MILITARY TECHNOLOGICAL COLLEGE

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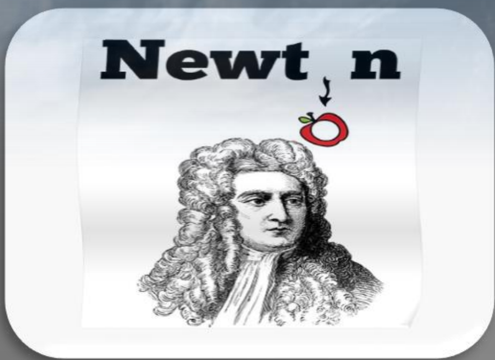

PHYSICS

WORKBOOK-2 **MODULE CODE-MTCG1017**

Term: 2 AY: 2023-2024 FPD

MILITARY TECHNOLOGICAL COLLEGE

Delivery Plan Year 2023-24 [Term 2]

Title / Module Code / Programme	Physics / MTCG1017/Foundation Programme Department (FPD)	Module Coordinator	Dr. Karim Sellami
Lecturers	TBA	Resources & Reference books	Moodle & Workbooks
Duration & Contact Hours	Term 2: 6 hrs. × 11weeks = 66 hrs.		

Week No.	Topics	Hours	Learning Outcome No.
1	**1. Units and unit conversions** 1.1. System of units, base and derived units 1.2. Unit conversions	2	1
	2. Nature of matter 2.1. Matter 2.2. States of matter (solid, liquid gas and plasma), and change of states. 2.3. Structure of an atom: shell, nucleus, electrons 2.4. Chemical Compounds 2.5. Periodic Table	4	
2	**3. Classification of physical quantities** 3.1 Scalar & Vector quantities 3.2 Vector representation in Cartesian plane 3.3 Properties of vectors 3.4 Vector addition and subtraction	4	
	4. Linear Motion 4.1 Distance and displacement 4.2 Speed and velocity 4.3 Accelerated Motion	2	2
3	4.4 Kinematic Equations of motion. 4.5 Motion under the influence of gravity	2	
	5. Force, momentum and impulse 5.1. Fundamental Forces 5.2. Types of Forces (Contact and Non-Contact Forces) 5.3. Mass and weight 5.4. Newton's 1^{st} Law and its application: Equilibrium **Revision Continuous Assessment-1**	4	
	Continuous Assessment-1 (Chapters 1 to 4)		**1**

4	5.5. Newton's 2^{nd} law and its application: Acceleration 5.6. Newton's 3^{rd} law and its application 5.7. Linear Momentum and Impulse 5.8. Conservation of linear momentum 5.9. Friction-Kinetic and Static Friction	2	2
	6. Work, Energy and Power 6.1 Work and Energy 6.2 Types of Mechanical Energy 6.3 Law of Conservation of Energy 6.4 Power	4	
5	6.5 Machines 6.6 Velocity ration, mechanical advantage and efficiency **7. Rotational Motion** 7.1. Linear and angular velocity 7.2. Uniform Circular Motion & Centripetal force 7.3. Moment of Force (Torque)	6	
6	7.4. Moment of Inertia 7.5. Angular Momentum a. Conservation of angular momentum **b.** Gyroscope	4	
	8. Solids 8.1. Hooke's law Stress, Strain and Young's Modulus **Revision Continuous Assessment-2**	2	3
	Continuous Assessment-2 (Chapters 5 to 8)		2
7	**9. Fluids** 9.1. Fluid statics a. Density b. Relative density c. Hydrometer d. Adhesion e. Cohesion f. Pressure in liquids g. Absolute and gauge pressure h. Measurement of pressure	4	3
	Lab Experiment	2	7
8	i. Buoyancy and Archimedes' Principle j. Pascal's law 9.2 Fluid dynamics a. Types of fluid b. Viscosity	6	3

	c. Fluid resistance and aerodynamic drag d. Bernoulli's Principle & Applications of Bernoulli's Principle **10. Thermodynamics** 10.1. Heat, Temperature, and Temperature Scales		
	Lab Experiment (continuation)		7
9	10.2. Calorimetry a. Specific heat capacity b. Latent Heat 10.3. Types of Heat Transfer 10.4. Thermal Expansion 10.5. Ideal Gas Law	6	4
10	10.6 Laws of Thermodynamics **11. Wave Motion and Sound** 11.1. Waves a. Anatomy of waves Types of waves 11.2. Standing waves 11.3. Fundamental frequency and harmonics 11.4. Sound waves	6	6
11	**12. Optics** 12.1. Introduction to light 12.2. Law of reflection and refraction 12.3. Critical Angle and Total internal reflection 12.4. Fibre Optics **Revision for Final Exam**	6	5
12	**FINAL EXAM (Chapter-9 to Chapter-12)**		**2, 3, 4, 5, 6 & 7**
	Total Hours	**66**	

Indicative Reading

#	Title/Edition/Author	ISBN
1	Advanced Level Physics -7th Edition, 1986 By Michael Nelkon and Philip Parker	ISBN-13 : 978-0435923037 ISBN-10 : 043592303X
2	Physics-5th Edition, 2016 by Walker S. James	ISBN-13: 978-0321- 97644-4 ISBN-10: 0-321- 97644-4
3	Advanced Physics for You –2nd Edition, 2015 by Keith Johnson, Simmone Hewett, Sue Holt, John Miller	ISBN: 9780198355991
4	College Physics-11th Edition,2017 By Raymond A. Serway, Jerry S. Faughn	ISBN-13: 978-1305952300 ISBN-10: 9781305952300

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Module Coordinator	**Deputy Head FPD**	**Head FPD**

Contents

Chapter-5: Forces

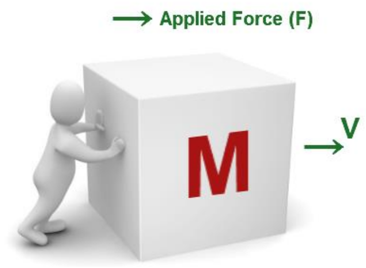


Fig-5.1, Force moving a body

A force is "a physical quantity which makes the body to move or tries to move." It is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force. Forces only exist as a result of an interaction.

5.1 Fundamental Forces

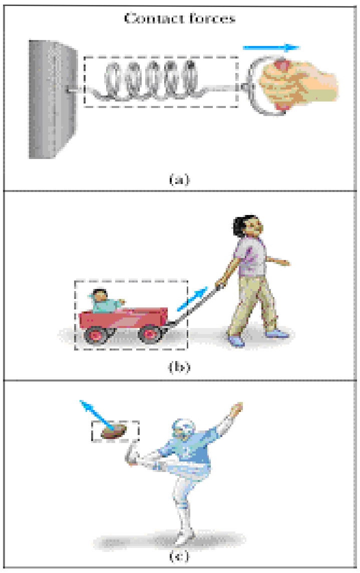


Figure 5.2. Examples of Contact Force

There exist four fundamental forces in nature, which are known as field forces. These are listed below in the order of decreasing strength:

Strong nuclear force – force that exist and binds protons and neutrons in the nucleus of an atom.

Electromagnetic forces – force between electric charges.

Weak nuclear forces - exists in certain radioactive decay processes.

Gravitational force – force of attraction between objects.

5.2 Types of Forces

Contact forces: A contact force results from a physical contact between two objects.

Examples of contact forces are:

If we pull on a spring the spring stretches as in fig-5.2.a.

A child is pulled by a lady fig-5.2.b.

When a football is kicked it is deformed and set in motion fig-5.2.c.

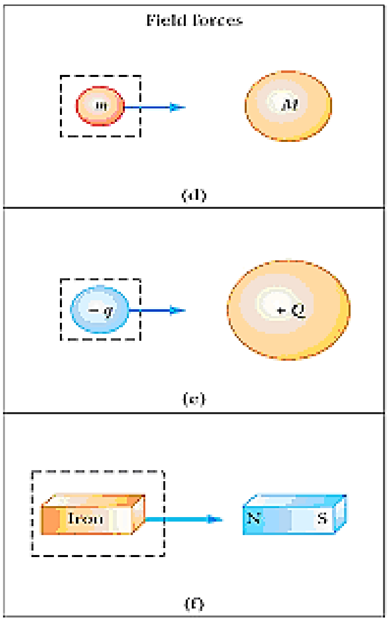


Fig-5.3. Examples of Non-contact Force

Field (non-contact) forces: No physical contact between two objects. Michael Faraday had introduced the concept of the field in electricity.

Examples of field (non-contact) forces:

Gravitational field force, is the force of gravitational attraction between two objects, as shown in Fig-5.3.d.

Electric filed force, is the force that one electric charge exerts on another electric charge as shown in Fig-5.3.e.

Magnetic field force, is the force when you bring a magnet near a piece of iron, the iron piece is attracted as shown in Fig-5.3.f. While the two similar poles of magnet move away from each other.

5.3 Mass and Weight

Mass (m**)**

The mass of an object is the amount (quantity) of matter it contains. The more the matter an object contains, the greater will be its mass. An elephant contains more matter than a mouse, so it has a greater mass. In SI unit mass is measured in kilogram (kg).

Note: Mass is a scalar quantity and object's mass remains the same wherever it is.

Weight (W)

The weight of an object is defined as the force of gravity on the object and may be calculated as the mass times the acceleration of gravity.

$W = mg$

Here, 'm' is the mass in kg and 'g' is the acceleration due to gravity. Since the weight is a force, so it is a vector quantity and its SI unit is newton (N).

The acceleration due to gravity, g, varies depending on the location. For example, on the surface earth, the acceleration due to gravity is g_{earth} = 9.8 m/s^2. While the on the surface of the moon, acceleration due to gravity is g_{moon} = 1.6 m/s^2.Near the surface of the sun, g_{sun}= 270 m/s^2.

Class Activity-1

<u>Choose the correct answer:</u>

1. Which statement is true about the mass (M) and weight (W) of a body?

A. $M_{Moon} = M_{Earth}$ and $W_{Moon} < W_{Earth}$
B. $M_{Moon} < M_{Earth}$ and $W_{Moon} < W_{Earth}$
C. $M_{Moon} < M_{Earth}$ and $W_{Moon} = W_{Earth}$

2. The weight of a man on the earth is 60 N. What is the approximate weight of the same man on the moon?

A. 6.12 N
B. 9.79 N
C. 60 N

3. Newton is a unit of…

a) Mass
b) Weight
c) Speed

5.4 Newton's First Law of Motion and its application: Equilibrium

An object at rest will remain at rest and an object in motion will continue in motion with its constant velocity unless it experiences a net external force acting on it.

Inertia:

Fig-5.4. Picture shows that the bigger the mass (car), the bigger is its inertia. Hence, more difficult to move.

"The inherent property of a body which does not change its state of rest or direction of motion by itself''. Inertia is the tendency of the object to remain at rest, and if moving, to continue its constant motion. Hence, if a body is moving with constant velocity it won't alter its velocity or direction, unless a force is applied on it.

The inertia of an object depends on its mass. A larger mass needs a larger force to overcome its inertia and change its motion.

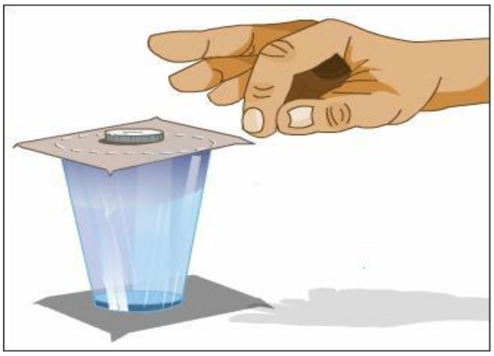


Fig-5.4.1, Example of Newton's 1st Law

Example:

The coin on top of the cardboard is an object at rest. It is not moving. When the cardboard is thumped, it moves out from under the coin, but because of inertia, the coin has a tendency to remain at rest instead of moving forward with the cardboard. Since the coin does not move forward, it drops into the glass when the cardboard was removed from underneath it. See fig-5.4.1.

