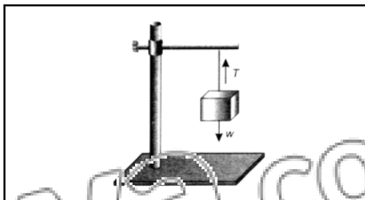


Figure: Tension in the String

Formula:

It is a reaction force of the weight and it is usually denoted by T.

$$T = -w = -mg$$

Unit:

Tension is a force so its S.I unit is newton (N).

Quantity:

Tension is a derived and vector quantity.

Direction:

The weight acts downwards while tension T in the string is acting upwards at the block. If the object is at rest, the magnitude of tension is equal to weight as shown in the figure:

Q.2 What is Atwood Machine? *(K.B+A.B)* **(Do you know PTB Pg. # 65)**

Ans: **ATWOOD MACHINE**

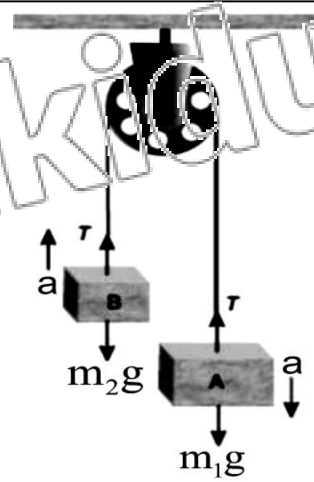


Figure: Atwood Machine Arrangements

Atwood Machine:

The above arrangements are known as Atwood machine. Atwood machine is an arrangement of two objects of unequal masses. Both the objects are attached to the ends of a string. The string passes over frictionless pulley. This arrangement is sometimes used to find the acceleration due to gravity by equation as:

$$g = \frac{m_1 + m_2}{m_1 - m_2} a$$

Q.3 What will be the tension in a rope that is pulled from its ends by two opposite forces 100 N each? *(U.B)* **(Ex. 3.8)**

Ans: **TENSION IN THE STRING**

The tension in a rope that is pulled from its ends by two opposite forces 100 N each will be 100 N.

Q.4 A body of mass 4kg has been hanged vertically with a string what will be tension in the string? *(U.B+A.B)*

Solution:

Given Data:

Mass of the body = m = 4kg

Gravitational Acceleration = g = $10ms^{-2}$

To Find:

Tension in the string = T = ?

Calculations:

We know,

$T = w = mg$

Putting values

$T = (4)(10)$

$T = 40$ N

Result:

Tension in the string is 40 N.

EXAMPLE 3.4

Two masses 5.2 kg and 4.8 kg are attached to the ends of an inextensible string which passes over a frictionless pulley. Find the acceleration in the system and the tension in the string when both the masses are moving vertically. ***(U.B+A.B)***

Solution:

Given Data:

Mass of first body = m_1 = 5.2 kg

Mass of second body = m_2 = 4.8 kg

Gravitational acceleration = g = 10 ms^{-2}

To Find:

Acceleration of the bodies = a = ?

Tension in the string = T = ?

Calculations:

When the two bodies are moving vertically then acceleration of the bodies is as,

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}$$

By putting the values in above equation, we have,

$$a = \frac{(5.2 - 4.8)}{(5.2 + 4.8)} \times 10$$

$$a = \left(\frac{0.4}{10}\right) \times 10$$

$$a = 0.4 ms^{-2}$$

Acceleration of the bodies = 0.4 ms^{-2}

When the two bodies are moving vertically then tension in the string is as,

$$T = \frac{2m_1m_2g}{m_1 + m_2}$$

By putting the values in above equation, we have,

$$T = \frac{2 \times 5.2 \times 4.8}{5.2 + 4.8} \times 10 \Rightarrow T = 50N$$

Tension in the string = 50 N

Result:

Hence, the acceleration of the bodies will be 0.4 ms^{-2} and tension in the string will be 50 N.

EXAMPLE 3.5

Two masses 4 kg and 6 kg are attached to the ends of an inextensible string which passes over a frictionless pulley such that mass 6 kg is moving over a frictionless horizontal surface and the mass 4kg is moving vertically downward. Find the acceleration in the system and the tension in the string. *(U.B+A.B)*

Solution:

Given Data:

Mass of the block moving vertically = m_1 = 4 kg

Mass of the block moving along table = m_2 = 6 kg

Gravitational acceleration = g = 10 ms^{-2}

To Find:

Acceleration of the bodies = a =?

Tension in the string = T =?

Calculations:

When one body is moving vertically and other body is moving horizontally then acceleration of the bodies is as,

$$a = \frac{m_1 g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$a = \frac{4}{4+6} \times 10$$

$$a = 4ms^{-2}$$

Acceleration of the bodies = 4 ms^{-2}

When the two bodies are moving vertically then tension in the string is as,

$$T = \frac{m_1 m_2}{m_1 + m_2} g$$

By putting the values in above equation, we have

$$T = \frac{4 \times 6}{4+6} \times 10 \Rightarrow T = 24N$$

Tension in the string = 24N

Result:

Hence, the acceleration in bodies will be 4 ms^{-2} and tension in the string will be 24 N.

MULTIPLE CHOICE QUESTIONS

1. **How much is the tension produced when one body moves vertically and the other moves horizontally as compared to the tension produced when both bodies move vertically: *(U.B)***
   (A) Half (B) One fourth
   (C) Double (D) Four times
2. **A block of 4 kg is supported by a string. The tension in the string is: *(A.B)***
   (A) 20 N (B) 40 N
   (C) 4 N (D) 0 N
3. **When a block is hanging with the help of a rope then weight of the body is balanced by: *(K.B)***
   (A) Acceleration (B) Inertia
   (C) Displacement (D) Tension
4. **There are how many cases of motion of the body hanging with the help of rope in text book? *(K.B)***
   (A) 1 (B) 2
   (C) 3 (D) 4
5. **Atwood machine is used to find value of? *(A.B)***
   (A) Density (B) Stress
   (C) Gravitational acceleration (D) Gravitational constant

FORCE AND MOMENTUM
LAW OF CONSERVATION OF MOMENTUM

LONG QUESTIONS

Q.1 How you can prove that rate of change in momentum of a body is equal to the applied force? *(K.B+U.B+A.B)*

OR Derive the relation between momentum and force. **(LHR 2015)**

Ans: **FORCE AND MOMENTUM**

Relation:

"Rate of change of Momentum is equal to applied Force**"**

Mathematically:

$$\frac{P_f - P_i}{t} = F$$

Proof:

Suppose a force **'F'** acts on a body of mass **'m'** moving with initial velocity **'v_i'** which produces an acceleration **a** in it. This changes the velocity of body to **'v_f'** after time **t**. If P_i and P_f be the initial momentum and final momentum of the body related to initial and final velocities, then,

Momentum of the body having velocity $v_i = P_i = mv_i$

Momentum of the body having velocity $v_f = P_f = mv_f$

Change in momentum = final momentum – initial momentum

$$P_f - P_i = mv_f - mv_i$$

$$P_f - P_i = m(v_f - v_i)$$

Dividing both sides by "t"

$$\text{Rate of change in momentum} = \frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

$$= m\frac{v_f - v_i}{m}$$

Since $a = \frac{(v_f - v_i)}{t}$

Hence, $\frac{P_f - P_i}{t} = ma$

We know, $F = ma$

$$\frac{P_f - P_i}{t} = F$$

SI unit of momentum defined by above equation is newton-second (Ns) which is the same as $kgms^{-1}$.

Conclusion:

Rate of change of momentum of a body is equal to the applied force on it and the direction of change of in momentum is in the direction of the force.

Newton's Second Law of Motion in Term of Momentum:

From above conclusion we can state Newton's Second law of motion in terms of momentum as

Statement:

"When a force acts on a body, it produces acceleration in the body and will be equal to the rate of change of momentum of the body.**"**

Q.2 State and explain Law of conservation of Momentum. ***(U.B+A.B+K.B)***

GRW 2013, LHR 2014)

Ans: **LAW OF CONSERVATION OF MOMENTUM**

Introduction:

Momentum of a system depends upon mass and velocity. As

$$P = mv$$

System:

A system is a group of interacting bodies with in certain boundaries.

