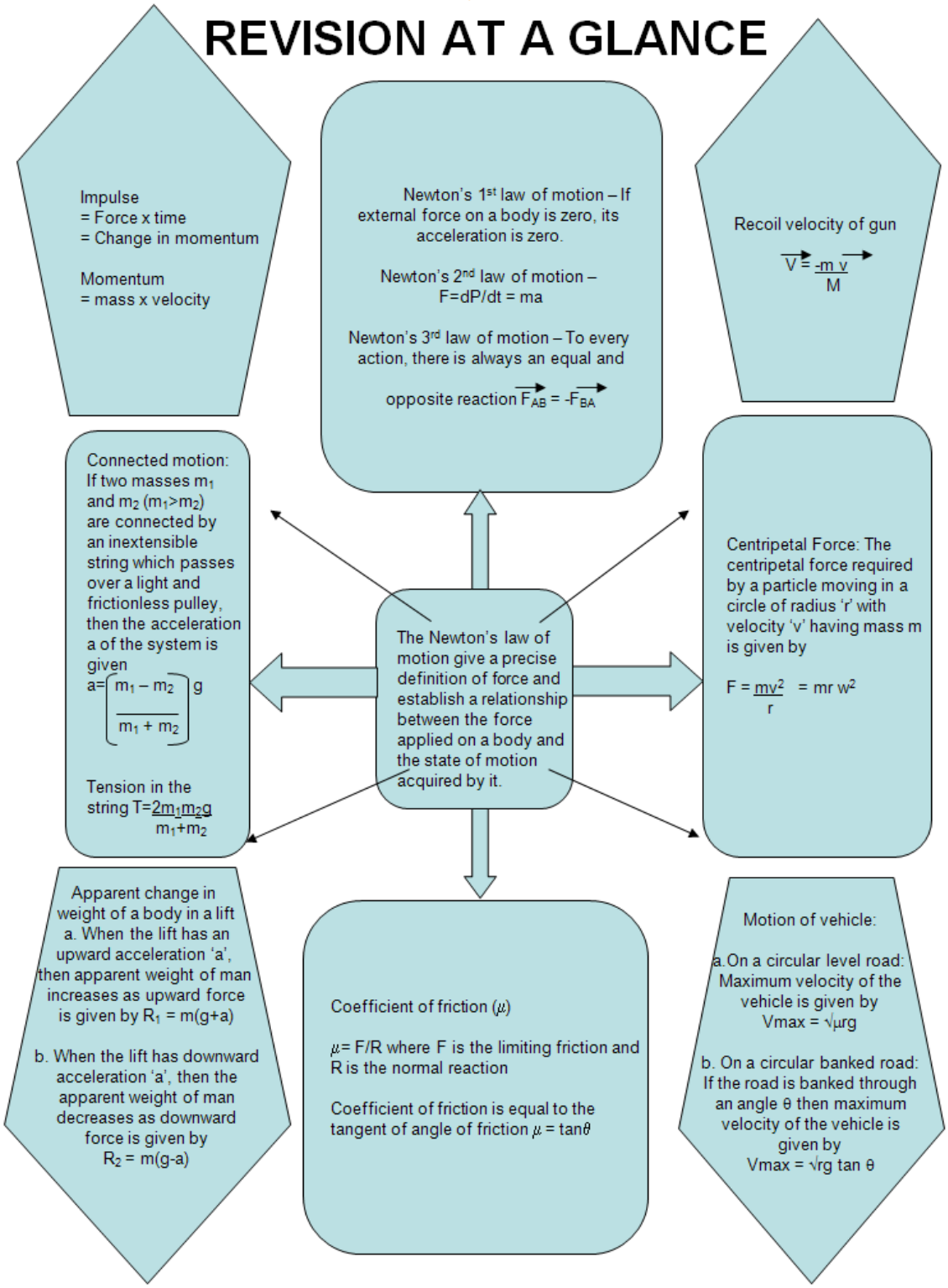
UNIT III- LAWS OF MOTION

REVISION AT A GLANCE



1. **Momentum: -** The momentum of a body is defined as the quantity of motion and is measured as the product of it mass and velocity.