Application of first law: Equilibrium

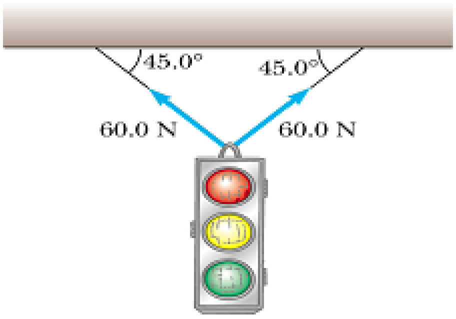
"An object either at rest or moving with a constant velocity is said to be in equilibrium if the net force acting on the object is zero, i.e. $\sum \mathbf{F} = \mathbf{0}$".

Equilibrium problems can be solved easily in terms of the components of the external forces acting on an object. For two- dimensional problem

$\sum \mathbf{F_x = 0}$ **and** $\sum \mathbf{F_y = 0}$.

For three-dimensional problem $\sum \mathbf{F_x = 0}$, $\sum \mathbf{F_y = 0}$ and $\sum \mathbf{F_z = 0}$.

Example: A traffic light weighing 85.0 N hangs vertically with the help of two other cables which makes an angle 45o with the horizontal as shown in the figure below. Find the tension in each cable.



Solution:

First, Let's draw the free body diagram.

In Physics and engineering, a **free body diagram** (**FBD**; also called a **force diagram**) is a graphical illustration used to visualize the applied forces, moments, and resulting reactions on a body in a given condition. It depicts a body or connected bodies with all the applied forces and moments, and reactions, which act on the body(ies).

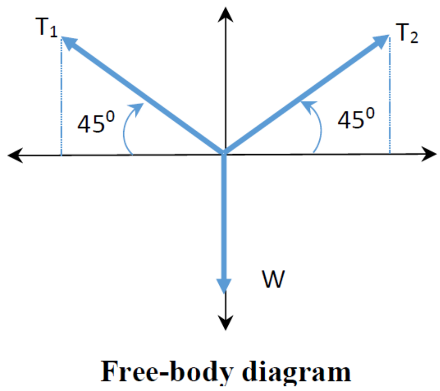
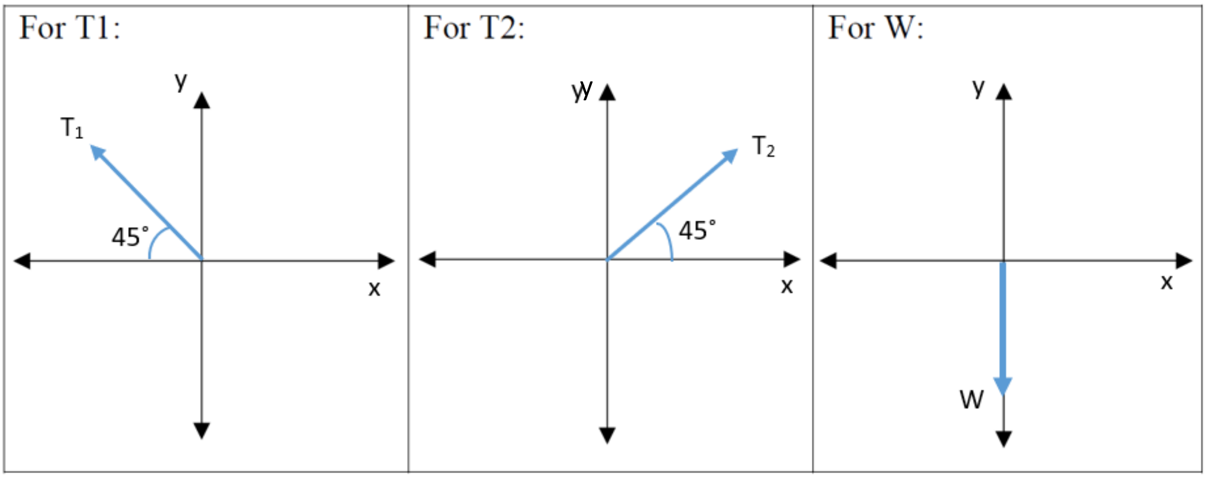


Fig-5.4.2, Free body Diagram

Then, draw the components of each vector here:



➢ The vector tension $\boldsymbol{T_1}$ has the following horizontal and vertical components:

$$\mathbf{T_1}\begin{pmatrix} T_{1x} = T_1 \times \cos 135^\circ = -T_1 \times \cos 45^\circ \\ T_{1y} = T_1 \times \sin 135^\circ = T_1 \times \sin 45^\circ \end{pmatrix}$$

➢ The vector tension $\boldsymbol{T_2}$ has the following horizontal and vertical components:

$$\mathbf{T_2}\begin{pmatrix} T_{1x} = T_2 \times cos45 \\ T_{1y} = T_2 \times sin45 \end{pmatrix}$$

➢ The vector weight **W** has the following horizontal and vertical components:

$$\boldsymbol{W}\begin{pmatrix} W_x = W \times \cos 270^\circ = 0 \\ W_y = W \times \sin 270^\circ = -W \end{pmatrix}$$

The condition of equilibrium gives us the following equations:

$$\sum F_y = 0 \text{ and } \sum F_x = 0$$

$$\sum F_y = T_{1y} + T_{2y} - W = 0$$

or $T_1 \sin 45^o + T_2 \sin 45^o = W = 85\ N$ **(1)**

and $\sum F_x = T_{1x} + T_{2x} = 0$

or $-T_1 \cos 45^o + T_2 \cos 45^o = 0$ **(2)**

solving equation (2) we get

$$T_1 = T_2 \left(\frac{\cos 45^o}{\cos 45^o}\right) = T_2 \quad \textbf{(3)}$$

Substituting this value in equation (1) we get

$$T_1 \sin 45^o + T_1 \sin 45^o = 85$$

$$2T_1 \sin 45^o = 85$$

$$T_1 = T_2 = 60.1\ N$$

5.5 Newton's Second Law of Motion and its Applications

"The net force, F, acting on an object with mass, m, is directly proportional to the product of its mass and acceleration."

Mathematically, we can write it as $\sum \vec{\boldsymbol{F}} = \boldsymbol{ma}$.

If an object of mass 'm' is acted on by a net force 'F', it will experience an acceleration a, where, $\boldsymbol{a} = \frac{\boldsymbol{F}}{\boldsymbol{m}}$. This means that it takes less force to move a smaller object than a bigger one or you have to push a heavy ball harder to get it move as fast as the smaller one.

Example-1. A 65 kg runner exerts a force of 52 N. What is the acceleration of the runner?

Solution:

$$\boldsymbol{a} = \frac{\boldsymbol{F}}{\boldsymbol{m}} = \frac{52N}{65kg} = 0.8m/s^2$$

Example-2. Four men push a stalled car in the same direction. Each man pushes with a 350 N force. What is the mass of the car if the car accelerates at 0.8 m/s^2? Neglect friction.

Solution:

$$\sum \boldsymbol{F} = \boldsymbol{ma}$$

$$4 \times (350N) = m \times (0.8m/s^2)$$

$$m = \frac{1400N}{0.8m/s^2} = 1750kg$$

5.6 Newton's Third Law of Motion and its Applications

"For every force that acts on an object, there is an equal and opposite reaction force on the other object".

Note: Action and reaction force always occur in pairs, acts on two different bodies simultaneously.

Example: Chemical reactions inside the rocket push gases out at a very high speed, there is an equal and opposite reaction to the force of the gases, which pushes the rocket upwards.

Fig-5.5.1, Newton's Third Law

Fig-5.5.2, Newton's Third Law

Example: Feet push down on the floor and the floor pushes up at feet as we walk.

Class Activity-2

A. Choose the correct answer:

1. A force of 5.0 N acts on a body of weight 9.8 N. The acceleration produced in **ms^{-2}** is :
 A. 49.0
 B. 5.0
 C. 0.51

2. For a car weighing 1000 N, what force would be required to accelerate the car to 3 ms^{-2}?
A. 327.2 N
B. 306.1N
C. 300.5 N

3. If we know an object is moving at constant velocity, we may assume:
 A. the net force acting on the object is zero
 B. there are no forces acting on the object
 C. the object is accelerating

B. Problem Solving

1. A sports car accelerates from 0 to 26 m/s in 6.5 seconds. The car exerts a force of 6600 N. What is the mass of the car?

2. For a car weighing 1200 N, what force would be required to accelerate the car to 3 ms^{-2}?

5.7 Linear Momentum and Impulse

Linear Momentum (p):

The linear momentum, p, of an object is equal to the product of its mass (m) and its velocity (v). It is a vector quantity. Mathematically, $p = mv$ and SI unit is $kg \cdot m/s$

Impulse (I)

If a body is subjected to a sudden blow, shock load or impact, it is possible to measure the change in momentum. Greater forces which acts for short time of action are called the impulsive forces or impulse.

Change of momentum due to force is called Impulse.

Fig-5.7, example of Impulsive Force

Impulse (I) = Change in momentum = Force×Time

$I = m \times (\Delta v) = m \times (v - u) = F \times \Delta t.$

Note: Impulse is a vector quantity, and its SI unit is kg m/s or Ns. Example: When a tennis ball is hit by a racket, a large force is exerted on the ball in a very short period of time. Typical impact time is in the order of milliseconds

5.8 Conservation of Linear Momentum

We say that momentum is a conserved quantity: “the total momentum before collision is equal to the total momentum after collision”. There are two (2) types of collision, namely: Inelastic and Elastic collisions. In this content, we will deal only the perfectly elastic collision. In this type of collision, the total kinetic energy and the total momentum of the system are conserved.

Fig-5.8, Collision and Conservation of Linear Momentum

According to the law of conservation of linear momentum:

Total momentum before collision = Total momentum after collision

$$(\vec{p}_1 + \vec{p}_2)_{initial} = (\vec{p}_1 + \vec{p}_2)_{final}$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Where m_1 is mass of first object, m_2 is mass of second object, u_1 is velocity of the first object before collision, u_2 is velocity of second object before collision, v_1 is velocity of the first object after collision, and v_2 is velocity of the second object after collision.

5.9 Friction- Kinetic and Static Friction

Friction – A force that resists the sliding or rolling of one solid object over another.

"The resistance to the motion of the object because of the interaction between the body and the surroundings is called the force of friction".

Without the force of friction, we cannot walk or run and is very important for the motion of wheeled vehicles. Actually it arises due to the contact between two surfaces.

Fig-5.9, Everyday life examples of friction

There are two kinds of frictional forces, Static and Kinetic friction.

Static Friction:

"When there is no motion or object just starts to slide".

The maximum force of static friction, f_s, between an object and a rough surface is proportional to the product of the magnitude of normal (reaction) force (N) acting on the object and the coefficient of static friction (μ_s). The maximum force occurs when the object starts to move. Mathematically, static friction can be written as

$$f_s = \mu_s N$$

Where **μ_s** is the coefficient of static friction and **N** is the normal force.

Static friction varies between zero and a maximum value, which depends upon the nature of the two surfaces in contact.

Kinetic Friction:

"When a body slides over a rough surface, the force of kinetic friction (f_k) opposes the motion and is also proportional to the magnitude of normal force (N)".

$$f_k = \mu_k N$$

Values of dimensionless constant 'μ' ranges from around 0.01 to 1.5. The table given below shows both the coefficient of static and kinetic friction for some materials.

Coefficients of Friction[a]

	μ_s	μ_k
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Copper on steel	0.53	0.36
Rubber on concrete	1.0	0.8
Wood on wood	0.25–0.5	0.2
Glass on glass	0.94	0.4
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Synovial joints in humans	0.01	0.003

[a] All values are approximate. In some cases, the coefficient of friction can exceed 1.0.

Fig-5.10, Some values of coefficient of friction

Class Activity-3

A. Choose the correct answer:

1. 1kg m/s = _________.