Isolated system:

An isolated system is a group of interacting bodies on which no external force is acting. If no unbalanced or net force acts on a system then its momentum remains constant thus, momentum of an isolated system remains constant.

Statement:

According to Law of Conservation of Momentum:

"The momentum of an isolated system of two or more than two interacting bodies remains constant**"**

Example:

Consider the example of an air-filled balloon. In this case, balloon and the air inside it form a system. Before releasing the balloon, the system was at rest and hence the initial momentum of the system was zero. As soon as the balloon is set free, air escapes out of it with some velocity. The air coming out of it possesses momentum. To conserve momentum, balloon moves in the direction opposite to the air coming out of it.

Mathematical Explanation:

Consider an isolated system of two spheres of masses $\mathbf{m_1}$ and $\mathbf{m_2}$ as shown figure. They are moving in a straight line with initial velocities $\mathbf{u_1}$ and $\mathbf{u_2}$ respectively. As shown in the figure:

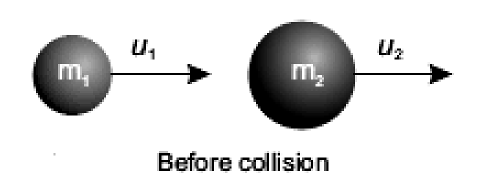


Figure: **Total Momentum of the System $m_1u_1 + m_2u_2$**

Momentum Before Collision:

Initial momentum of mass $m_1 = m_1u_1$

Initial momentum of mass $m_2 = m_2u_2$

Total momentum of the system before collision = $m_1u_1 + m_2u_2$

Suppose $\mathbf{u_1}$ is greater than $\mathbf{u_2}$. Sphere of mass $\mathbf{m_1}$ approaches the sphere of mass $\mathbf{m_2}$ as they move. After sometimes mass $\mathbf{m_1}$ hits $\mathbf{m_2}$ with some force. According to Newton's third law of motion, $\mathbf{m_2}$ exerts an equal and opposite reaction force on **m1**. Let their velocities become $\mathbf{v_1}$ and $\mathbf{v_2}$ respectively after collision.

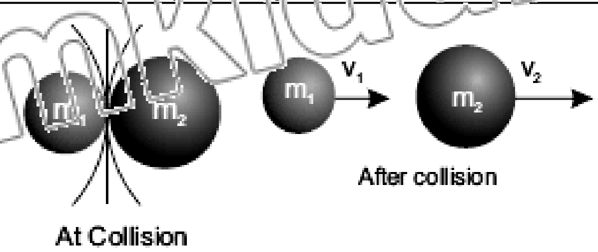


Figure: **Total Momentum of the System $m_1v_1 + m_2v_2$**

Momentum After Collision:

Final momentum of mass $m_1 = m_1v_1$

Final momentum of mass $m_2 = m_2v_2$

Total momentum of the system after collision $= m_1v_1 + m_2v_2$

According to law of conservation of momentum:

$$\begin{bmatrix}\text{Total initial momentum of} \\ \text{the system before collision}\end{bmatrix} = \begin{bmatrix}\text{Total final momentum of the} \\ \text{system after collision}\end{bmatrix}$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Result:

The above equation that the momentum of the isolated system before and after collision remains same which is the law of conservation of momentum.

Q.3 Write a note on applications of Law of Conservation of Momentum. ***(A.B)***

Ans: **APPLICATIONS OF LAW OF CONSERVATION OF MOMENTUM**

Law of Conservation of Momentum is an important law and has vast applications. This law is applicable universally i.e. true not only for bigger bodies but also for atoms and molecules.

Some applications are given below

- **To Find Velocity of The Gun:**

Consider a system of gun and a bullet. Before firing, the velocity of the bullet as well as that of gun was zero. Therefore, the total momentum of both the objects was also zero. We can write it as,

Total momentum of gun and bullet before firing = 0

When the gun is fired, bullet shoots out of the gun and acquire momentum. To conserve momentum the gun recoils backward. Now according to the law of conservation of momentum, the total momentum of the gun and bullet will also be zero after the gun is fired. Let **m** be the mass of the bullet and **v** be its velocity on firing the gun; **M** be the mass of the gun and **V** be the velocity with which it recoils. Thus the total momentum of the gun is fired will be:

Total momentum of the gun and bullet after the gun is fired = M V + m v

According to the law of conservation of momentum:

$$\begin{bmatrix}\text{Total momentum of the gun and the} \\ \text{bullet after the gun is fired}\end{bmatrix} = \begin{bmatrix}\text{Total momentum of the gun and the} \\ \text{bullet before the gun is fired}\end{bmatrix}$$

$$M V + m v = 0$$

OR $$M V = -m v$$

Hence $$V = -\frac{m}{M} v$$

The above equation gives the velocity **V** of the gun. Here negative sign indicates that velocity gun is opposite to the velocity of bullet i.e. the gun recoils. That is why the shoulder pressed hard during firing. Since mass of the gun is much larger than the bullet, therefore, the recoil is much smaller than the velocity of the bullet.

- **To Understand Working of Rockets or Jet Engines:**

Rocket or Jet engine also works on this same principle. In both of them, hot gases are produced due to the burning of fuel. These gases rush out with large momentum. Therefore the rockets or jet engines gain an equal and opposite momentum. This enables them to move with very high velocities.

SHORT QUESTIONS

Q.1 Momentum of a body depends on which factors? *(K.B)*

Ans: *Given on Page # 93*

Q.2 Define an isolated system? *(K.B)*

Ans: *Given on Page # 110*

Q.3 State Law of Conservation of Momentum. *(K.B)*

Ans: *Given on Page # 110*

Q.4 Why is the law of conservation of momentum important? *(K.B)*

Ans: **<u>IMPORTANCE OF LAW OF CONSERVATION OF MOMENTUM</u>**

Law of conservation of momentum is very important in our daily life. It has vast applications and is applicable universally on bigger bodies as well as on atoms and molecules. It helps us to understand:

- Working of a system of gun and bullet,
- Working of rockets and jet engines etc.

Q.5 When a gun is fired, it recoils. Why? *(K.B)*

Ans: **<u>GUN RECOILS</u>**

Total momentum of the gun and the bullet is zero before the firing. When gun is fired, bullet moves in forward direction and attains momentum as a result the gun recoils to conserve momentum according to Law of Conservation of Momentum.

Q.6 Write relation between Force and Momentum. *(K.B)*

Ans: **<u>FORCE AND MOMENTUM</u>**

<u>Relation</u>:

"Rate of change of Momentum is equal to applied Force**"**

<u>Mathematically</u>:

$$\frac{P_f - P_i}{t} = F$$

Q.7 State Newton's Second Law of Motion in terms of Momentum. *(K.B)*

Ans: **<u>NEWTON'S SECOND LAW OF MOTION IN TERMS OF MOMENTUM</u>**

We can state Newton's Second law of motion in terms of momentum as

<u>Statement</u>:

"When a net force acts on a body, it produces acceleration in the body and the net force will be equal to the rate of change of momentum of the body.**"**

<u>Mathematically</u>:

$$\frac{P_f - P_i}{t} = F$$

Q.8 Prove that $kgms^{-1}$ = Ns *(K.B)*

Ans: **<u>PROOF</u>**

As we know that

"Rate of change of Momentum is equal to applied Force**"**

$$\frac{P_f - P_i}{t} = F$$

$$P_f - P_i = F \times t$$

$$m\Delta v = F \times t$$

Putting units, $kgms^{-1} = Ns$

Hence Proved

Q.9 Why are fragile objects packed in Styrofoam rings or polythene sheets with air cavities in it? *(K.B)* **(Useful Information Pg. # 68)**

Ans: **IMPACT TIME**

Fragile objects such as glass wares etc. are packed with suitable materials such as Styrofoam rings, balls, polythene sheets with air sacks etc. Air enclosed in the cavities of these materials makes them flexible and soft. During any mishap, they increase the impact time on fragile objects. An increase in impact time lowers the rate of change of momentum and hence lessens the impact of force. This lowers the possible damage due to an accident.