2. **Force: -** A force is that which tends to set a body at rest in motion or which tends to change the speed, direction or motion of a moving object.

3. **Inertia: -** The inertia is the property of a body by virtue of which it opposes any change in a state of rest or uniform motion in a straight line.

4. **Newton's 1st law of motion: -** Everybody continues in its state of rest or o uniform motion in a straight line unless it is compelled by external force to change that state.

5. **Newton's 2nd law of motion: -** The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.

   $\rightarrow$

   $F = d\,P/dt$

6. **Newton's 3rd law of motion: -** To every action, there is an equal and opposite reaction.

   $\rightarrow \quad \rightarrow$

   $F_{AB} = -F_{BA}$

7. **Newton's 2nd law is the real law: -** Since both Newton's 1st law and 2nd law are contained in the 2nd law of motion, hence 2nd law is called real law of motion.

8. **Impulse: -** The change in momentum of a body is called impulse.
   Impulse = Force x Time.

9. **The law of conservation of momentum: -** When two or more bodies interact with one another, their total momentum along a straight a line remains constant, provided no external forces are acting.
   e.g. Recoil of a gun, explosion of bomb.

10. **Apparent change in weight of a body in a lift: -**

    a. When the lift has an upward acceleration 'a', then apparent weight of man increases as upward force is given by
       $R_1 = m\,(g + a)$

    b. When the lift has downward acceleration 'a', then the apparent weight of man decreases as down-ward force is given by
       $R_2 = m\,(g - a)$

11. **Connected Motion: -** If 2 masses m_1 and m_2 ($m_1 > m_2$) are connected by an inextensible string which passes over a light and frictionless pulley,
    The acceleration of the system

    $$a = (m_1 - m_2)/ (m_1 + m_2) \times g$$

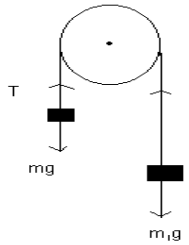
    If $m_1 = m_2 = m$ (say), then $a=0$

    Tension in the string

    $$T = (2m_1m_2)g / (m_1 + m_2)$$

    If $m_1 = m_2 = m$ (say), then

    $T = mg$.



12. **Concurrent Forces: -** A number of forces acting at the same point are called concurrent forces.

13. **Equilibrium in concurrent forces: -** A number of concurrent forces are aid to be in equilibrium, if their resultant is 0.

14. **Friction :-** Friction is the force opposing the relative motion between two forces which are in contact with each other.

15. **Coefficient of friction: -** The ratio of limiting friction to the normal reaction between any 2 given surfaces is a constant. This constant is called coefficient of frictionμ. If F is the limiting friction and R is the normal reaction, then

    $$F = \mu R$$

    μ is also called coefficient of static friction.

16. Kinetic friction is always less than static friction.

17. **Angle of friction: -** It is the angle between the normal reaction and resultant of limiting friction and normal reaction.

18. Coefficient of friction is equal to the tangent of angle of friction.

19. **Angle of repose: -** It is the angle of inclined plane with the horizontal at which a body placed it just begins to slide down.

20. **Rolling friction: -** The opposing force which comes into play when one body rolls or tends to roll over the surface of another body is called rolling friction.

21. **Methods of increasing friction: -**
    a. By making both the surface rough.
    b. By making both surface smooth.

22. **Methods of decreasing friction: -**
    a. Polishing the surface
    b. Lubricating
    c. By providing streamlines shape
    d. Converting sliding friction into rolling friction
    e. Proper selection of materials

23. **Centripetal Force: -** A force which deflects a particle from its straight line path and makes it to move in a circular path is called centripetal force.