A. 1 N m
B. 1 N s
C. 1 N/m

2. An 85 kilogram motorcycle is moving at a speed of 40 m/s. Its momentum is…

A. 0.47 kg.m/s
B. 2.125 kg. m/s
C. 3400 kg. m/s

3. The physical quantity, which is equal to rate of change of momentum, is…

A. Acceleration
B. Impulse
C. Force

4. Which of the following will have more friction?

A. Surface of wet soap
B. Surface of tyres

C. Surface of mirror

5. Which of the following is responsible for wearing out of bicycle tyre?

A. Muscular force
B. Magnetic force
C. Frictional force

B. Problem Solving

1. A 1000 kg car accidentally drops from a crane and crashes at 30 m/s to the ground below and comes to an abrupt halt. What impulse acts on the car when it crashes?

Fig-5.11, Car held by crane

2. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 m/s. If the mass of the ball is 0.15 kg, determine the impulse imparted to the ball.

Fig-5.12, Batsman hitting a ball

3. A force of 20N is needed to move a body of mass 40kg along a footpath with uniform velocity. Find the coefficient of dynamic friction. (Consider $g = 10\ m/s^2$).

Worksheet-5

A. Choose the correct answer

1. Inertia is the property by virtue by which the body is unable to change by itself the

A. state of uniform linear motion only
B. state of rest only
C. the state of rest and of uniform linear motion

2. Which of the following is an example of the type of force that does not act at a distance?
A. gravitational
B. magnetic
C. contact force

3. The mass of an object whose weight is 98 N is…
A. 98 kg
B. 1 kg
C. 10 kg

4. Essential characteristic of equilibrium condition for a body is
A. momentum should be equal to zero
B. acceleration should be equal to zero
C. velocity should be equal to zero

5. The physical quantity, which is equal to change in momentum, is
A. Force
B. Impulse
C. Inertia

6. Least amount of friction is required in which of the following sports?
A. Car Race
B. Football
C. Ice Skating

7. A 0.10 kg model rocket's engine is designed to deliver an impulse of 6.0 Ns. If the rocket engine burns for 0.75s, what is the average force does the engine produce?
A. 0.8 N
B. 8 N
C. 80 N

B. Problem Solving:

1. An aircraft weighing 6400 pound lands at a speed of 10 ft. /sec and stops in 10 seconds. What is the force generated by the breaks? (consider g = 32 ft./sec^2)

2. A bicycle has a momentum of 24 kg m/s. What momentum would the bicycle have if it had

a) twice the mass and was moving at the same speed?

b) the same mass and was moving with twice the speed?

3. A 12kg ball moving at 37m/s strikes a second ball at rest. After the collision the 12kg ball is moving with a velocity of 19m/s and the second ball is moving with a velocity of 4m/s. What is the mass of the second ball?

C. Fill in the blanks:

1. Forces that exist and binds nucleons in the nucleus of an atom are called _____________.
2. Newton's first law explains ______________________.
3. The product of mass of a body and its velocity in known as____________________.
4. No physical contact between two objects take place in ________________________forces.
5. ___________________is the force between two objects that slide one over the other.

Chapter-6: Work, Energy and Power

6.1 Work and Energy

Work

The work done by a constant force is measured by the dot product of the force and the displacement vectors.

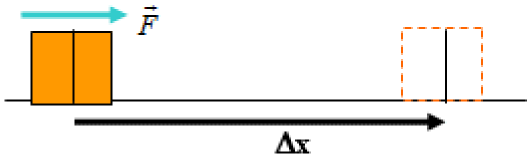


Fig-6.1, Work done in the direction of Force

If the force $\vec{F}$ displaces an object through a distance Δx in the direction of force as shown in the figure above then the work done is:

W= F. Δx

Work is a scalar physical quantity. The SI Unit of work is Joule (J) or N.m.

In case the force $\vec{F}$ acts along a direction making angle 'θ' with the direction of displacement Δx as shown in the figure then work done by a constant force $\vec{F}$ is:

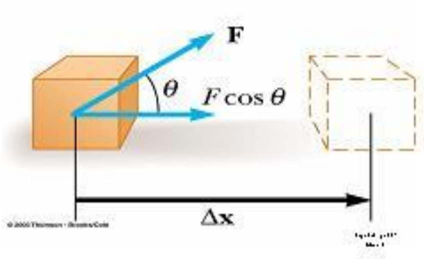


Fig-6.2, Work done

W = (**F** cosθ). Δ**x**

Depending on the value of the angle θ between the force and the displacement we have 3 cases.

(i) **If θ is between 0º and 90º** ($0 \leq \theta \leq 90°$) then, cosθ >0, so the work done by the force is positive and in this case when $\vec{F}$ and Δx are in the same direction i.e. **θ = 0º** then cosθ = 1, then $W = F.\Delta x$ the work done by the force in this case is maximum.

(ii) If **θ = 90º**, $\vec{F}$ and Δx are perpendicular to each other i.e. θ = 90º then cos 90º = 0, then the work done will be **zero**.

(iii) If **θ is between 90º and 180º** (cos θ <0), so the work done by the force is negative. $\vec{F}$ is said to be a resistant force like for example the work done by the friction force.

Note: 1 Joule could be defined as the work done when a force of 1 Newton moves a body through a distance of 1 meter.

Example-1. A man exerts a force of 50 N to push a trolley through a distance of 20 m. What work is done by the man?

Solution:

$W = F \cdot \Delta x$

$W = (50\ N) \times (20\ m)$

$$W = 1000\ Nm\ or\ Joule$$

Energy

Energy is the capacity to do work. Energy is a scalar quantity and its SI unit is Joule (J) or N.m.

Work done = Energy transferred

This means that whenever you apply work on an object, there is a corresponding change in its energy. Mathematically, this can be written as $W = \Delta E$.

There are many types of energy (i.e. light, heat, chemical, nuclear, mechanical energy etc.) In this section, we will be dealing with mechanical energy only.

6.2 Types of Mechanical Energies

We will be studying mainly mechanical energy, which is of two types, namely kinetic and potential energy.

Kinetic Energy

"The kinetic energy of a body is the energy due to its motion." Mathematically,

$$KE = \frac{1}{2}mv^2$$

where 'm' is the mass of a body moving at a speed 'v' .

KE. is also scalar quantity. KE unit in SI and CGS systems are **J** and **erg** same as that of work.

The work-energy theorem states that the total work W_{net} on a system changes its kinetic energy,

$$W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \Delta KE$$

Example-2. A body of mass 5.0 kg initially at rest is subjected to a force of 20.0 N. What is the kinetic energy gained by the body at the end of 10.0 s?

Solution:

Given: m = 5.0 kg, F = 20.0 N, u = 0 and t = 10.0 s

$$a = \frac{F}{m} = \frac{20}{5} = 4.0ms^{-2}$$

Let 'v' be the velocity of the body after 10.0 s, then

$$v = u + a\,t = 0 + 4.0 \times 10 = 40.0 \text{ ms}^{-1}$$

K.E. of the body after 10.0 s is: K.E. = ½ mv^2 = ½ × 5.0× (40.0) ×2 = 4000.0 J

Potential Energy

"The potential energy of a body is the energy due to its position or shape or size." Mathematically,

$$PE = mgh$$

where 'm' is the mass of a body, 'g' is acceleration due to gravity = 9.8 m/s^2 and 'h' is height.

PE is also a scalar quantity. PE unit in SI and CGS systems are Joule and erg, respectively the same as that of work.

Example-3. What is the potential energy of an object with mass 15 kg and raised from the ground to a height of 35 m?

Solution:

$$P.E = mgh$$

$$P.E = 15kg \times \left(9.8\frac{m}{s^2}\right) \times (35\ m)$$

$$P.E = 5145\ kg\ {m^2}/{s^2}\ \ or\ N \cdot m\ or\ Joule$$

Class Activity-1

A. Choose the correct answer:

1. Which of the following is a set of units for work?

A. Newton, m/s^2, Joule
B. Joule, kg m^2/s^2, Nm
C. Erg, m/s^2, N/m

2. A mass of 400 kg moves 27 meters with a force of 54N. What is the work produced?

A. 10.1 kJ
B. 583.2 kJ
C. 1458 J

3. The work done by gravity during the descent of a freely falling object…

A. Is positive
B. Is negative
C. Zero

4. A man of mass 60 kg jumps to a height of 2 m. Assuming 'g' as 10 m/s^2, his potential energy at the highest point is…

A. 1200 J
B. 12 J
C. 1.2 J

5. What is the kinetic energy of an aircraft of mass 2 metric tons and has a velocity of 6 m/s?

A. 36 kJ
B. 3.6 kJ
C. 360 J

B. Problem Solving:

1. Calculate work when a 100 N force is applied to move a 15 kg object a distance of 5 meters.

2. If 150 J of work is needed to move a box 10 m, how much force was used?

3. How much work must be done to stop a 1250 Kg car travelling at 100 km/h?

4. How fast must a 3000 kg elephant move to have the same kinetic energy as a 65 kg sprinter running at 10 m/s?

6.3 Law of Conservation of Energy

It states that "Energy can neither be created nor destroyed, it only changes from one form to another form." or

"In an isolated conservative system, the sum of K.E. and P.E. of the system always remain constant".

Mathematically $E_{final} = E_{initial}$

$(K.E. + P.E)_{final} = (K.E. + P.E.)_{initial}$

$K.E_{final} + P.E._{final} = K.E._{initial} + P.E_{initial}$

$K.E_{final} - K.E._{initial} = P.E_{initial} - P.E._{final}$

$\Delta K.E. = -\Delta P.E$

Example-4. Using conservation of mechanical energy, find the velocity with which a stone will strike the ground when it is dropped from a height of 80.0 m. ($g = 10\ m/s^2$)

Solution:

$$\Delta KE = -\Delta PE$$

$$m{v_f}^2 - 0 = -[0 - mg(80\text{m})]$$

$$\frac{1}{2}m{v_f}^2 = mgh_i$$

$${v_f}^2 = 2 \times (10m/s^2) \times (80m)$$

$$v_f = \sqrt{1600m^2/s^2} = 40.0m/s$$

6.4 Power

The rate of doing work is called power (P). Thus, the power is written as follows:

$$P = \frac{work\ done}{time} = \frac{Force \times displacement}{time}$$

$$P = \frac{F \cdot d}{t} = F \cdot v$$

SI unit: Watt or 'W'. 1 watt = 1 joule per second.

Note: Power is a **scalar** quantity.

Example-5. Calculate the work done in one hour by an electric motor in a washing machine which has an output power rated 1.5 kW.

Solution:

$$P = \frac{W}{t}$$

$$W = Pt = 1.5 \times 10^3 \times 3600 = 5.4 \times 10^6\ J$$

Fig-6.3, Examples of Energy

Class Activity-2

A. Choose the correct answer:

1. Which of the following is a set of units for Power?
A. Watt, erg, J/s
B. J/s, kg m^2/s^3, Watt
C. Watt, N m/s, erg

2. If you push an object with a force of 10 N for 5 m in 20 second, how much power is used?
A. 25 watts
B. 2.5 watts
C. 250 watts

3. A 6.0 kg block is released from rest 80 m above the ground. When it has fallen 60 m, its kinetic energy is approximately:
A. 4700 J
B. 3500 J
C. 1200 J

B. Problem Solving:

1. How high will a 1.85 kg rock go if thrown straight up by someone who does 90 J of work?

2. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down?

3. A novice skier, starting from rest, slides down a frictionless 35˚ incline whose vertical height is 185 m. How fast is he going when he reaches the bottom?

6.5 Machines

Machines are mechanical devices that help make our work easier. It makes us easier to move objects from one point to another or help us lift heavier objects.

There are two (2) types of machines: 1.) Simple machine and 2.) Compound machine.

Simple machines have different types. These include inclined plane, levers, pulleys, wheel and axle, wedges, screws, and gears (See Figure 6.4). Compound machines are made up of combination of these simple machines (See Figure 6.5).