Q.10 What is role of crumple zones in front and rare part of vehicles? *(K.B)*
(Useful Information Pg. # 68)

Ans: **ROLE OF CRUMPLE ZONES**

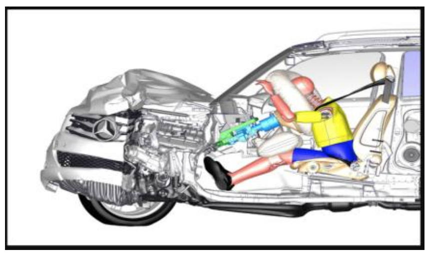


Figure: Crumple Zones Save Life

In an accident at high speed, the impact force is very large due to the extremely short stopping time. For safety purposes, vehicles have rigid cages for passengers with crumple zones at their front and rear ends. During an accident, crumple zones collapse. This increases the impact time by providing extra time for crumpling. Impact of force is highly reduced and saves the passengers from severe injuries.

Q.11 Write role of seat belts. *(K.B)* **(Useful Information Pg. # 69, Ex. 3.18)**

Ans: **ROLE OF SEAT BELTS**

In case of an accident, a person not wearing seatbelt will continue moving until stopped suddenly by something before him. This something may be a windscreen, another passenger or back of the seat in front of him/her. Seatbelts are useful in two ways:

- They provide an external force to a person wearing seatbelt.
- The additional time is required for stretching seat belts. This prolongs the stopping time for momentum to change and reduces the effect of collision.

Q.12 What observation of Newton led to the concept of momentum and second law of motion? *(C.B)*

Ans: Newton noted that, when the same force acted for the same time on different masses, a large mass would gain less velocity than a smaller one, but the change in 'mass × velocity' was the same in every case. It was this observation that led to the concept of momentum and the second law.

Q.13 What is impulse?

Ans: the quantity 'force × time' is called impulses.

Resultant force × time = change in momentum

Resultant force × time = impulse

EXAMPLE 3.6

A body of mass 5 kg is moving with a velocity of 10ms^{-1}. Find the force required to stop it in 2 seconds. *(U.B+A.B)*

Solution:

Given Data:

Mass of the body = m_1 = 5kg

Initial velocity of the body = v_i = 10ms^{-1}

Final velocity of the body = v_f = 0 ms^{-1}

Time to stop the body = t = 2 s

To Find:

Force required to stop = F = ?

Calculations:

We know that,

$$F = m\left(\frac{v_f - v_i}{t}\right)$$

Putting values in formula

$$F = 5\left(\frac{0-10}{2}\right)$$

$$F = \left(\frac{-50}{2}\right)$$

$$F = -25N$$

Result:

Hence, the force required to stop the body will be 25 N.

EXAMPLE 3.7

A bullet of mass 20 g is fired from a gun with a muzzle velocity 100 ms^{-1}. Find the recoil of the gun if its mass is 5 kg. *(U.B+A.B)*

Solution:

Given Data:

Mass of the bullet = m = 20g =0.02kg

Velocity of the bullet = v = 100ms^{-1}

Mass of the Gun = 5kg

To Find:

Recoil of the Gun = V = ?

Calculations:

As we know that

$$V = -\frac{m}{M}v$$

By putting the values, we have

$$V = -\frac{0.2kg(100)ms^{-1}}{5kg}$$

$$V = -0.4ms^{-1}$$

Result:

Hence, negative sign shows that gun recoils with velocity of 4ms^{-1}.

MULTIPLE CHOICE QUESTIONS

1. **Rate of change of momentum is equal to: *(K.B)***

   (A) Force (B) Velocity

   (C) Acceleration (D) Impulse

2. **Direction of the rate of change of momentum is in the direction of: *(K.B)***

   (A) Acceleration (B) Momentum

   (C) Velocity (D) Force

3. **Which of the following is the unit of momentum? *(K.B)***

(A) Nm (B) $kgms^{-1}$

(C) Ns (D) Both b and c

4. Momentum of a moving body depends upon its: *(K.B)*

(A) Mass (B) Velocity

(C) Weight (D) Both a & b

5. Motion of the rocket is an example of: *(A.B)*

(A) First law of motion (B) Law of conservation of Momentum

(C) Law of conservation of Energy (D) Weigh

6. Crumple zones save us from injuries during accidents by: *(K.B)*

(A) Decreasing impact time (B) Increasing impact time

(C) Keeping impact time constant (D) None

3.3 FRICTION

LONG QUESTIONS

3.3 Q.1 Define and explain friction? Write cause of friction and derive its mathematical formula. *(K.B+U.B+A.B)*

Ans: **FRICTION**

Definition:

"The force which opposes the motion of moving objects is called friction.**"**

Factors Effecting the Friction:

Friction is a force that comes into action as soon as a body is pushed or pulled over a surface. In case of solids, the force of friction between two bodies depends upon many factors such as nature of the two surfaces in contact and the pressing force between them.

Example:

Rub your palm over different surfaces such as table, carpet, polished marble surface, brick, etc. You will find smoother is the surface, easier it is to move over the surface. Moreover, harder you press your palm over the surface, more difficult would it be to move.

Cause of Friction:

No surface is perfectly smooth. A surface that appears smooth has pits and bumps that can be seen under microscope. A magnified view of a surface in contact shows the gaps and contacts between them. The contact points between the two surfaces form a sort of **cold welds**. These cold welds resist the surfaces from sliding over each other. Adding weight over the upper block increases the force pressing the surfaces together which increases the resistance. Thus greater is the pressing force greater will be the friction between sliding surfaces.

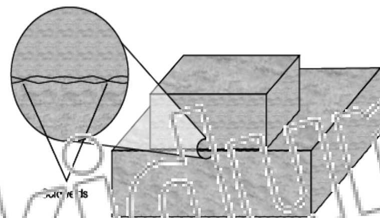


Figure: Formation of Cold Welds Causes Friction

Mathematical Derivation:

Friction is equal to the applied force that tends to move a body at rest. This friction between surfaces at rest is called the static friction. It increases with the applied force. Friction can also be increased to a certain maximum value. It does not increase beyond this. This maximum value of friction is known as force of **limiting friction (Fs)**. It depends on the **normal reaction** (pressing force) between the two surfaces in contact. The ratio between the force of **limiting friction Fs** and the **normal reaction R** is constant. This constant is called the **coefficient of friction** and is represented by **μ**.

$$\mu = \frac{F_s}{R}$$

$$F_s = \mu R$$

If m is the mass of the block, then for horizontal surface;

$$R = mg$$

Hence $$F_s = \mu\, mg$$

Here "**μ**" is constant of proportionality and it is called coefficient of Limiting Friction.

Coefficient of Friction:

As we know,

$$F_s = \mu R$$

And $$\mu = \frac{F_s}{R}$$

Hence we can define coefficient of friction as:

"The ratio between **Limiting Friction (F_s)** and **Normal Reaction (R)** of the surface is constant, this constant is called coefficient of Friction".

Unit:

As it is ratio between two similar quantities so it has no unit.

Value:

Its value depends upon nature of the material.

3.3 Q.2 Define two kinds of a friction. *(Conceptual Base)*

Ans: When the block below is pulled gently, friction stops it moving. As the force is increased, the friction rises until the block is about to slip. This is the starting of static friction. With a greater downward force on the block, the static friction is higher. Once the block starts to slide, the friction drops: moving or dynamic friction is less than static friction.

Dynamic friction heats materials up. When something is moved against the force of friction, its energy of motion (called kinetic energy) is changed into thermal energy (heat). Brakes and other machinery must be designed so that they get rid of this thermal energy. Otherwise their moving parts may become so hot that they seize up.

Static friction is greater than ... .dynamic friction

3.3 Q.3 Explain the rolling friction. ***(K.B)***

Ans: **ROLLING FRICTION**

Definition:

"Friction between surfaces being rolled on each other by using wheel, tyre or ball bearings is called rolling friction."

Wheel as Greatest Invention:

The most important invention in the history of mankind was a wheel. By using wheel we can reduce friction because wheel converts sliding friction into rolling friction.