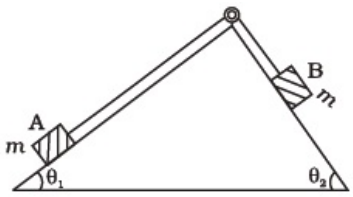
    The centripetal force required by a particle moving in a circle of radius 'r' with velocity v having mass m is given by

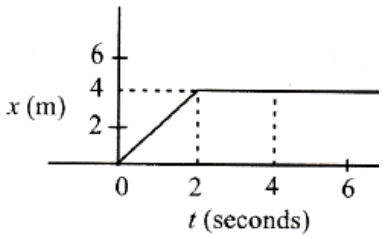
    $F = mv^2/r = mr\omega^2 = 4\pi^2mn^2f$

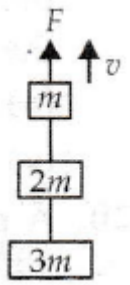
    It always acts along the radius of the circle towards the center of the circle.

24. **Motion of vehicle: -**
    a. *On a circular level road:-* The requires centripetal force is provided by the friction between the tyres and the road, and maximum velocity of the vehicle is given by
    $$v_{max} = \sqrt{\mu rg}$$

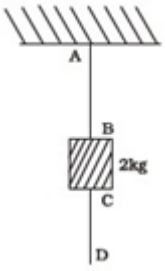
    b. *On a circular banked road:-* If the road is banked through an angle θ then maximum velocity of the vehicle is given my
    $$v_{max} = \sqrt{rg \tan\theta}$$***

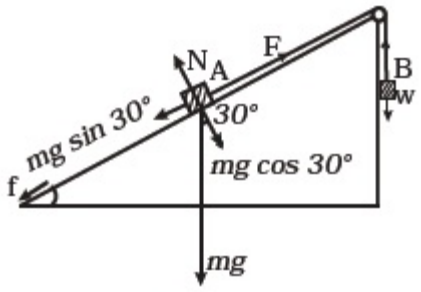
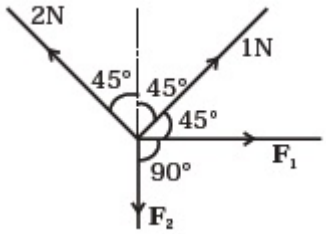
S.No.	Question Details		Marks
	MCQ		
1	In Fig. 5.3, a body A of mass m slides on plane inclined at angle θ_1 to the horizontal and μ_1 is the coefficient of friction between A and the plane. A is connected by a light string passing over a frictionless pulley to another body B, also of mass m, sliding on a frictionless plane inclined at angle θ_2 to the horizontal. Which of the following statements are true?  		**1**
	a) A will never move up the plane.	b) A will just start moving up the plane when $\mu = \sin\theta_2 - \sin\theta_1 / \cos\theta_1$	
	c) For A to move up the plane, θ_2 must always be greater than θ_1	d) B will always slide down with constant speed.	
2	A body of mass 2kg travels according to the law $x(t) = pt + qt^2 + rt^3$ where $p = 3\ ms^{-1}$, $q = 4\ ms^{-2}$ and $r = 5\ ms^{-3}$. The force acting on the body at t = 2 seconds is		**1**
	a) 136 N	b) 134 N	
	c) 158 N	d) 68 N	
3	A boy of mass 50 Kg running at 5 m/s jumps on to a 20Kg trolley travelling in the same direction at 1.5 m/s. What is the common velocity?		**1**