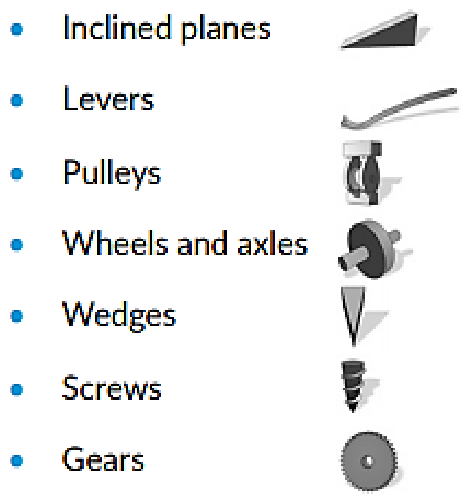


Fig-6.4 Examples of Simple machines

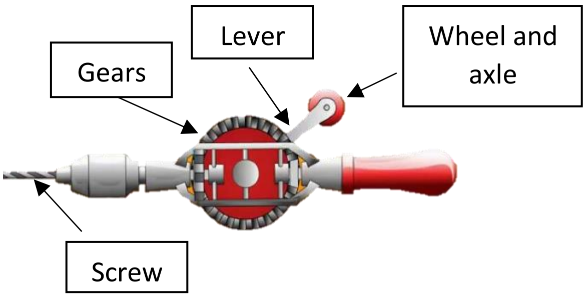


Fig-6.5. A hand drill is an example of a compound machine.

Inclined plane

An inclined plane is a flat surface that is at an angle to the load. An example of an inclined plane is ramp for wheelchairs. The inclined plane of the ramp makes it easier for the person in the wheelchair to move up into a building. (See Fig 6.6)

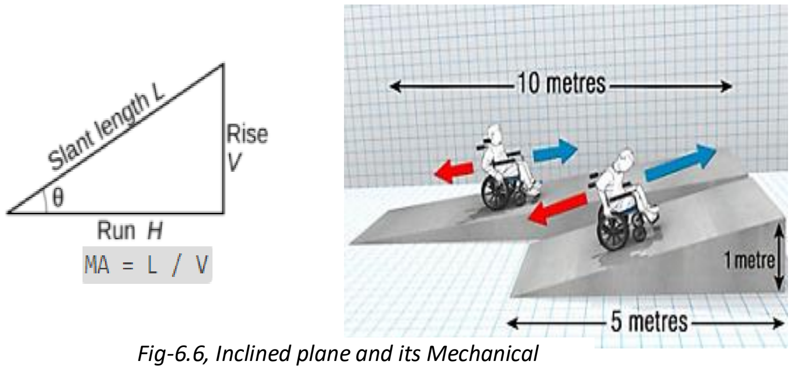


Fig-6.6, Inclined plane and its Mechanical

Levers

A lever is a rigid bar that rotates around a fixed point called fulcrum. A lever is a rigid body capable of rotating on a point on itself used to gain mechanical advantage. On the basis of the location of fulcrum, load and effort, the lever is classified into three types, namely: class 1, class 2 and class 3 levers.

Class 1 lever - A lever has a fulcrum between the load and the effort.

Advantage: Less effort is required to lift the load.

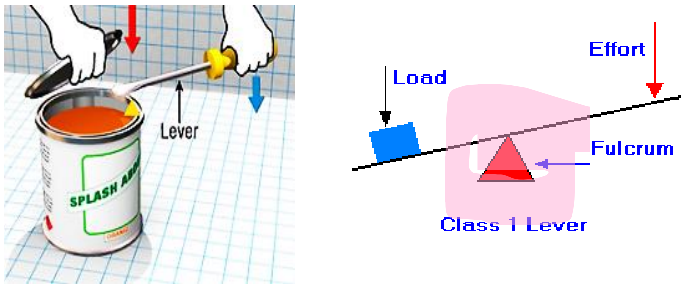


Fig- 6.7. Example of Class 1 lever.

Class 2 lever – It has a fulcrum at one end of the lever and effort is applied to the opposite force.

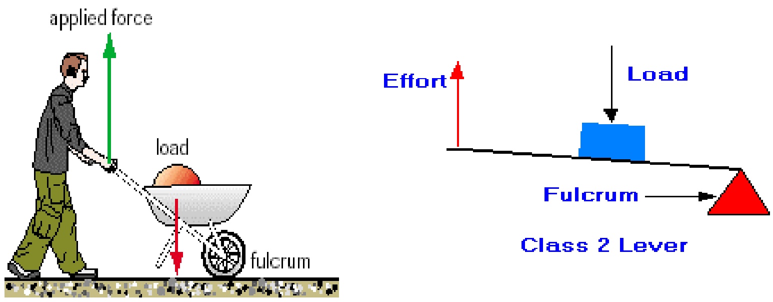


Fig-6.8. A Wheelbarrow. An example of class 2 lever.

Class 3 lever - Force is applied between the fulcrum and the load. This is used to move the load a greater distance than the effort applied.

Disadvantage: Much greater effort required to produce moment.

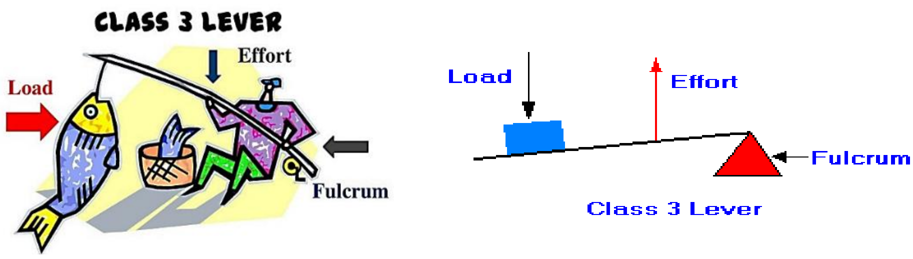


Fig-6.9. An example of class 3 lever.

Gear

A gear is a wheel with teeth around its rim that mesh with the teeth of another wheel to transmit motion. Gears are used to transmit power (as in a car transmission) or change direction of motion in a mechanism (as in a differentia axle).

The relationship between the input speed to the gearbox and the output speed delivered to the driven load is commonly referred to as the gear ratio. One of the simplest ways to determine the gear ratio is to take the ratio of driven gear teeth to driving gear teeth.

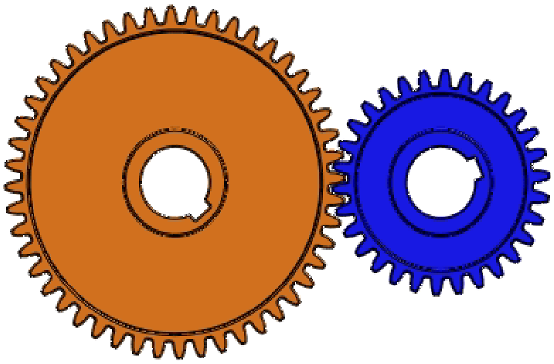


Fig-6.10, Gear

$$\text{Gear Ratio} = \frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1}$$

Where, $\omega_1$and ω_2: Angular speed in rad/s for diver and driven gear respectively.

$n_1$and n_2: Gear speed in RPM for diver and driven gear respectively.

$d_1$and d_2: Diameters for diver and driven gear respectively.

T_1 and T_2: Number of teeth per inch on diver and driven gear respectively.

6.6 Velocity ratio, Mechanical Advantage and Efficiency

Velocity Ratio – the ratio of the distance moved by the effort and distance moved by the load. Mathematically, it can be written as

$$\boldsymbol{VR} = \frac{distance\ moved\ by\ the\ effort}{distance\ moved\ by\ the\ load}$$

For example, a load is being lifted using a lever. The distance moved by the effort is 1 m while the distance moved by the load is 200 mm. Then the velocity ratio of the lever is

$$\boldsymbol{VR} = \frac{1\,m}{200\ \times\ 10^{-3}m} = 5$$

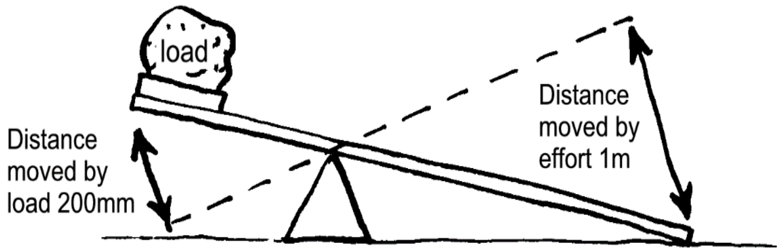


Fig-6.11 Velocity Ratio

Mechanical Advantage:

The ratio of the load (weight) and the effort (force exerted). Larger mechanical advantage means the machine can move heavier objects with less application of force. For example, from the figure

Fig-6.12, Mechanical Advantage of Lever

$$\boldsymbol{MA} = \frac{load}{effort} = \frac{\text{Effort arm length}}{\text{Load arm length}}$$

$$= \frac{\mathbf{400}}{\mathbf{160}} = \frac{\mathbf{2.5}}{\mathbf{1}} = \mathbf{2.5}\ (\boldsymbol{no\ unit})$$

Where the effort arm length is the distance between effort to the fulcrum, and the load arm length is the distance between load to the fulcrum.

Efficiency – describes the ratio of the useful work done by the machine to the total work input. It is mathematically written as,

$\boldsymbol{Efficiency} = \frac{\boldsymbol{work\ output}}{\boldsymbol{work\ input}} \times \mathbf{100\%}$, since $Work = F \cdot d$ then

$\boldsymbol{Efficiency} = \frac{\boldsymbol{F_{load} \cdot d_{load}}}{\boldsymbol{F_{effort} \cdot d_{effort}}} \times \mathbf{100\%}$**Or** From the definition of velocity ratio and mechanical advantage,

$$\boldsymbol{Efficiency} = \frac{\boldsymbol{MA}}{\boldsymbol{VR}} \times \mathbf{100\%}$$

<u>**Example 6.**</u> A wheelbarrow with a load of 300 N is being carried by a man who exerted a force of 100N. The distance moved by the effort is 300 mm and the distance moved by the load is 100 mm (See figure-17).

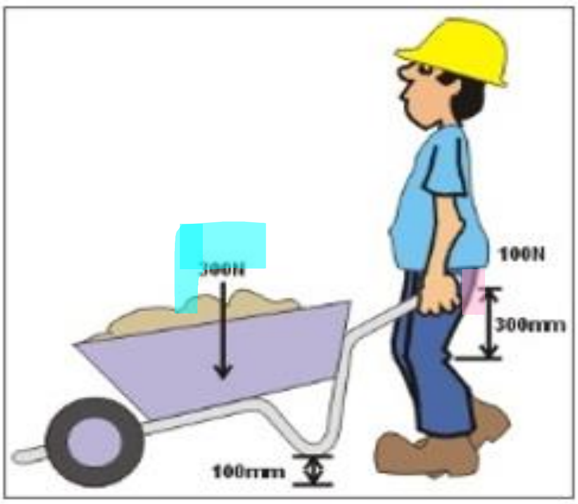


Fig-6.13, Wheelbarrow

Find the

A) Mechanical advantage,

B) Velocity ratio and

C) Efficiency of the wheelbarrow.

Solution:

$$MA = \frac{load}{effort} = \frac{300N}{100N} = 3$$

$$VR = \frac{distance\ moved\ by\ the\ effort}{distance\ moved\ by\ the\ load} = \frac{300\ mm}{100\ mm} = 3$$

$$Efficiency = \frac{MA}{VR} \times 100\% = \frac{3}{3} \times 100\% = 100\%$$

Class Activity-3

A. Choose the correct answer:

1. The mechanical advantage of any machine is:

A. The work done by the machine
B. The ratio of the work done by the machine to the work expended on it.
C. The ratio of the force exerted by the machine to the force applied to it.