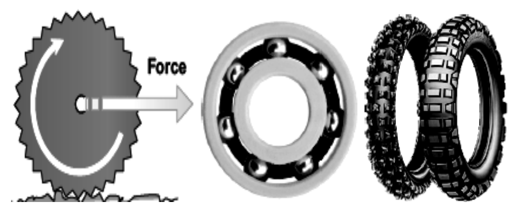


Figure: Friction May Cause the Body to Roll

Less Friction in Rolling Bodies:

When axle of a wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the direction to the applied force. Rolling friction is extremely less than sliding friction due to less **in contact surface area** and less **cold-weld** regions between surfaces. The wheel rolls without rupturing the cold welds. The fact that rolling friction is less than sliding friction is applied in ball bearing to reduce losses due to friction.

Necessary Road Grip:

The wheel would not roll on pushing it if there would be no friction between the wheel and the ground that is provided by threads of the tyres. Thus, friction is desirable for wheels to roll over a surface. It is dangerous to drive on a wet road because the friction between the road and the tyres is very small. This increases the chance of slipping the tyres from the road. The threading of tyres is designed to increase friction. Thus, threading improves road grip and make it safer to drive even on wet road.

Sliding Friction in Brakes:

A cyclist applies brakes to stop his/her bicycle. As soon as brakes are applied, the wheels stop rolling and begin to slide over the road. Since sliding friction is much greater than rolling friction, the cycle stops very quickly.

3.3 Q.4 Explain the roll of friction in Braking and explain the Skidding. ***(K.B)***

Ans: **BRAKING AND SKIDDING**

The wheels of a moving vehicle have velocity components:

- Motion of wheel along the road
- Rotation of wheels about their axis

To move a vehicle on the road as well as to stop a moving vehicle requires friction between its tyres and the road.

Example:
If the road is slippery or the tyres are worn out then the tyres instead of rolling, slip over the road. The vehicle will not move if the wheels start slipping at the same point on the slippery road. Thus for the wheels to roll, the force of friction (gripping force) between the tyres and the road must be enough that prevents them from slipping.
Similarly, to stop a car quickly, a large force of friction between the tyres and the road is needed. But there is a limit to this force of friction that tyres can provide.

Skidding:
If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. It will lose its directional control that may result in an accident. In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speeds. Moreover, it is unsafe to drive a vehicle with worn out tyres.

Figure: A Car Skidding

3.3 SHORT QUESTIONS

Q.1 Define friction? Write cause of friction its formula, unit and direction. ***(K.B+U.B)***
Ans: Given on Page # 115

Q.2 Define coefficient of friction. Write its formula and unit (if any)? ***(K.B)***
Ans: *Given on Page #* 116

Q.3 Write some situations where friction is desirable ***(A.B)***
OR Describe two situations in which force of friction is needed. **(Ex. 3.14)**
Ans: **FRICTION IS DESIRABLE**

Friction plays very important role in our daily life. It is desirable in following situations:

- Friction is needed to walk on the ground. It is risky to run on wet floor with shoes that have smooth soles. Athletes use special shoes that have extraordinary ground grip. Such shoes prevent them from slipping while running fast.
- Friction is desirable for stopping bicycle for that purpose we apply brakes. The rubber pads pressed against the rims provide friction. It is the friction that stops the bicycle.
- Friction is desirable while writing.
- Friction is highly desirable while climbing a hill.

Q.4 Write some situations where friction is undesirable. ***(K.B)***
Ans: **FRICTION IS UNDESIRABLE**

Friction is undesirable in following situations:

- Where we have to move with high speed e.g. while skating we do not need friction.
- Friction is not desirable in those situations, where we have to conserve energy.

Q.5 Write down the advantages and disadvantages of friction. ***(A.B)***
(LHR 2011, 2017, GRW 2011, 2012, GRW 2013)

Ans: **ADVANTAGES AND DISADVANTAGES**

Friction has both advantages and disadvantages. Some of them are given below:

Disadvantages:

- Friction is undesirable when moving at high speed because it opposes the motion and thus limits the speed of the moving objects.
- Most of our useful energy is lost as heat and sound due to the friction between various moving parts of machines.
- In machines, friction also causes wear and tear of their moving parts.

Advantages:

- We write due to presence of friction between paper and pencils.
- Friction enables us to walk on the ground.
- We can tie a knot due to friction
- A nail stays in the wood due to friction.
- Birds can fly, due to air resistance. The reaction of pushed air enables the birds to fly.

Q.6 Write down the methods to reduce friction. ***(K.B)***
OR Describe ways to reduce friction. **(Ex. 3.16, LHR 2013)**

Ans: **METHODS TO REDUCE FRICTION**

The friction can be reduced by:

- Making the sliding friction smooth
- Making the fast moving objects a streamline shape (fish shape) such as car, aero-planes, etc. this causes the smooth flow of air and thus minimizes air resistance at high speeds.
- Lubricating the sliding surfaces.
- Using ball bearings or roller bearings. Because the rolling friction is lesser than the sliding friction.

Q.7 Define Sliding and rolling friction? ***(K.B)***

Ans: **SLIDING FRICTION**

Definition:

"The frictional force opposing the sliding or dragging of one solid body over another solid body is called sliding friction.**"**

ROLLING FRICTION

Definition:

"Friction between surfaces being rolled on each other by using wheel, tyre or ball bearings is called rolling friction".

Q.8 Why Rolling friction is always less than sliding friction why? ***(K.B)***
(Ex. 3.17, LHR 2013, 2014)

Ans: **REASON FOR BEING LESS**

Rolling friction is always less than sliding friction due to less **in contact surface area** and less **cold-weld** regions between surfaces. The wheel rolls without rupturing the cold welds. The fact that rolling friction is less than sliding friction is applied in ball bearing to reduce losses due to friction.

Example:

It is easy to roll a cylindrical eraser on a paper sheet than to slide it because rolling friction is less than sliding friction.

Q.9 Suppose you are running and want to stop at once. Surely you will have to produce negative acceleration in your speed. Can you tell from where does the necessary force come? *(K.B)*

Ans: **FORCE NEEDED TO STOP**

While running when we want to stop at once, we press the ground firmly with our feet. Thus friction comes into play due to relative motion of our feet and ground which acts opposite direction to our motion and it reduces our speed and ultimately we come to stop.

Q.10 Have a look on the figure and answer given Questions. *(K.B)* **(Quick Quiz Pg. # 74)**

Figure: Threated Vs Plain Shoe

1. Which shoe offer less friction?

Ans: **LESS FRICTION**

Shoe with flat sole will offer less friction

2. Which shoe is better for walking on dry track?

Ans: **BETTER FOR WALKING**

On dry track, shoe with flat sole is batter for walking.

3. Which shoe is better for jogging?

Ans: **BETTER FOR JOGGING**

Shoe which has not flat sole is batter for jogging.

4. Which sole will wear out early?

Ans: **WEARING OUT**

Shoe with flat sole will wear out early.

Q.11 **(Quick Quiz PTB Pg. # 75)**

1. Why is it easy to roll a cylindrical eraser on a paper sheet than to slide it?(K.B)

Ans: **ROLLING CYLINDER**

It is easy to roll a cylindrical eraser on a paper sheet than to slide it because rolling friction is less than sliding friction.

2. Do we roll or slide the eraser to remove the pencil work from our notebook?(K.B)

Ans: **SLIDING ERASER**

We slide the eraser to remove the pencil work from our notebook because we need more friction to remove the work and sliding friction is greater than rolling friction.

Q.12 In which case it is easy for the tyre to roll over? *(K.B)*

(i) rough ground (ii) smooth ground

Rough Ground: In case of rough ground it is difficult for the tyre to roll over because rough surface offer more friction.

Smooth Ground: In case of smooth ground it is easier for the tyre to roll over because smooth surface offer less friction.

Q.13 In which case do you need smaller force and why? ***(K.B)***
(i) rolling (ii) sliding

Rolling:

In case of rolling friction we need smaller force because there is contact with earth on only a single point.

Sliding:

In case of sliding friction we need greater force because all the body is in contact with the earth.