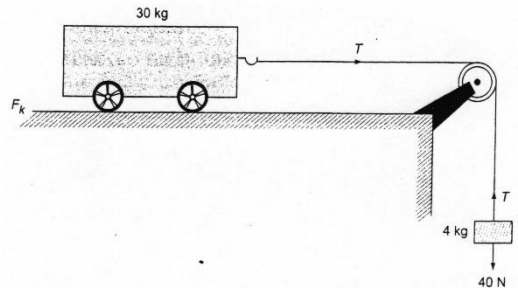
	a)4m/s	b) 3 m/s	
	c.)3.5 m/s	d) None of the above	
4	In the figure given, the position-time graph of a particle of mass 0.1 kg is shown. The impulse at t = 2 sec is 		**1**
	a) 0.2 kg m/s	b**)** - 0.2 kg m/s	
	c) 0.1 kg m/s	d) - 0.4 kg m/s	
5	The pulleys and strings shown in figure are smooth and of negligible mass. for the system to remain in equilibrium, the angle should be:		**1**
	a) zero	b)30^0	
	c) 45^0,	d) 60^0	
6	The force acting on a body whose linear momentum changes by 20kgm/s in 10s is:		**1**
	a) 2N	b) 4N	
	c)1N	d)5N	
7	A body of mass 5 kg is acted upon by two perpendicular forces of 8N and 6N, the magnitude of acceleration of the body is:		**1**
	a)2m/s^2	b)4m/s^2	
	c)3m/s^2	d)1m/s^2	
8	A light string passing over a smooth light pulley connects two blocks' masses M and m (M>m) vertically. If the acceleration of the system is g/8, then the ratio of the masses M to m is:		

	a) 8:1,	b) 9:7	
	c)4:3	d)5:3	
9	An explosion blows a rock into three parts. two parts go off at right angles to each other. these two are, 1 kg first part moving with velocity 12 ms^{-1} and 2 kg, second part moving with velocity of 8 ms–1. if the third part flies off with a velocity of 4 ms^{-1}, its mass would be:		**1**
	a)3kg	b) 5kg	
	c) 7kg	d) 12Kg	
10	3 blocks with masses m to 2m and 3m are connected by Strings as shown in the figure after an upward force f is applied on block and the masses move upward at constant speed V , the net force on the block of mass 2 m is: 		**1**
	a)6mg	b)0	
	c)2mg	d) 3mg	
11.	Assertion: A body can have acceleration even if its velocity is zero at a given instant of time . Reason :A body is momentarily at rest when it reverses its direction of motion.		

	a. Assertion is correct, reason is correct; reason is a correct explanation for assertion.	b. Assertion is correct, reason is correct; reason is not a correct explanation for assertion	
	c. Assertion is correct, reason is incorrect	d. Assertion is incorrect, reason is correct.	
12.	Assertion: If the net external force on the body is zero, then its acceleration is zero. Reason: Acceleration does not depend on force.		
	a. Assertion is correct, reason is correct; reason is a correct explanation for assertion	b. Assertion is correct, reason is correct; reason is not a correct explanation for assertion	
	c. Assertion is correct, reason is incorrect	d. Assertion is incorrect, reason is correct.	
13.	Assertion: A horse can run a cart in empty space , Reason: The reaction of the ground on the feet of the horse is not necessary to run the cart .		
	a. Assertion is correct, reason is correct; reason is a correct explanation for assertion	b. Assertion is correct, reason is correct; reason is not a correct explanation for assertion	
	c. Assertion is correct, reason is incorrect	d. Assertion is incorrect, reason is correct	
14.	Assertion: On a rainy day ,it is difficult to drive a car or a bus at high speed. Reason: The value of coefficient of friction is lowered due to wetting of the surface		
	a. Assertion is correct, reason is correct; reason is a correct explanation for assertion	b. Assertion is correct, reason is correct; reason is not a correct explanation for assertion	
	c. Assertion is correct, reason is incorrect	d. Assertion is incorrect, reason is correct	
15	Assertion: If two objects of different masses have same momentum, the lighter body possess greater velocity. Reason: For all bodies momentum always remains same.		