2. Which of the following options is the correct one?

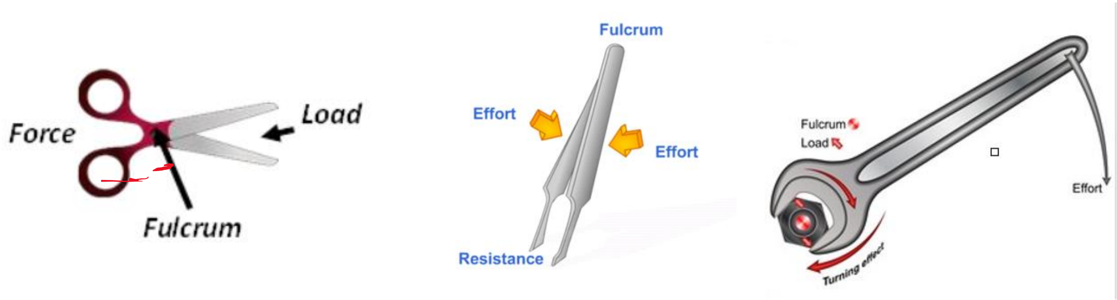


Fig-6.14 Question-2

	1st class level	2nd class lever	3rd class lever
A	Tweezers	Spanner	Scissors
B	Spanner	Scissors	Tweezers
C	Scissors	Spanner	Tweezers

3. In which type of levers, the velocity ratio is less than one?

A. 1st class lever
B. 2nd class lever
C. 3rd class lever

4. In a gear train the driver has 100 TPI and the driven has 50 TPI.

A. The driven rotates twice as fast.
B. The driver and driven rotate at the same speed.
C. The driven rotates half as fast.

5. If a machine has a mechanical advantage of 20 and a velocity ratio of 40.The efficiency of the machine is_______________.

A. 80 %
B. 50%
C. 20%

B. Problem Solving:

1. Calculate the mechanical advantage of a ramp (inclined plane) that is 8.0 m long and 1.75 m high?

2. A lever of length 112 cm is used with a fulcrum placed 16 cm from the end bearing the load. Find the mechanical advantage of the lever.

Worksheet 6

A. Choose the correct answer:

1. Khalid lifts a barbell 2.0 m above the ground in 5s. If he lifts it the same distance in 10s, the work done by him is:

A. Four times as great
B. Two times as great
C. The same

2. How much work is done by the force of gravity to push a wooden box of 50 kg along the ground through a distance of 5 m?

A. 0 J
B. 5 J
C. 10 J

3. If the speed of an object is doubled then its kinetic energy is ___________.

A. Doubled
B. Quadrupled
C. Halved

4. In a gear train system, if a smaller gear is driven by a larger gear, which of the following statements is true?

A. The smaller gear will rotate quicker than the larger gear
B. The larger gear will rotate quicker than the smaller gear
C. Both gears have the same rotation speed.

B. Problem Solving:

1. An object of mass 40 kg is moved horizontally by a force of 50 N. What is the work produced if the object moves a distance of 5 m?

2. A bullet of mass 10 g leaves a rifle at an initial velocity of 1000 m/s and strikes the earth at the same level with a velocity of 500 m/s. Find the work done in joule to overcome the resistance of air.

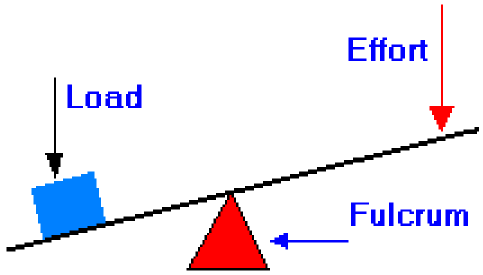
3. How long will it take a 1750W motor to lift a 315 kg piano to a sixth-story window 16.0 m above?

4. Using a gear train system, the speed of the driven gear with 120 TPI was increased 3 times compared to the rotation speed of the driver gear. What is the number of TPI of the driver gear?

5. Suppose you have a 10 m first class lever and you put a fulcrum 1.20 m from the load which is at one end of the lever. If you can push down 460 N, what is the heaviest load that you can lift?

B. Identification:

Write the name of the given simple/compound machines. Write your answer on the space provided.



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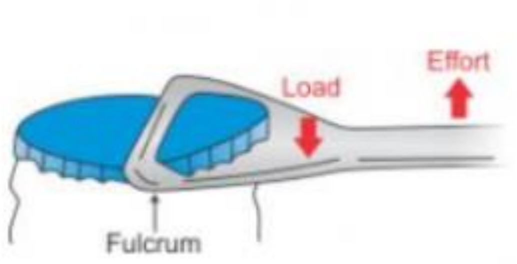

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C. Fill in the blanks:

Velocity ratio	Machines	Zero	Mechanical advantage
Power	Work	Energy	One hundred

1. Capacity to do work is called_________________.
2. The ratio of load to effort is known as __________________.
3. __________________are mechanical devices that help make our work easier.
4. The product of force and distance is known as____________________.
5. Efficiency of any engine is always less than_________________

Chapter-7 Rotational Motion

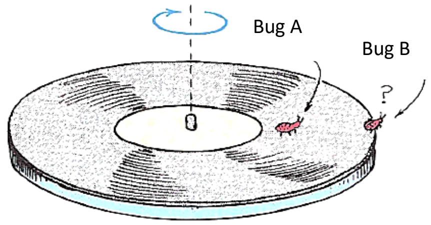


Fig-7.1 Understanding Circular Motion

From the figure on the left, which one moves faster? Bug A which is near the center of the turntable? Or Bug B which is farther away from the center of the turntable? Or do they have the same speed? The answer will depend on which speed you are referring to: linear or angular speed.

7.1 Linear and Angular Velocity

Linear displacement or just simply displacement is the total distance travelled. In rotational motion, the linear displacement is equivalent to the arc length, s. While the angular displacement is the angle swept by the object in radians. Take note that 1 complete revolution is equivalent to 2π radians (1 rev = 2π rad).

The relation between linear and angular displacement is given by $\boldsymbol{s = r\theta}$.

Linear velocity, v, is the displacement occurred per unit time. Travelling a greater distance in the same time means greater speed. The distance travelled or arc length on the outer part of the turntable is longer compared to the inner part, hence, bug B has greater linear velocity compared to bug A. The unit for linear velocity is m/s. Same as before, this can be written as,

$$v = \frac{s}{t}$$

Angular velocity, ω, is the number of revolutions or rotations per unit of time (RPM). All parts of the turntable turns about the axis of rotation at the same time, hence, Bugs A and B have the same angular velocity. The angular speed is measured in terms of rev/s or rad/s. Mathematically, it is written as,

$$\omega = \frac{\theta}{t}$$

Linear and angular velocities are related by the equation: $\boldsymbol{v = r\omega}$

<u>Class Activity-1</u>

Choose the correct answer:

1. 45 degrees is equivalent to how many radians?

a) 45 radians

b) 7.85 radians

c) 0.79 radians

2. 15 rev/min is equivalent to:

a) 1.57 rad/s

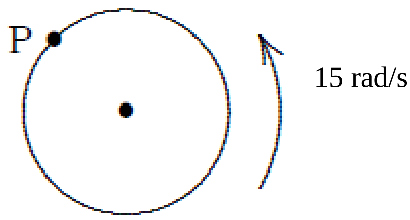
b) 25 rad/s

c) 15.7 rad/s

Problem Solving

1. If a wheel is turning at the rate 3.0 rad/s, then what is the time it takes to complete one revolution?

2. The figure shows a cylinder of radius 0.85 m rotating about its axis at 15 rad/s. What is the speed at point P?



3. If a wheel turning at a constant rate completes 100 revolutions in 10s, then calculate its angular speed in rad/s.

7.2 Uniform Circular Motion and Centripetal Force

When an object moves in a circle with a constant speed, the motion is said to be uniform circular motion. A car rounding a curve at constant speed, or a satellite revolving around the earth at constant speed are examples of uniform circular motion.

Centripetal Force

In uniform circular motion, although the speed is constant, the direction of the object changes at every point. This change in direction is caused by the centripetal force that pulls the object towards the center. Hence, the direction of the radial acceleration is always directed towards the center of the circle. The magnitude of the radial acceleration is constant but its direction changes at every point.

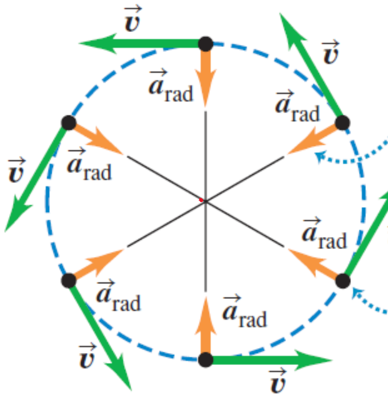


Fig-7.2 Centripetal Force

The radial acceleration is given by $\boldsymbol{a_{radial}} = \frac{\boldsymbol{v^2}}{\boldsymbol{r}}$ and from Newton's 2nd Law of motion, the expression for the centripetal force is given by: $\boldsymbol{F_c} = \frac{\boldsymbol{mv^2}}{\boldsymbol{r}}$, where m is the mass of the body, v its linear speed and r is the radius of the circular path.

This force according to the above equation, is

- directly proportional to the mass of an object in circular motion.
- inversely proportional to the radius of the circle in which the object travels.

Example-1.) A race car travels in a circular track of radius 200.0 m. If the car moves with a constant speed of 80.0 m/s, find: a.) angular velocity, b.) radial acceleration and c.) Centripetal force if the cars' mass is 2500kg.

Solution:

v = rω

80= 200×ω

ω= 0.4 rad/s

$$a_{radial} = \frac{v^2}{r} = \frac{(80m/s)^2}{200m} = 32\ m/s^2$$

$$F = ma = (2500kg) \times \left(\frac{32m}{s^2}\right) = 8.0 \times 10^4 N$$

7.3 Moment of Force (Moment or Torque)

In the previous section, we discussed that an object changes its velocity whenever there is an application of force. For rotational motion, torque changes the rotational state of things.

If you want to make a stationary object to move, apply force. If you want to make stationary object rotate, apply torque.

"The turning effect of a force about the axis of rotation is called moment of force or torque."

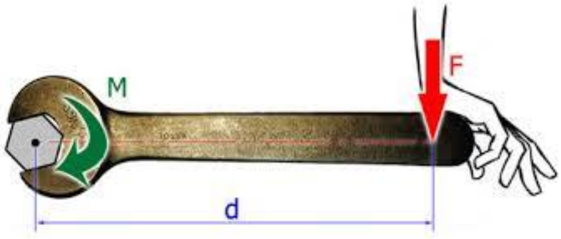


Fig-7.3 Lever Arm

It is measured by the product of the magnitude of the force and the perpendicular distance of the line of action of the force from the axis of rotation, symbolically denoted by a Greek letter ‘τ’ (tau).

Thus, **Torque (τ) = force × perpendicular distance from the axis of rotation**

$\tau = F \times d\ sin\theta,$ Where “*d*” is the distance called lever arm or moment arm of the force ‘F’.

1. Its unit in SI system is Nm or kg. m^2/s^2

2. It is a vector quantity wherein the direction is perpendicular to the plane determined by the lever arm and the force

3. The sign of the torque is positive and negative if its turning effect is anticlockwise and clockwise, respectively.

Example-2.) A wrench is being used to turn a nut. It has a lever arm of 0.3 m and a force of 100N is being applied as shown in the figure. What is the torque applied?