Q.14 Many people believes that rolling window down of their car can decrease the fuel consumption as compared to drive with window up and use Ac? ***(C.B)***

Ans: Yes their perception is right but not always. In summer temperature is high generally, so people want to save their fuel because fuel consumption increase in summer. When you are driving with low speed you can roll your car window down because dynamic friction of air is law at low speed and do not use Ac. But when you drive fast than roll window up because dynamic friction of air at that time is maximum and consume more fuel as compared to Ac.

Q.15 Why the body of car make smooth? ***(C.B)***

Ans: Air resistance is a form of dynamic friction. When a car is travelling fast, it is the largest of all the frictional forces opposing motion. Air resistance waste energy, so less air resistance means better fuel consumption. Car bodies are specially shaped to smooth the air flow past them and reduce air resistance. A low frontal area also helps.

Q.16 Why the top of surfboard is rough and down side of the surfboard is smooth? ***(C.B)***

Ans: the top of a surfboard is often given a wax coating. Tiny bumps of wax increase friction by sticking to the surfer's fe4et. However, the underside of a surfboard has a smooth, glassy surface so that it can slide across the water with as little friction as possible.

Q.17 Why do meteoroids (shooting star) burn up in the mesosphere?

Ans: Meteoroids burn up in the mesosphere because of the presence of atmosphere. Due do presence of gases, friction is created and heat is generated causing meteoroids to burn in mesosphere.

3.3 MULTIPLE CHOICE QUESTIONS

1. The force which resists the motion of one surface on another surface is known as: ***(K.B)***
(A) Gravity (B) Friction
(C) Weight (D) Repulsion

2. When object is at rest, the force of friction is known as: ***(K.B)***
(A) Static friction (B) Limiting friction
(C) Kinetic friction (D) Dynamics friction

3. The maximum value of static friction is known as: ***(K.B)***
(A) Static friction (B) Limiting friction
(C) Kinetic friction (D) Dynamics friction

4. When an object is in motion then the force of friction is known as: ***(K.B)***
(A) Static friction (B) Limiting friction
(C) Kinetic friction (D) Dynamics friction

5. Static friction is:
(A) Less than kinetic friction (B) Quartered to kinetic friction
(C) Greater than kinetic friction (D) Equal to kinetic friction

6. Rolling friction is: ***(K.B)***
(A) Less than sliding friction (B) Quartered to sliding friction
(C) Greater than sliding friction (D) Equal to sliding friction

7. The unit of coefficient of friction is: ***(K.B)***
(A) Newton (B) Dynes
(C) No unit (D) Kilogram

8. Friction of liquids is: *(K.B)*
(A) Less than friction of solids
(B) Quartered to friction of solids
(C) Greater than friction of solids
(D) Equal to friction of solids

9. In rolling friction surfaces have less: *(K.B)*
(A) Area of contact
(B) Normal Reaction
(C) Weight
(D) Roughness

10. The rolling friction is: *(K.B)*
(A) 10 times less than sliding friction
(B) 50 times less than sliding friction
(C) 100 times less than sliding friction
(D) 1000 times less than sliding friction

11. Friction in the human joints is much reduced due to the presence of: *(K.B)*
(A) Bones
(B) Muscles
(C) Fluid
(D) Gas

12. Value of coefficient of friction (μ_k) depends upon: *(K.B)*
(A) Nature of the surfaces
(B) Area of contact
(C) Weight
(D) All of above

13. Frictional forces follow which law of motion? *(K.B)*
(A) First
(B) Second
(C) Third
(D) Fourth

14. A spider web remains intact due to: *(K.B)*
(A) Weight
(B) Momentum
(C) Tension
(D) None of these

15. Value of coefficient of static friction (μ_s) is usually: *(K.B)*
(A) Less than μ_k
(B) Quartered to μ_k
(C) Greater than μ_k
(D) Equal to μ_k

16. Sliding friction is commonly converted into rolling friction by the use of: *(K.B)*
(A) Ball bearing
(B) Oil
(C) Grease
(D) Polish

17. The front sides of high speed vehicles, aero planes and ships are shaped wedge like to reduce: *(K.B)*
(A) Weight
(B) Pressure
(C) Speed
(D) Friction

18. The value of coefficient of friction between iron and iron is: *(K.B)*
(A) 1
(B) 0.6
(C) 0.2
(D) 0.62

19. The value of coefficient of friction between tyre and wet road is: *(K.B)*
(A) 1
(B) 0.6
(C) 0.2
(D) 0.62

20. The value of coefficient of friction between tyre and dry road is: *(K.B)*
(A) 1
(B) 0.6
(C) 0.2
(D) 0.62

21. The value of coefficient of friction between wood and wood is: *(K.B)*
(A) 1
(B) 0.6
(C) 0.2
(D) 0.62

22. The value of coefficient of friction between wood and concrete is: *(K.B)*
(A) 1
(B) 0.6
(C) 0.2
(D) 0.62

23. Which of the following material lowers friction when pushed between metal plates?
***(K.B)*(LHR 2014, 2015)**
(A) Water
(B) Fine marble powder
(C) Air
(D) Oil

3.4 UNIFORM CIRCULAR MOTION

LONG QUESTIONS

3.4 Q.1 Define Centripetal force Derive its formula. *(K.B+U.B+A.B)*(GRW 2015, LHR 2015, 2017)

Ans: **CENTRIPETAL FORCE**

Definition:

"Centripetal force is a force that keeps a body to move in circle."

Formula:

Formula of centripetal is given below:

$$F_c = \frac{mv^2}{r}$$

Unit:

Unit of centripetal force is newton (N)

Quantity:

It is a vector and derived quantity

Direction:

It is directed towards centre of the circle perpendicular to the direction of the motion of the body at any point.

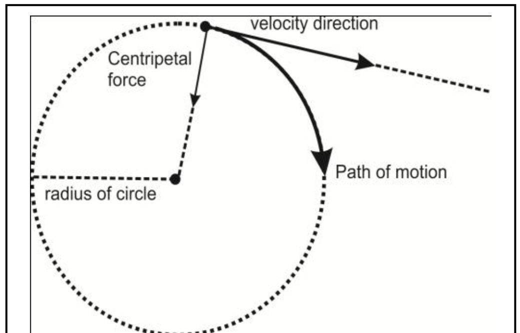


Figure: Motion Under Centripetal Force

Derivation of Formula:

Let a body of mass **m** moves with uniform speed **v** in a circle of radius **r** as shown in the figure:

The acceleration a_c produced by the centripetal force F_c is given by

Centripetal acceleration $a_c = \frac{v^2}{r}$

According to Newton's second law of motion, the centripetal force F_c is given by,

$$F_c = ma_c$$

$$F_c = \frac{mv^2}{r}$$

Factors:

Centripetal force depends upon following factors

Mass of the Object:

If we double the mass of the body, required centripetal force to compel it to move in circular path will become double.

Radius of the Circular:

If we double the radius of the circle, required centripetal force to compel the body to move in circular path will become half.

Speed of the body:

If we double the speed of the body, required centripetal force to compel the body to move in circular path will become four times greater.

Examples:

- The moon revolves around the Earth in circular path, the required centripetal force is provided by the gravitational pull of the Earth.
- A stone tied with string, whirled in circular path is compelled to move in circular path by centripetal force provided by our muscles via string.

- While the coaster cars move around the loop, the track provides centripetal force preventing them to move away from the circle.

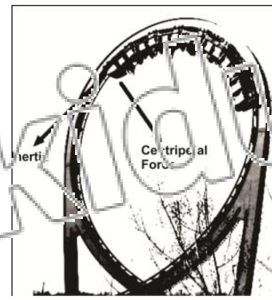


Figure: **Coaster Cars Working Under Centripetal Force**

3.4 Q.2 Define and explain Centrifugal force. Is it a reaction of centripetal force? *(U.B+K.B)*
(GRW 2014)

Ans: **CENTRIFUGAL FORCE**

Definition:

"A force which compels the body to move away from circular path is known as centrifugal force".