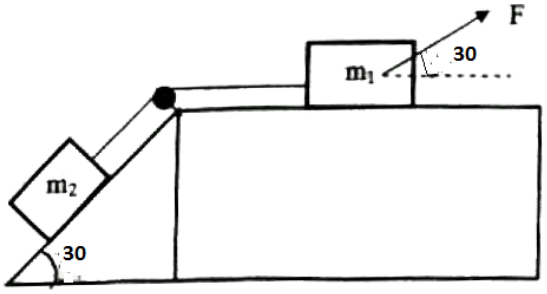
	a. Assertion is correct, reason is correct; reason is a correct explanation for assertion	b. Assertion is correct, reason is correct; reason is not a correct explanation for assertion	
	c. Assertion is correct, reason is incorrect	d. Assertion is incorrect, reason is correct	
16	Why is it easier to maintain the motion than to start it?		**1**
17	What happens to limiting friction, when a wooden block is moved with increasing speed on a horizontal surface?		**1**
18	What happens to coefficient of friction, when weight of body is doubled?		**1**
19	Sparks fly off tangentially from the grinding stone. Why?		**1**
20	Why are wheels of an automobile made circular?		**1**
21	A gramophone disc is making 60 rpm .A coin of mass 0.01 kg is placed at a distance of 0.07 m from the centre. Calculate the centrifugal force acting on the coin. [Ans:2.77 $x10^{-2}$ N]		**2**
22	The coefficient of friction between rubber tyres and road is 0.25. Find the maximum speed with which car can be driven around a curve of radius 39.2 m without skidding. [Ans:9.8ms^{-1}]		**2**
23	A girl riding a bicycle along a straight road with a speed of 5 m s^{-1} throws a stone of mass 0.5 kg which has a speed of 15 m s^{-1} with respect to the ground along her direction of motion. The mass of the girl and bicycle is 50 kg. Does the speed of the bicycle change after the stone is thrown? What is the change in speed, if so?		**2**
25.	A mass of 2 kg is suspended with thread AB (Fig. 5.5). Thread CD of the same type is attached to the other end of 2 kg mass. Lower thread is pulled gradually, harder and harder in the downward direction so as to apply force on AB. Which of the threads will break and why?  		**2**

26	Block A of weight 100 N rests on a frictionless inclined plane of slope angle 30°.A flexible cord attached to A passes over a frictionless pulley and is connected to block B of weight W. Find the weight W for which the system is in equilibrium.  	**2**
27	There are four forces acting at a point P produced by strings as shown in Fig. 5.11, which is at rest. Find the forces F_1 and F_2  	**3**
28	A cricket ball of mass 0.2 kg moves with a velocity of 20 m/s and is brought to rest by a player in 0.1s.Find (a)the impulse of the ball and (b)the average force applied by the player.	**3**
29	A ball of mass 100 gram falls from a height of 5 m and rebounds to a height of 1.25 m. Calculate the impulse and average force between the balls and ground , if the time during which they are in contact 0.1 *s* .Take g =10 m/s^2 .[Ans: 1.5Ns, 15 N]	**3**
30	(a)Derive the expression for the maximum velocity, a vehicle can have when it is travelling in a banked road by considering friction? (b)A particle of mass 100g is moving in a vertical circle of radius 2m.The particle is just looping the loop. What is the speed of the particle and tension in the string at the highest point of the circular path?	**3**
31	A bomb at rest explodes in to three fragments of equal masses. Two fragments fly off at right angles to each other with velocities of 9m/s and 12 m/s. Calculate the speed of the third fragment. (15 m/s)	**3**
32	What is the acceleration of the block and trolley system shown in figure, if the coefficient of kinetic friction between the trolley and the surface is 0.04. What is the tension in the string? Take g = 10 m/s^2. Neglect the mass of the string.	**3**