Solution: $\tau = F \times d\ sin\theta$

$\tau = 100N \times 0.3m \times sin90°$

$\tau = 30\ N \cdot m$

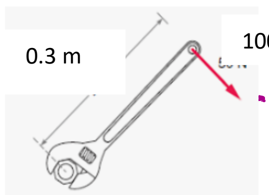


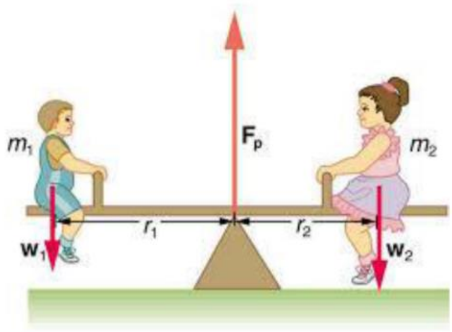
Fig-7.4, A wrench used to turn a nut

When two or more forces are acting on a body causing its rotation about a pivot or axis of rotation, the condition to have equilibrium position is that the sum of the moments of the forces rotating the object clockwise should be equal to the moments of the forces rotating the object anticlockwise. This could be formulated mathematically by the formula:

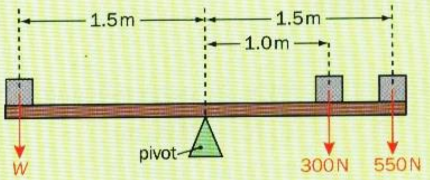
$$\sum \tau_{clockwise} = \sum \tau_{anticlockwise}$$

For example, in the case of the two kids in the picture, the condition for these two kids to be in rest position is that given by:

$W_1 \times r_1 = W_2 \times r_2$, Where W_1 and W_2 are the weights of the kids and ‘r_1’ and ‘r_2’ are their corresponding distances from the pivot point.



The seesaw in the diagram is balanced.
Use the principle of moments to calculate the weight, W.



Taking moments about the pivot:

$$\text{sum of anti-clockwise moments} = \text{sum of clockwise moments}$$
$$W \times 1.5\text{ m} = (300\text{ N} \times 1.0\text{ m}) + (550\text{ N} \times 1.5\text{ m})$$
$$W \times 1.5\text{ m} = 300\text{ N m} + 825\text{ N m}$$
$$W \times 1.5\text{ m} = 1125\text{ N m}$$
$$\therefore W = \frac{1125\text{ N m}}{1.5\text{ m}} = \underline{750\text{ N}}$$

Fig-7.5, Problem on Moments

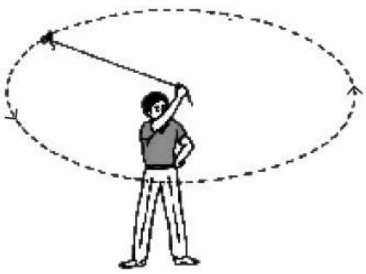
Class Activity-2

Choose the correct answer:

1. What happens to the object's linear speed when the centripetal force is being doubled?

a) Doubled
b) One half
c) Multiplied by $\sqrt{2}$

2. A stone is tied on one end of a string with a length of 1.0 m and whirled at a constant angular speed of 1.20rev/s (see figure below). What happens to the stone's linear speed as you decrease the length of the string by half?



a) Remains the same
b) Doubled
c) ne half

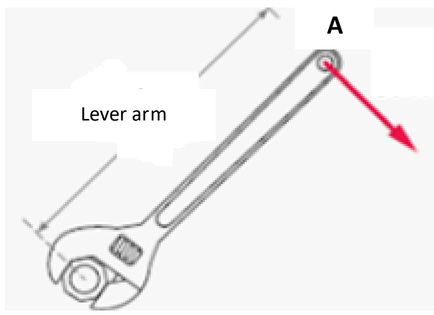
3. Torque causes the object to change its rotational state. Which of the following sets affects torque?

a) Force and lever arm
b) Force only
c) Force, lever arm and the angle between them

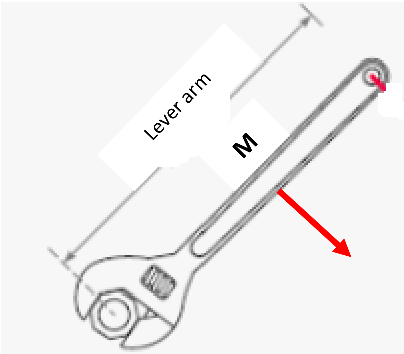
Problem Solving

1. The bolts of an engine require tightening to a torque of 95 N.m. If a wrench is 30 cm long, what would be the force must the mechanic apply if force is applied

a) Perpendicular to the lever arm at point A.



b.) Perpendicular in the middle of the wrench at point M?



2. A 2500 kg car turns a certain curve with a constant linear speed of 40 km/h. If the radius of the curve is 35 m, what is the centripetal force experience by that car?

7.4 Moment of Inertia

Just like an object at rest stays at rest and an object in motion tends to remain moving in a straight line, an object rotating about an axis tends to remain rotating about the same axis unless interfered with external influence. This property of a rotating object to resist changes in its rotational state of motion is called moment of inertia or rotational inertia.

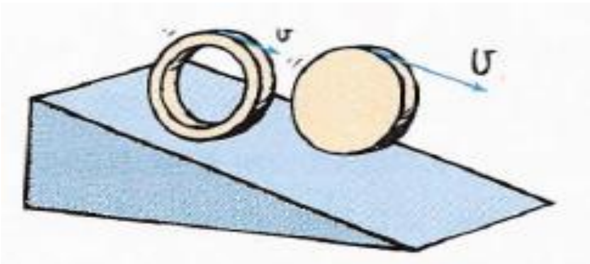


Fig-7.6 Hoop vs. Solid cylinder. With the same mass and radius, the hoop rotates slower than the solid cylinder because the mass of the hoop is distributed away from the center (higher moment of inertia).

The moment of inertia of an object depends on its mass distribution. The further away the mass from its axis of rotation or pivot point, the more it resists change in rotational motion.

"The moment of inertia of a particle about an axis of rotation is given by the product of the mass of the particle and the square of the perpendicular distance of the particle from the axis of rotation".

$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots$

From the equation above, when r is large, then I is large also. This means that the masses are distributed further from the axis of rotation and hence the more it resists the change in rotational motion. So, the larger the moment of inertia of an object is, the more "lazy" it rotates.

7.5 Angular Momentum

Angular momentum (L) is defined as the product of radius ‘r’ and momentum ‘p’ of the object. Mathematically, it is written as,

$L = r \times mv$

For a rigid body, the angular momentum is given by,

$L = r \times mv$ but since $v = r\omega$ then

$L = rm \times (r\omega) = mr^2\omega$ and since $I = mr^2$ then,

$$L = I\omega$$

“If a body is rotating about an axis, then the sum of moments of the linear momenta of all the particles about the given axis is called the angular momentum of the body about the axis.

The rate of change of angular momentum is given by,

$\frac{\Delta L}{\Delta t} = \frac{\Delta(I\omega)}{\Delta t}$. But we know also that $\frac{\Delta\omega}{\Delta t} = \alpha$ and $I = mr^2$ then,

$\frac{\Delta L}{\Delta t} = I\alpha = mr^2\alpha = r \times (mr\alpha)$.

Also, the tangential acceleration is given by $a_T = r\alpha$ and from the 2nd Law of Newton F=ma, we can write,

$\frac{\Delta L}{\Delta t} = r \times ma = r \times F = \tau$, or we can write this as

$\boldsymbol{\tau} = \frac{\boldsymbol{\Delta L}}{\boldsymbol{\Delta t}} = I\alpha$

Therefore, the rate of change of the angular momentum is equal to torque. Or one can say, that when you apply torque you are also changing the angular momentum. The greater the torque you apply, the faster is the change of angular momentum (faster rotation).

A. Law of Conservation of Angular Momentum

If the net external torque acting on a system is zero

($\Sigma\,\tau = 0$) then $\frac{\Delta L}{\Delta t} = 0$.

Therefore the angular momentum

$L = I\omega =$ constant,

which leads to $L_1 = L_2$ or $I_1 . \omega_1 = I_2 . \omega_2$

(Initial angular momentum = final angular momentum).

One of the applications of the conservation of the angular momentum is the gyroscope.

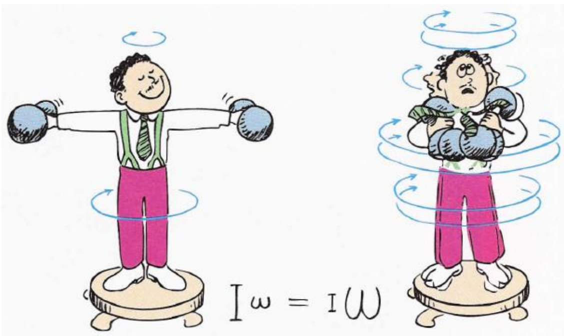


Figure 7.7. Conservation of angular momentum. When the man pulls his arms, and the weights inside, he decreases his rotational inertia I, and his rotational speed ω increases.

B. Gyroscope

A typical type of gyroscope is made by suspending a relatively massive rotor (fly wheel) inside three rings called gimbals. Mounting each of these rotors on high quality bearing surfaces nearly frictionless insures that very little torque can be exerted on the inside rotor. At high speeds, the gyroscope exhibits extraordinary stability of balance and maintains the direction of the high speed rotation axis of its central rotor. The implication of the conservation of angular momentum L is that the angular momentum of the rotor maintains not only its magnitude, but also its direction in space in the absence of external torque. The classic type gyroscope finds application in gyro-compasses, but there are many more common examples of gyroscopic motion and stability. Spinning tops, the wheels of bicycles and motorcycles, the spin of the earth in space

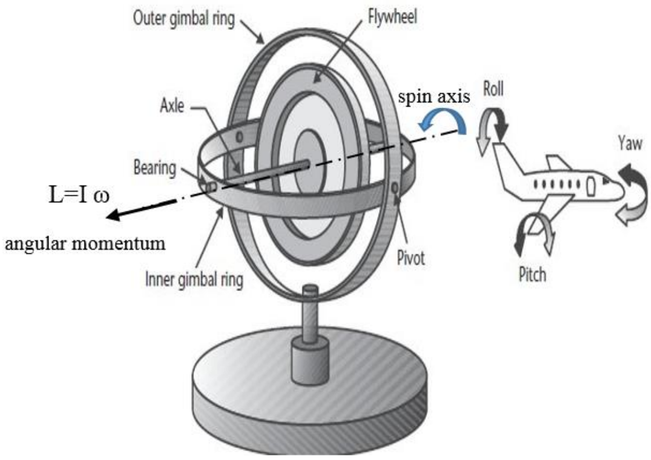


Figure-7.8 Gyroscope

It is important to note that gyroscopes are used in several of an aircraft's instruments, which are vital to the safety of the aircraft especially in bad weather conditions.

<u>Class Activity-3</u>

<u>Choose the correct answer:</u>

When a rotating rigid object has constant angular momentum, this means that ___________.

a) the angular velocity is zero.
b) the angular velocity is constant.
c) the angular acceleration is constant.

1. Which of the following statements is TRUE for a rotating wheel that is constantly moving along a flat surface?

a) Its moment of inertia is changing every time it completes one revolution.
b) Its angular momentum is always the same.
c) Its angular momentum is changing every 2π radians.

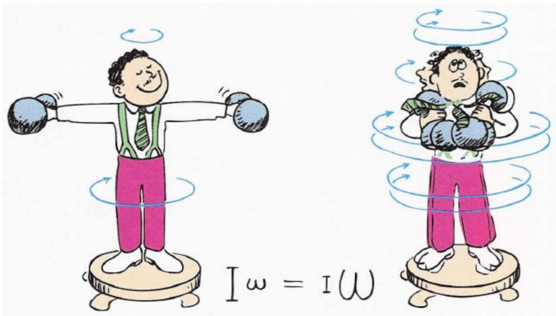
2. A ventilation fan with a moment of inertia of 0.034 kg m^2 has a net torque of 0.11 Nm applied to it. What angular acceleration does it experience?

a) 5.3 rad/s^2
b) 4.0 rad/s^2
c) 3.2 rad/s^2

<u>Problem Solving</u>

1. A meter long light rod carries 10 g masses at each ends and in the middle. What is the moment of inertia of the system about the axis passing through one end and perpendicular to the length of the rod?

2. A boy stands on a freely rotating platform with his arms stretched and his angular velocity is 0.25 rev/s. But when he draws hands in, his angular velocity is 0.8 rev/s. Find the ratio of its moment of inertia.