Formula:

It is reaction of centripetal force.
Formula of centripetal is given below:

$$F_r = \frac{mv^2}{r}$$

Unit:

Unit of centrifugal force is newton (N)

Quantity:

It is a vector and derived quantity

Direction:

It is directed away from the centre of the circle perpendicular to the direction of the motion of the body at any point.

Example:

Consider a stone tied with a string moving in a circle. The necessary centripetal force acts on the stone through the string that keeps it in the move in a circle. According to Newton's third law of motion, there exists a reaction to centripetal force. Centripetal reaction that pulls the string outward is sometimes the centrifugal force.

3.4 SHORT QUESTIONS

Q.1 Define circular motion. *(K.B)*

Ans: **CIRCULAR MOTION**

Definition:

"Motion of the body moving in the circular path is known as circular motion."

Examples:

- The motion of the moon around the Earth is nearly in circular orbit.
- The paths of electrons moving around the nucleus in an atom are also nearly circular.
- Motion of the stone tied with the string

Figure: Examples of Circular Motion

Q.2 Can a body move with uniform velocity in a circle? If not, why? *(K.B)*

Ans: **NO UNIFORM VELOCITY IN CIRCLE**

When a body is moving in circle it may have uniform speed but its velocity is non-uniform because direction of the body is changing at every instant

Q.3 Define centripetal acceleration. *(K.B)*

Ans: **CENTRIPETAL ACCELERATION**

Definition:

"The acceleration produced by the centripetal force in a body moving in circular path is known as centripetal acceleration."

Formula:

It is represented by a_c. and its formula can be derived as:

We know,

$$F_c = \frac{mv^2}{r}$$

According to Newton's 2nd Law of Motion F= ma

So, $F_c = ma_c$

So, Centripetal Force is given by,

$$ma_c = \frac{mv^2}{r}$$

$$a_c = \frac{v^2}{r}$$

Unit:

Its unit is ms^{-2}

Q.4 Why centripetal acceleration acts towards the centre? *(Conceptual Base)*

Ans: The centripetal acceleration acts towards the centre because velocity is speed in a particular direction so a change in velocity can mean either a change in speed or a change in direction. If something has a changing velocity, then it has acceleration-in the same direction as the force. So, with circular motion, the acceleration is towards the centre of the circle. It may be difficult to imagine something accelerating towards a point without getting closer to it, but the object is always moving inwards from the position it would have had if traveling in a straight line.

Q.5 Why outer edge of the road is kept higher than inner edge (banking of road)? Explain. *(K.B+A.B)* **(LHR 2013)**

Ans: **BANKING OF THE ROADS**

When a car takes a turn, centripetal force is needed to keep it in its curved track. The friction between the tyres and road provides the necessary centripetal force. The car would skid away if the force of friction between the tyres and the road is not sufficient enough particularly when the roads are wet. This problem is solved by banking of curved roads.

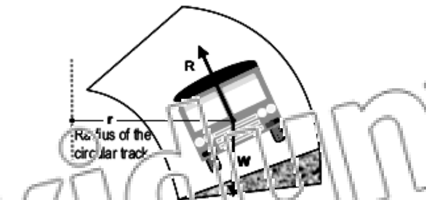


Figure: Outer Edge of the Curved Road is Elevated to Prevent Skidding

Banking of a road means that the outer edge of a road is raised. Banking causes a component of vehicle's weight to provide the necessary Centripetal force while taking a turn. Thus banking of road prevents skidding of vehicle and thus makes the driving safe.

Q.6 Why cyclists bend himself toward the inner side of the curved path while taking turn with high speed? *(U.B+A.B)*

Ans: **BENDING OF CYCLISTS**

A cyclist bend himself toward the inner side of the curved path while taking turn with high speed to provide necessary centripetal force with his weight to take turn in circular path to avoid slipping.

Q.7 Can a body move along a circle without the centripetal force? *(K.B)*

Ans: **CIRCULAR MOTION AND CENTRIPETAL FORCE**

When a body moves in a circular path, it does so under the action of centripetal force. This force is directed towards the center along the radius of the circle. As the radius is perpendicular to the tangent of the circle, the centripetal force keeps the body in circular path. Thus, in absence of centripetal force, the body cannot move in a circular path.

Q.8 Moon revolves around the earth, from where it gets necessary centripetal force? *(K.B)*

Ans: **CENTRIPETAL FORCE ON MOON**

The gravitational force between the earth and the moon provides the necessary centripetal force to moon for revolving around the earth.

Q.9 Define centrifuge? *(K.B)*

Ans: **CENTRIFUGE**

Definition:

"All devices that work on the principle of centrifugal force is called centrifuge."

Examples:

Following are important centrifuge machines:

- Washing machine dryer
- Cream separator

Q.10 Explain the function of washing machine (dryer). *(A.B)*

OR Why the spinner of washing machine is made to spin at very high speed? **(Ex. 3.20)**

Ans: **WASHING MACHINE DRYER**

Construction:

The dryer of a washing machine is basket spinner. They have perforated wall having large numbers of fine holes in the cylindrical rotor. The lid of the cylindrical container is closed after putting wet clothes in it.

Figure: Washing Machine Dryer

Working:

- It works on the principle of centrifuge Machine.
- When it spins at high speed, the water from wet clothes is forced out through these holes due to lack of centripetal force.

Q.11 Explain the function of cream separator. *(A.B)*

Ans:

CREAM SEPARATOR

Construction:

Most modern plants use a separator to control the fat contents of various products. A separator is a high – speed spinner. It consists of a bowl.

Working:

- It acts on the same principle of centrifuge machine.
- The bowl spins at very high speed causing the heavier contents of the milk to move outwards in the bowl pushing the lighter contents inwards towards the spinning axis. Cream or butterfat is lighter than other components in the milk. Therefore, skimmed milk, which is denser than cream is collected at outer wall of the bowl. The lighter part (cream) is pushed towards the center from where it is collected through a pipe.

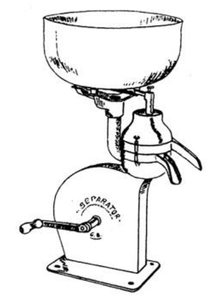


Figure: A Cream Separator

EXAMPLE 3.8

A stone of mass 100 g is attached to a string 1m long. The stone is rotating in a circle with a speed of 5 ms^{-1}. Find the tension in the string.(U.B+A.B)

Solution:

Given Data:

Mass of the body = m = 100g = 0.1 kg

Radius of the circle = r = 1 m

Speed of the body = v = 5 ms^{-1}

To Find:

Tension in the string = $T = F_c = ?$

Calculations:

In this case tension in the string will provide necessary centripetal force.
As we know that,

$$T = F_c = \frac{mv^2}{r}$$

By putting the values, we have

$$T = F_c = \frac{0.1(5)^2}{1}$$

$$T = F_c = 2.5\text{N}$$

Result:

Hence, the tension in the String will be 2.5 N.

MULTIPLE CHOICE QUESTIONS

1. **In circular motion, the motion of every particle of body is: *(K.B)***
(A) Different (B) Opposite
(C) Same (D) None of these

2. **The force which compels a body to move in circle is: *(K.B)***
(A) Centripetal force (B) Centrifugal force
(C) Perpendicular force (D) Tension

3. **If the velocity of a moving body in a circle is doubled, then its centripetal force is *(A.B)***
(A) Double (B) Half
(C) Four times (D) Remain

4. **The centripetal acceleration is always along: *(K.B)***
(A) Normal forces (B) Centripetal force
(C) Mass (D) Horizontal force

5. **If centripetal force acting on a body is doubled then its velocity will become: *(A.B)***
(A) Double (B) Opposite
(C) Half (D) Four times

MCQ'S ANSWER KEY (TOPIC WISE)

3.1 FORCE, INTERTIA AND MOMENTUM

1	2	3	4	5	6	7	8
A	C	B	C	A	B	C	C

3.2 NEWTON'S LAWS OF MOTION

1	2	3	4	5	6	7	8	9	10	11	12
B	B	A	C	A	B	B	A	B	C	B	A
13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
C	C	D	C	D	A	C	A	B	C	D	D
25	**26**	**27**	**28**								
A	D	A	B								