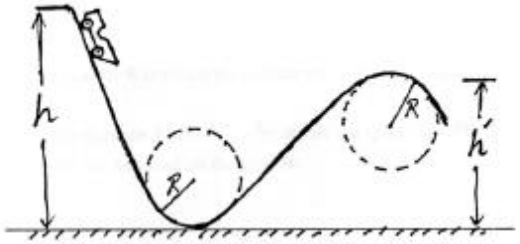


33 a) (**i)** Why does a cyclist bend inward while riding along a curved road? **5**
(ii) If both the speed of the body and radius of its circular path are doubled, how will the magnitude and direction of centripetal force change? Give reason?

b) Two bodies of mass $\mathbf{m_1=40kg}$, and $\mathbf{m_2=10kg}$ are connected with a light rope through a pulley (no friction between the rope and the pulley). $\mathbf{m_2}$ moves on surface with angle of $\mathbf{30^0}$. A force of **100N** acts on $\mathbf{m_1}$ and the system accelerates. Calculate the acceleration of the system? Take $g=10m/sec^2$



34 In a roller coaster, a car starts from rest at a height $\mathbf{h_0}$, and roll down into a valley whose shape is circular with radius **R** , and then up a mountain whose top is also circular with radius **R**, as shown in the figure. Assume the contact between the car and the roller coaster is frictionless. Assume that the car is constrained to follow the track. **5**



a) Find an expression the speed of the car at the bottom of the valley.
b) If the net force on the passengers is equal to 8 mg at the bottom of the valley, find an expression for the radius R of the arc of a circle that fits the bottom of the valley.

	c) A small stone, of mass **0.2kg**, tied to a mass less, inextensible string, is rotated in a vertical circle of radius **2m**. If the particle is just able to complete the vertical circle, what is its speed at the lowest and the highest point of its circular path?	
35	What is meant by banking of road? What is need the of banking? Obtain an expression for the maximum speed with which a vehicle can safely negotiate a curved road banked at an angle **θ**. The coefficient of friction between the wheels and the road is **μ**.	**5**
36.	**Case Study: 1** **Read the following paragraph and answer the questions.** Principle of Conservation of Linear Momentum- According to this principle, in an isolated system, the vector sum of all the system's linear momenta is conserved and is unaffected by their interactions reciprocal action and response. Mutual forces between pairs of particles in an isolated system (i.e., a system with no external force) can thus produce changes in the linear momentum of individual particles. The linear momentum changes cancel in pairs, and the overall linear momentum remains unaltered because the mutual forces for each pair are equal and opposing. As a result, an isolated system of interacting particles' total linear momentum is conserved. This principle is a direct result of Newton's second and third laws of motion. (i)Explain how, a karate player can break a pile of tiles with a single blow of his hand? (ii) How is impulse related to linear momentum? (**iii)**Two masses of M and 4M are moving with equal kinetic energy. Find the ratio of their linear momenta? **OR** (iv)A shell of mass 10 kg is moving with a velocity of 10 ms^{-1} when it blasts and forms two parts of mass 9 kg and 1 kg respectively. If the first mass is stationary, find the velocity of the second?	

Case Study 2

Read the following paragraph and answer the questions.

Types of Friction:

There are 3 types of friction: Static, Limiting and Kinetic Friction.

Static Friction- The opposing force that comes into play when one body tends to move over the surface of another body, but the actual motion has yet not started is called Static friction.

Limiting Friction- Limiting friction is the maximum opposing force that comes into play when one body is just on the verge of moving over the surface of the other body.

Kinetic Friction - Kinetic friction or dynamic friction is the opposing force that comes into play when one body is moving over the surface of another body.

(i) Show that Angle of friction is equal to angle of repose?

(ii)Draw the graph which shows the variation of friction with applied force?

(iii) A block of mass M=5kg is resting on a rough horizontal surface for which the coefficient of friction is 0.2. When a force F=40N is applied in horizontal direction, find the acceleration of the block? ($g=10ms^2$).?

OR

A block of mass 0.1kg is held against a wall applying a horizontal force of 5N on the block. If the coefficient of friction between the block and the wall is 0.5. then find magnitude of the friction force acting on the block.