Worksheet 7

Choose the correct answer

1. The angular speed of the minute hand of a watch is:

a) $60/\pi$ rad/s

b) 60π rad/s

c) $\pi/1800$ rad/s

2. When an object is in uniform circular motion, the centripetal force causes the object to:

a) Change its speed but at constant direction.

b) Change its direction but at constant speed.

c) Change its direction and speed at the same time.

3. Which of the following angles between force and lever arm gives maximum torque?

a) 0^o

b) 45^o

c) 90^o

4. If a non-zero net torque is applied to a rotating object, then the object will experience:

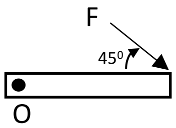
a) A constant angular speed

b) An angular acceleration

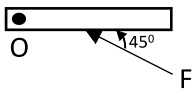
c) An increasing moment of inertia

5. Which of the following produces more torque? (Note: Point O is the pivot point, F and length are the same)

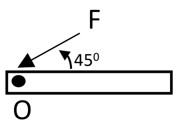
a)



b)



c)



Problem Solving

1. Calculate the angular velocity (in rad/s) of the Earth

a) in its orbit around the Sun, and

b) about its axis.

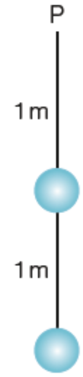
2. An airplane's propeller is rotating at 1900 rpm (rev/min).

a) Compute the propeller's angular velocity in rad/s.

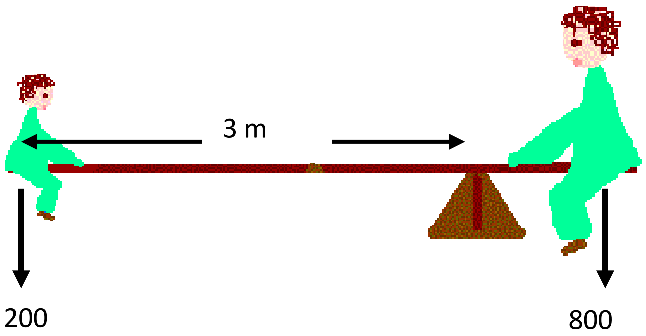
b) How many seconds does it take for the propeller to turn through 350 revolutions?

3. What is the torque required to rotate a disk with moment of inertia $I = 0.08\ kg\ m^2$ and angular acceleration of $2\ rad/s^2$?

4. In figure below, two 1 kg masses rotate about point P. The masses are connected by a very strong light rod (i.e. we can neglect its mass). Calculate the moment of inertia through the point P and perpendicular to length of the string.



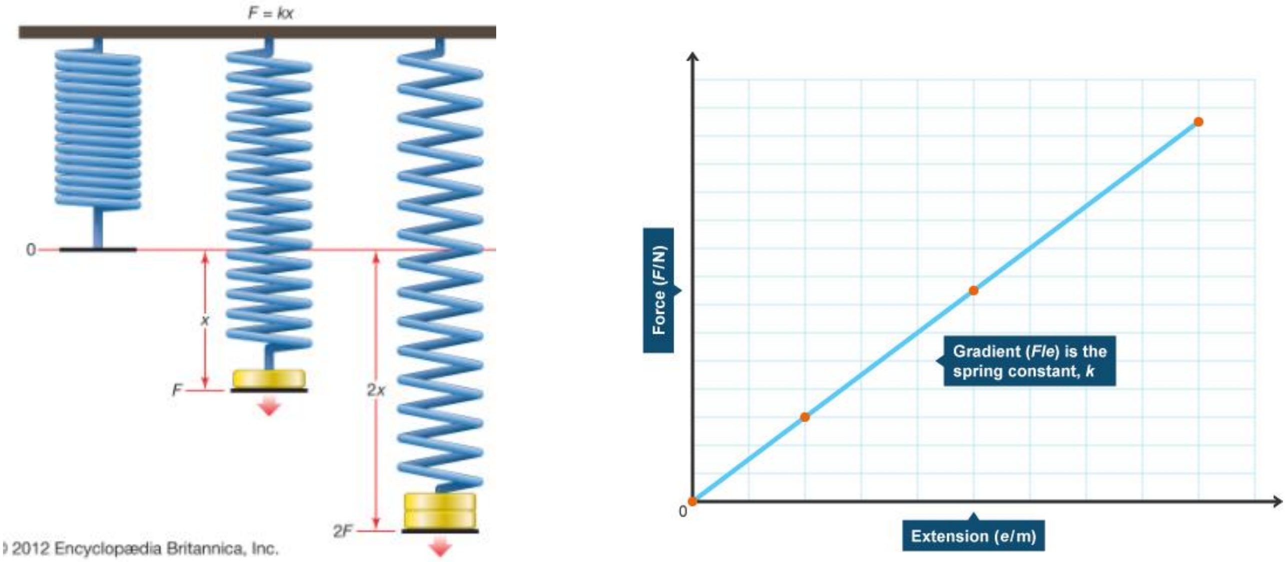
5. An 800 N man is playing on a seesaw with his son who has a weight of 200N. If the child is sitting 3 meters away, how far will the man have to sit to balance the seesaw?



Chapter-8: Solids

8.1 Hooke's Law

Hooke's law states that, "within elastic limit, the amount of stretch (elongation) is proportional to the applied force".



.Fig-8.1, Hooke's Law

Hooke's Law can be written as **F=k x**,

Where 'F' is the force applied (stress), 'x' is the extension or elongation (strain) and 'k' is the constant of proportion which represents the spring constant in the case of the spring-mass elastic system.

8.2 Stress, Strain and Young's Modulus

When an engineer designs a component or structure he needs to know whether it is strong enough to prevent failure due to the loads encountered in service. He analyses the external forces and then deduces the forces or stresses that are induced internally.

Notice the introduction of the word Stress. Obviously; a component which is twice the size is stronger and less likely to fail due an applied load. So an important factor to consider is not just force, but size as well. Hence we talk about stress.

Stress (σ): is the applied force per unit area of cross section and can be calculated from the equation:

$$Stress\ (\sigma) = \frac{Force}{Area}$$

Units of stress are N/m^2 or Pascal (Pa)

8.2.1 Five (5) Types of Stress in Mechanical Bodies:

Tension

Force that tends to pull an object apart.

Fig-8.2(a), Tensile Stress

Compression

Resistance to an external force that tries to push an object together.

Fig-8.2(b), Compression Stress

Torsion

Torsional stress is applied to a material when it is twisted. Torsion is actually a combination of both tension and compression.

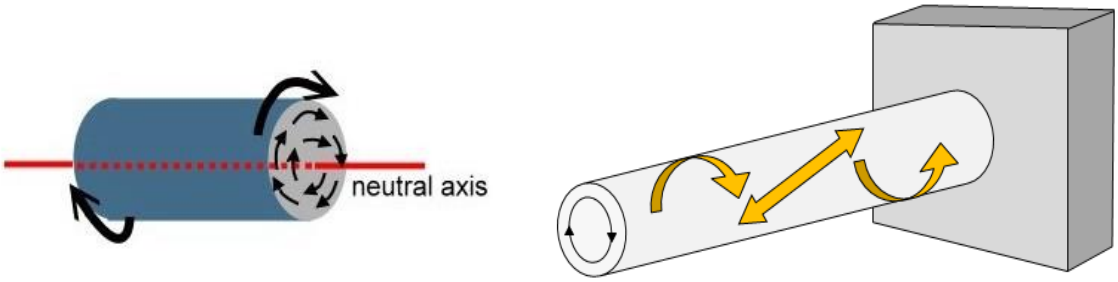


Fig-8.2(c), Torsion Stress

Bending

Bending stress is the normal stress that an object encounters when it is subjected to a large load at a particular point that causes the object to bend and become fatigued.

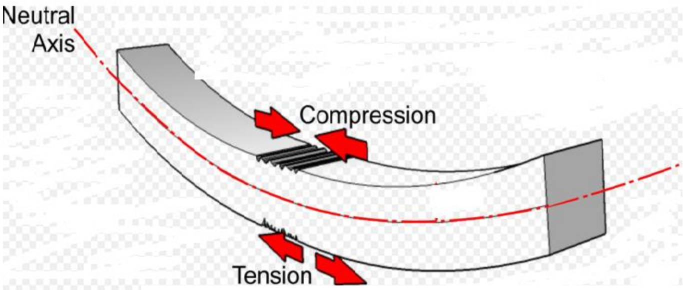


Fig-8.2(d), Bending Stress

Shear

Combines tension and compression is the shear stress, which tries to slide an object apart. Shearing occurs when the applied load causes one 'layer' of material to move relative to the adjacent layers etc.

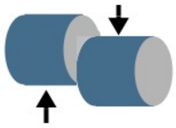


Fig-8.2(d), Shear Stress

8.4 Strain

Stain is the measure of the degree of distortion or deformation.

Strain (ε) is the ratio of the change in length and the original length of the object or actual distortion divided by the original length (in other words, elongation per unit length).

This is termed as Strain, symbol 'ε' (epsilon). Strain has no unit and it is only expressed as a ratio or percentage.

Strain (ε) = $\frac{change\ in\ dimension}{original\ dimension} = \frac{(\Delta l)}{l_o}$

Class Activity-1

A. Choose the correct answer:

1. A wire is stretched 3 mm by a force of 150 N. Assuming the elastic limit is not exceeded, the force that will stretch the wire to 5 mm is:

A. 150 N
B. 250 N
C. 450 N

2. Due to forces acting, pillars supporting a bridge will experience…

A. Tension
B. Compression
C. Torsion

3. The force which produces twisting deformation is _________

A. Torsion.
B. Strain.
C. Shear.

B. Problem Solving:

1. For the wire in question-1(Class Activity-1), what will the extension be when the applied force is 450 N?

2. How much force is necessary to stretch a spring at $\Delta x = 0.25m$ when the spring constant is 95 N/m?

Young's Modulus (Y or E)

Young's modulus measures the resistance of a material to elastic (recoverable) deformation under load. It is the ratio of stress and strain. Mathematically, it can be written as

$$Y = \frac{stress}{strain} = \frac{F/A}{\Delta l/l_0}.$$

It has same unit as stress N/m^2 or Pascal (Pa)

If a length of elastic is pulled, it stretches. If the pull increases, it stretches more; if the pull is reduced, it contracts. Elasticity is the ability of the material to return to its original size or shape after the deforming force is removed

An elastic material has a high Young's modulus and changes its shape only slightly under elastic loads (e.g. steel). A flexible material has a low Young's modulus and changes its shape considerably (e.g. rubbers).

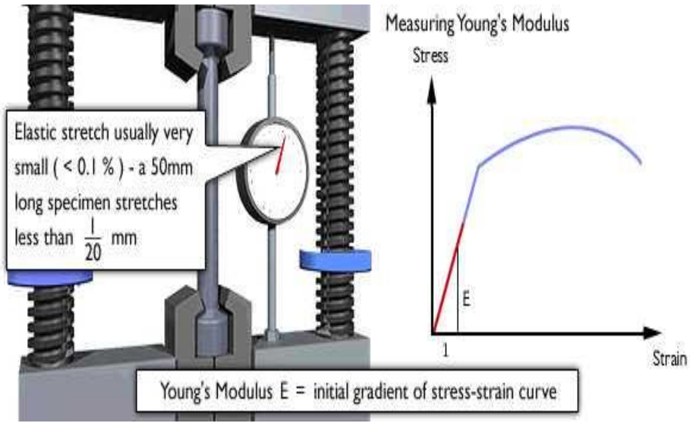


Fig-8.4, Measuring Young's Modulus

The elasticity of a component means how much it deflects under a given load. This depends on the Young's modulus of the material, but also on how it is loaded (tension, or bending) and the shape and size of the component.

Importance of Young's Modulus:

In Engineering and materials science, elasticity is very important in designing products which can only be allowed to deflect by a certain amount (e.g. bridges, bicycles, furniture).

Elasticity is important in springs, which store elastic energy (e.g. vaulting poles, bungee ropes).

In transport applications (e.g. aircraft, racing bicycles) elasticity is required at minimum weight. In these cases materials with a large specific elasticity are best.