TENSION AND ACCELERATION IN STRING

1	2	3	4	5
A	B	D	B	C

FORCE AND MOMENTUM
LAW OF CONSERVATION OF MOMENTUM

1	2	3	4	5	6
A	D	D	D	B	B

3.3 FRICTION

1	2	3	4	5	6	7	8	9	10	11	12
B	A	B	D	C	A	C	A	A	C	C	D
13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	
C	C	C	A	D	A	C	A	B	D	D	

3.4 UNIFORM CIRCULAR MOTION

1	2	3	4	5
C	A	C	B	D

TEXT BOOK EXERCISE

MULTIPLE CHOICE QUESTIONS

Encircle the correct answer from the given choices.

i. Newton's first law of motion is valid only in the absence of. *(K.B)*(LHR 2014, GRW 2015)

(a) force (b) net force
(c) friction (d) momentum

ii. Inertia depends upon: *(K.B)* (LHR 2017)

(a) force (b) net force
(c) mass (d) velocity

iii. A boy jumps out of a moving bus. There is a danger for him to fall: *(K.B)* (LHR 2017)

(a) towards the moving bus (b) away from the bus
(c) in the direction of motion (d) opposite to the direction of motion

iv. A string is stretched by two equal and opposite forces of 10 N each. The tension in the string is: *(A.B+U.B)*

(a) Zero (b) 5 N
(c) 10 N (d) 20 N

v. The mass of a body: *(K.B)*

(a) decreases when accelerated (b) increases when accelerated
(c) decreases when moving with high velocity (d) none of the above

vi. Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulling such that both move vertically. The acceleration of the bodies is: *(K.B)*

(a) $a = \frac{(m_1 - m_2)g}{m_1 + m_2}$ (b) $a = \frac{m_1 g}{m_1 + m_2}$

(c) $a = \frac{(m_1 + m_2)g}{m_1 - m_2}$ (d) $a = \frac{m_2 g}{m_1 + m_2}$

vii. Which of the following is the unit of momentum? *(K.B)* (GRW 2013, LHR 2015)

(a) Nm (b) $kgms^{-2}$
(c) Ns (d) Ns^{-1}

viii. When horse pulls a cart, the action is on the: *(K.B)* (GRW 2017)

(a) cart (b) earth
(c) horse (d) earth and cart

ix. Which of the following material lowers friction when pushed between metal plates? *(K.B)* (LHR 2014, 2015)

(a) water (b) fine marble powder
(c) air (d) oil

ANSWER KEY

i	ii	iii	iv	v	vi	vii	viii	ix
b	c	c	c	d	a	c	b	d

3.1 Define the following terms: ***(K.B)***

i) Inertia **ii) Momentum** **iii) Force**

iv) Force of friction **v) Centripetal force**

3.2 What is difference between: ***(K.B)***

(i) Mass and weight

(ii) Action and reaction

(iii) Sliding friction and rolling friction

Ans: *Given on the previous pages*

3.4 What is the law of inertia?

Ans: *Given on the previous pages* #94

3.5 Why is it dangerous to travel on the roof of a bus? ***(K.B)***

Ans:

TRAVELLING ON THE ROOF

It is dangerous to travel on the roof of a bus because when brakes are applied suddenly, the lower part of body of passenger sitting on its roof comes to rest immediately but due to inertia upper part of his body continues its motion in a straight line and he may fall forward and gets injured if there is no support.

3.6 Why does a passenger move outward when a bus takes a turn? ***(K.B)***

Ans:

OUT WARD MOTION

When a moving bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

3.7 How can you relate a force with the change of momentum of a body? ***(K.B)***

Ans: See Q.no.6 Long Question

3.8 What will be the tension in a rope that is pulled from its ends by two opposite forces 100 N each? ***(U.B)***

Ans:

TENSION IN THE ROPE

The tension in a rope that is pulled from its ends by two opposite forces 100 N each will be 100 N.

3.9 Action and reaction are always equal and opposite then how does a body move? ***(K.B)***

Ans:

ACTION AND REACTION

Action and reaction are equal in magnitude but opposite in direction. Action and reaction do not act on the same body. Action is applied on one body due to which an equal and opposite reaction is acting on another body. Both of these do not neutralize each other due to which the body will move.

3.10 A horse pushes the cart. If the action and reaction are equal and opposite then how does the cart move? ***(U.B)***

Ans:

MOTION OF THE CART

Yes, Action and reaction are equal in magnitude but are opposite in direction but they do not cancel each other because they act on two different bodies.

The horse apply action on the road by his feet, the reaction is given by the road on the horse, due to which horse moves. The cart which is tied with the horse will also move.

3.11 What is the law of conservation of momentum? ***(K.B)***

Ans: *Given on page # 110*

3.12 Why is the law of conservation of momentum important? ***(K.B+A.B)***

Ans:

LAW OF CONSERVATION OF MOMENTUM

Importance:

Law of conservation of momentum has vast applications and is applicable universally on bigger bodies as well as on atoms and molecules. A system of gun and bullet, rocket and jet engines etc. work on the Principle of law of conservation of momentum. This law helps us to understand variations in quantity of motion of different bodies.

3.13 When a gun is fired, it recoils. Why? *(K.B)*

Ans: *Given on the previous pages # 111*

3.14 Describe two situations in which force of friction is needed? *(K.B)*

Ans: *Given on the previous pages # 118*

3.15 How does oiling the moving parts of a machine lower friction? *(K.B)* **(GRW 2017)**

Ans: **OILING LOWERS FRICTION**

As the friction of liquids is less than friction of solids. So oiling the moving parts of the machines lower the friction. Oil makes cold weld loose by making pits and bumps slippery hence oiling lowers friction.

3.16 Describe ways to reduce friction. *(K.B)* **(LHR 2014)**

Ans: *Given on page # 119*

3.17 Why rolling friction is less than sliding friction? *(K.B)* **(LHR 2013, 2014)**

Ans: *Given on page # 119*

3.18 What you know about the following: *(K.B)*

(i) Tension in the string **(TOPIC TENSION AND ACCELERATION IN THE STRING SHORT QUESTION#1)**

(ii) Limiting force of friction **(TOPIC 3.3 FRICTION LONG QUESTION#1)**

(iii) Braking force **(TOPIC 3.3 FRICTION LONG QUESTION#3)**

(iv) Skidding of vehicles **(TOPIC 3.3 FRICTION LONG QUESTION#3)**

(v) Seatbelts **(TOPIC FORCE AND MOMENTUM SHORT QUESTION#11)**

(vi) Banking of roads **(TOPIC 3.4 UNIFORM CIRCULAR MOTION SHORT QUESTION#4)**

(vii) Cream separator **(TOPIC 3.4 UNIFORM CIRCULAR MOTION SHORT QUESTION#10)**

3.19 What would happen if all friction suddenly disappears? *(K.B)*

Ans: **FRICTION SUDDENLY DISAPPEARS**

If all friction suddenly disappears the movement will become uncontrollable. The balance of natural forces will be disturbed and the whole system will collapse.

3.20 Why the spinner of washing machine is made to spin at very high speed? *(K.B)*

Ans: **SPINNER OF WASHING MACHINE**

Spinner of washing machine is made to spin at high speed because water is to be thrown out of wet clothes through perforated walls. Water moves out due to lack of centripetal force. As we know,

$$F_c = \frac{mv^2}{r}$$

This formula indicates that when speed will be high more centripetal force will be required to make the water particles to move in circles hence due to lack of centripetal force water moves out through perforated walls.

NUMERICAL PROBLEMS (U.B + A.B)

3.1 A force of 20 N moves a body with an acceleration of 2 ms^{-2}. What is it its mass? **(LHR 2013)**

Solution:

Given Data:

Force acting on the body = F = 20 N

Acceleration of the body = a = 2 ms^{-2}

To Find:

Mass of the body = m =?

Calculations:

From Newton's second law of motion

$$F = ma$$

So $$m = \frac{F}{a}$$

By putting the values, we have

$$m = \frac{20}{2}$$

$$m = 10 \text{ kg}$$

Result:

Hence, mass of the body will be 10 kg.