The degree of elongation or distortion has to be considered in relation to the original length. The graph in the figure below shows how stress varies with stress when a steel wire is stretched until it breaks.

At first the graph is straight line (O to B), which obeys Hooke's law; the stress increases in a linear form.

Up to the **Yield Point** the area is known as the **Elastic Region** of the material. The proportionality limit has limited engineering significance because of its great dependence upon the precision available for its determination and for engineering usage the elastic limit has little significance.

Past the elastic limit the graph flattens out, which means that each increase in tension by a given amount produces a greater increase in length than it did below the elastic limit, the rod stretches more rapidly.

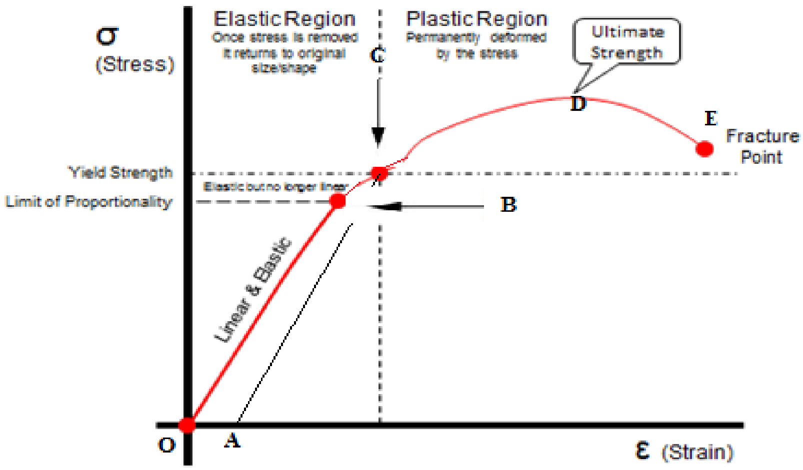


Fig-8.5, Stress-Strain Curve

If the tension is removed after having exceeded the elastic limit, the rod remains longer than it was originally; it has undergone **Plastic Deformation**. The **Ultimate Strength** of the rod is the greatest tension it can withstand without breaking, and it corresponds to the highest point on the curve.

Class Activity-2

A. Choose the correct answer:

1. The ratio of tensile stress to tensile strain is…
A. Young’s Modulus
B. spring constant
C. velocity

2. The unit of strain is…
A. Pascal
B. unit less quantity
C. N/m^2

3. When a steel bar is overstressed, what is the name of the point at which it does not return to its original form after the load is released?
A. Ultimate point.
B. Yield point.
C. Young's modulus.

B. Problem Solving

1. Consider an iron rod with a cross sectional area 1000 mm^2 that has a force of 66,700N applied to it. Find the stress in the rod?

2. A 1m long wire increases by 10^{-3} of its original length when a stress of 10^8 Nm^{-2} is applied to it. What is the Young’s Modulus of the material of the wire?

Worksheet-8

A. Choose the correct answer:

1. Hooke's Law is valid up to…

A. Limit of proportionality
B. Yield point
C. Ultimate strength

2. Whenever a material is loaded within elastic limit then normal stress is ________ strain.

A. proportional
B. inversely proportional
C. equal to

3. The stress produced when a material is pulled (along length) apart is called:

A. Tension.
B. Torsion.
C. Compression

B. Problem Solving

1. A spring has a spring constant of 56 N/m. How far will it stretch when a block weighing 18N is hung at its end?

2. A metal wire is 2.5 mm diameter and 2 m long. A force 12 N is applied on it and it stretches by 0.3 mm. Assume the material is elastic, determine the following:

a) The stress in the wire σ

b) The strain in the wire ε

c) Calculate the Young's Modulus of the wire.

ARABIC TRANSLATION OF PHYSICS TECHNICAL TERMS

ترجمة المصطلحات الفيزيائية إلى اللغة العربية (الجزء الأول)

Chapter 1

Acceleration: التسارع
Angular displacement: الإزاحة الزاوية
Base units: وحدات أساسية
Conversion: التحويل
Convert: حول
Density: الكثافة
Derived units: وحدات مشتقة
Electric current: التيار الكهربائي
Force: القوة
Frequency: التردد
Heat Energy: الطاقة الحرارية
Length: الطول
Luminous intensity: شدة الإضاءة
Mass: الكتلة
Momentum: كمية الحركة أو الزخم
Multiplier: مضاعف
Physical quantity: كمية فيزيائية
Power: القدرة
Prefixes: البادئات
Pressure: الضغط
Resistance: المقاومة
Speed: السرعة
Sphere: كرة
Circular loop: حلقة دائرية
System of Units: نظام الحدات
Temperature:الحرارة
Time: الزمن
Unit of length: وحدة الطول
Unit of mass: وحدة الكتلة
Unit of time: وحدة الزمن
Value: قيمة
Velocity: السرعة المتجهة
Voltage: فرق الجهد
Volume: الحجم
Work: الشغل

Chapter 2

Anion: أنيون
Atom: الذرة
Atomic mass: العدد الكتلي
Atomic number: العدد الذري
Boiling point: نقطة الغليان
Cation كاتيون:
Chemical bonds: الروابط الكيميائية
Classification of matter: تصنيف المادة
Combinations: مزج
Compound: مركب
Condensation: التكثف
Covalent bond: الرابطة التساهمية
Deposition: الترسب
Electrons: الإلكترونات
Element: عنصر
Evaporation: التبخر
Freezing: تجميد
Gain of electrons: اكتساب إلكترونات
Gas: غاز
Heterogeneous: غير متجانس
Homogeneous: متجانس
Ionic bonds: الروابط الأيونية
Isotopes: النظائر
Liquid: سائل
Loss of electrons: فقدان إلكتروتات
Matter: المادة
Melting point: نقطة الذوبان
Melting: ذوبان
Mixture: خليط
Nature of matter: طبيعة المادة
Neutral atom ذرة متعادلة:
Neutrons: النوترون
Nucleus: النواة

Periodic table: الجدول الدوري
Plasma: بلازما
Protons: البروتون
Pure substance: مادة نقية
Ratio: نسبة
Shell الهيكل أو الغلاف:
Solid: صلب
Solidification: تصلب
Structure of an Atom: بنية الذرة
Sublimation: التسامي
Valence electron: إلكترون تكافؤي
Valence shell: مدار تكافؤ أو غلاف تكافؤ
Wet sand: رمل مبلل

Chapter 3

Adding: جمع
Cartesian plane: المستوى الديكارتي
Component of a vector: مكونات المتجه
Direction: إتجاه
Displacement: الإزاحة
Distance: المسافة
Dividing: قسمة
East: الشرق
Equality of vectors: مساواة متجهين
Magnitude: مقدار
Multiplying: ضرب
North: الشمال
Perimeter of circle: محيط الدائرة
Properties: خصائص
Resultant: محصلة
Scalar quantity: كمية عددية
South: الجنوب
Subtracting: طرح
Vector quantity: كمية متجهة
Vector representation: تمثيل المتجهات
Vector: متجه
Weight: الوزن
West: الغرب

Chapter 4

Accelerated motion: حركة متسارعة
Center of gravity: (الثقل)مركز الجاذبية
Cliff: جرف
Final velocity: السرعة النهائية
Free fall: السقوط الحر
Gravity: الجاذبية
Initial velocity: الحركة الإبتدائية
Kinematic equations of motion: معادلات الحركة
Motion: حركة
Non-accelerated motion: حركة غير متسارعة

Chapter 5

Action and reaction: الفعل و ردة الفعل
Advantages of friction: مزايا الإحتكاك
Aluminum: الألومنيوم
Ball bearing: (المدحرجات)كريات المحمل
Coefficient of kinetic friction: معامل الإحتكاك الحركي
Coefficient of static friction: معامل الإحتكاك السكوني
Collision: تصادم
Conservation of linear momentum: حفظ كمية التحرك الخطية
Conserved: محفوظ
Contact force: قوة متصلة
Copper: النحاس
Disadvantages of friction: (عيوب)سلبيات الإحتكاك
Elastic collision: تصادم مرن
Electric field force: قوة المجال الكهربائي
Electromagnetic force: القوة الكهرومغناطسية
Equilibrium: التوازن
Force: قوة
Friction: الإحتكاك
Glass: الزجاج
Gravitational force: قوة الجاذبية
Impulse: الدفع
Inertia: القصور
Iron: حديد
Kinetic Energy: الطاقة الحركية

Kinetic friction: الإحتكاك الحركي
Linear momentum: كمية الحركة الخطية
Magnetic field force: قوة المجال المغناطيسي
Methods of reducing friction: طرق تقليل الإحتكاك
Newton's first law of motion and its application: قانون نيوتن الأول في الحركة و تطبيقاته
Newton's second law of motion and its application: قانون نيوتن الثاني في الحركة و تطبيقاته
Newton's third law of motion and its application: قانون نيوتن الثالث في الحركة و تطبيقاته
Reason: السبب
Rest: ساكن
Rubber: المطاط
Static friction: الإحتكاك السكوني
Steel: الفولاذ
Strong nuclear force: القوة النووية القوية
Use of lubricants: استخدام زيت التشحيم
Wax: الشمع
Weak nuclear force: القوة النووية
Wood: الخشب

Chapter 6

Centrifugal force: قوة الطرد المركزي
Centripetal force: القوة المركزية
Class 1 lever: رافعة من الدرجة الأولى
Class 2 lever: رافعة من الدرجة الثانية
Class 3 lever: رافعة من الدرجة الثالثة
Compound pulley: بكرة مركبة
Efficiency: الكفاءة / الفعالية
Effort: جهد
Energy transferred: الطاقة المنقولة
Energy:
Exert: يبذل
Fixed pulley: بكرة ثابتة
Fulcrum: نقطة إرتكاز
Gears:التروس/ مسننات
Inclined planes: مستوى مائل
Lever: رافعة
Linear displacement: الإزاحة الخطية
Linear velocity: السرعة الخطية
Load: حمولة/ ثقل
Mechanical advantage: الفائدة الميكانيكية
Movable pulley: باكرة متحركة
Potential Energy:الطاقة الكامنة/ طاقة الوضع/ الطاقة المخزنة
Power: الطاقة
Pulley: بكرة
Rotational motion: الحركة الدائرية
Screws: برغي
Uniform circular motion: الحركة الدائرية المنتظمة
Uniform: منتظم
Velocity ratio: النسبة السرعية
Wedges: وتد(أوتاد)
Wheels and axles: العجلة و المحور
Work: الشغل

Chapter 7

Angular momentum: العزم الزاوي أو الزخم الزاوي
Anticlockwise: عكس عقارب الساعة
Axis of rotation: محور الدوران
Balance: توازن
Centre of gravity: مركز الجاذبية
Clockwise: دوران مع عقارب الساعة
Greek letter: حرف يوناني
Gyroscope: جيروسكوب
Maintains: تحافظ
Moment of couple: عزم الإزدواج
Moment of force: عزم القوة
Moment: العزم
Perpendicular: عمودي
Pivot: محور
Rotational inertia: القصور الذاتي الدوراني
Stability: الثبات
Stationary: ثابت
Torque: العزم

Turning effect: تأثير دوراني

Chapter 8

Application: تطبيق

Bending: تقوس (إنحناء)

Compression: إنضغاط

Constant of proportion: ثابت التناسب

Elastic region: المنطقة المرنة

Elasticity: المرونة

Elongation: استطالة

Hooke's law: قانون هوك

Importance: أهمية

Increases: يزيد

Linear form: شكل خطي

Plastic deformation: تشويه بلاستيكي

Proportional: تناسب طردي

Shear: قص

Spring: زنبرك – نابض

Strain: إنفعال

Stress: ضغط(إجهاد)

Stretch: يتمدد

Tension: توتر(شد) سحب

Torsion: الإلتواء

Ultimate strength: القصوى (المتانة)الصلابة

Wire: سلك

Yield point: منطقة منخفضة

Young's modulus: نموذج(معامل) يونج

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