3.2 The weight of a body is 147 N. What is its mass? **(LHR 2013, 2015)**

Solution:

Given Data:

Weight of the body = w = 147 N

Gravitational acceleration = g = 10 ms^{-2}

To Find:

Mass of the body = m = ?

Calculations:

As we know that

w = mg

So $m = \frac{w}{g}$

By putting the values, we have

$m = \frac{147}{10}$

m = 14.7 kg

Result:

Hence, the mass of the body will be 14.7 kg.

3.3 How much force is needed to prevent a body of mass 10 kg from falling?

Solution:

Given Data:

Mass of the body = 10 kg

Gravitation acceleration = g = 10 ms^{-2}

To Find:

Force required to prevent the body from falling = R = ?

Calculations:

As we know that in stable position,

R = w = mg

By putting the values, we have

R = w = 10 x 10

R = 100 N

Result:

Hence, the force required to prevent the body from falling will be 100 N.

3.4 Find the acceleration produced by a force of 100 N in a mass of 50 kg. **(GRW 2013)**

Solution:

Given Data:

Force acting on the body = F = 20 N

Mass of the body = m = 50 kg

To Find:

Acceleration of the body = a = ?

Calculations:

From Newton's second law of motion

F = ma

So $a = \frac{F}{m}$

By putting the values, we have

$a = \frac{100}{50}$

a = 2 ms^{-2}

Result:

Hence, the acceleration produced will be 2 ms^{-2}.

3.5 A body has weight 20 N. How much force is required to move it vertically upwards with an acceleration of 2 ms^{-2}.

Solution:

Given Data:

Weight of the body = 20 N

Acceleration of the body = a = 2 ms^{-2}

Gravitational acceleration = g = 10 ms^{-2}

Normal reaction = R = w = 20 N

To Find:

Force acting on the body moving vertical upward = F =?

Calculations:

As we know that

w = mg

So $m = \frac{w}{g}$

By putting the values, we have

$m = \frac{20}{10} \Rightarrow m = 2\ kg$

From Newton's second law of motion

F = ma

By putting the values, we have

F = 2 x 2 $\Rightarrow$ F = 4 N

Now net force required to move the body upward = normal reaction + force producing acceleration

= 20 N + 4 N $\Rightarrow$ 24 N

Result:

Hence, the force acting on the body moving vertical upward will be 24 N.

3.6 Two masses 52 kg and 48 kg are attached to the ends of a string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies.

Solution:

Given Data:

Mass of first body = m_1 = 52 kg

Mass of second body = m_2 = 48 kg

Gravitational acceleration = g = 10 ms^{-2}

To Find:

Acceleration of the bodies = a = ?

Tension in the string = T = ?

Calculations:

When the two bodies are moving vertically then acceleration of the bodies is as,

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$a = \frac{(52 - 48) \times 10}{52 + 48}$$

$$a = \frac{40}{100} \Rightarrow a = 0.4\ ms^{-2}$$

Acceleration of the bodies = 0.4 ms^{-2}

When the two bodies are moving vertically then tension in the string is as,

$$T = \frac{2m_1m_2g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$T = \frac{2 \times 52 \times 48 \times 10}{52 + 48} \Rightarrow T = \frac{49920}{100}$$

T = 499.2 N = 500 N

Tension in the string = 500 N

Result:

Hence, the acceleration in and tension and tension will be 0.4 ms^{-2} and 500 N respectively.

3.7 Two masses 26 kg and 24 kg are attached to the ends of a string which passes over a frictionless pulley. 26 kg is lying over a smooth horizontal table. 24 kg mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies.

Solution:

Given Data:

Mass of the block moving vertically = $m_1 = 24$ kg

Mass of the block moving along table = $m_2 = 26$ kg

Gravitational acceleration = g = 10 ms^{-2}

To Find:

Acceleration of the bodies = a = ?

Tension in the string = T = ?

Calculations:

When one body is moving vertically and other body is moving horizontally then acceleration of the bodies is as,

$$a = \frac{m_1 g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$a = \frac{24\times10}{24+26}$$

$$a = \frac{240}{50} \Rightarrow a = 4.8\ ms^{-2}$$

Acceleration in bodies = 4.8 ms^{-2}

When the two bodies are moving vertically then tension in the string is as,

$$T = \frac{m_1 m_2 g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$T = \frac{24\times26\times10}{24+26}$$

$$T = \frac{6240}{50} \Rightarrow T = 124.8\ N = 125\ N$$

Tension in the string = 125 N

Result:

Hence, acceleration in bodies will be 4.8 ms^{-2} and tension in the string will be 125 N.

3.8 How much time is required to change 22 Ns momentum by a force of 20 N?

(LHR 2014)

Solution:

Given Data

Change in momentum = ΔP = 22 Ns

Force applied = F = 20 N

To Find:

Time required = t = ?

Calculations:

As we know that, $F = \frac{\Delta p}{t} \Rightarrow t = \frac{\Delta p}{F}$

By putting the values, we have

$$t = \frac{22}{20} \Rightarrow t = 1.1 s$$

Result:

Hence, the time required to change the momentum of the body will be 1.1 s.

3.9 How much is the force of friction between a wood block of mass 5 kg and the horizontal marble floor? The coefficient of friction between wood and marble is 0.6.

Solution:

Given Data:

Mass of the block = m = 5 kg

Coefficient of friction = μ_s = 0.6

To Find:

Force of friction = F_s = ?

Calculations:

As we know that

$$F_s = \mu_s mg$$

By putting the values, we have

$$F_s = 0.6 \times 5 \times 10$$

$$F_s = 30 \text{ N}$$

Result:

Hence, the force of friction between a wooden block and horizontal marble floor will be 30 N.

3.10 How much centripetal force is needed to make a body of 0.5 kg to move in a circle of radius 50 cm with a speed of 3 ms^{-1}? (LHR 2012)

Solution:

Given Data:

Mass of the body = m = 0.5 kg

Radius of the circle = r = 50 cm = 0.5 m

Speed of the body = v = 3 ms^{-1}

To Find:

Centripetal force = F_c = ?

Calculations:

As we know that

$$F_c = \frac{mv^2}{r}$$

By putting the values, we have

$$F_c = \frac{0.5 \times (3)^2}{0.5}$$

$$F_c = 9 \text{ N}$$

Result:

Hence, the centripetal force needed, will be 9 N.

SELF TEST

Time: 40 min. **Marks: 25**

Q.1 Four possible answers (A), (B), (C) & (D) to each question are given, mark the correct answer. **(6×1=6)**

1. Newton's first law of motion is valid only in the absence of:
(A) Force (B) Net force
(C) Friction (D) Momentum

2. Inertia depends upon:
(A) Force (B) Net force
(C) Velocity (D) Mass

3. A block of 4 kg is supported by a string. The tension in the string is:
(A) 20 N (B) 40 N
(C) 4 N (D) 0 N

4. Rate of change of momentum is equal to:
(A) Force (B) Velocity
(C) Acceleration (D) Impulse

5. When object is at rest, the force of friction is known as:
(A) Static friction (B) Limiting friction
(C) Kinetic friction (D) Dynamics friction

6. In circular motion, the motion of every particle of body is:
(A) Different (B) Opposite
(C) Same (D) None of these

Q.2 Give short answers to following questions. **(5×2=10)**

i. A lead shot of mass 5g is fired with an air gun. If the velocity of the shot is 60 ms^{-1}. What is its Momentum?
ii. An inflated balloon shoots off when its air is released. Why?
iii. Why is it hard to stop fast moving and heavy vehicles?
iv. A body of mass 5 kg is moving with a velocity of 10 ms^{-1}. Find the force to stop it in 2 s.
v. What is centripetal force? Write its dependence.

Q.3 Answer the following questions in detail. **(4+5=9)**

a) State and Explain law of conservation of momentum.
a) A stone of mass 100 g is attached to a string 1m long. The stone is rotating in a circle with a speed of 5 ms^{-1}. Find the tension in the string.

<u>Note</u>:
Parents or guardians can conduct this test in their supervision in order to check the skill of students.