FRICTION

SYNOPSIS

FRICTION AND FRICTIONAL FORCES :

- **FRICTION :** The property by virtue of which an opposing force is generated between two rough surfaces in contact with each other and which opposes the sliding of one surface over the other is known as friction.
- **FRICTIONAL FORCE :** The force which opposes the sliding or relative motion of two bodies in contact with each other, is called frictional force. Frictional force some times may be in the direction of motion of the body

  EX : 1. If you are walking due east frictional force is due east only

  2. Engine is connected rear wheels of a car. When the car is accelerated, direction of frictional force on the rear wheels will be in the direction of motion and on the front wheels in the opposite direction of motion

TYPES OF FRICTIONAL FORCE AND THEIR DEFINITION

There are three types of frictional forces

i. Static friction

ii. Dynamic friction

iii. Rolling friction

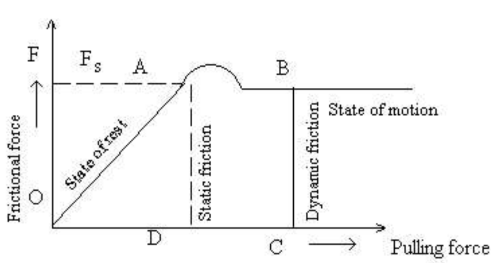
- **STATIC FRICTION :** The frictional force, which is effective before motion starts between two surfaces in contact with each other, is known as static friction

Note : 1. Static frictional force is a self adjusting one

2. The maximum frictional force when the body is ready to start is called limiting frictional force

- **DYNAMIC OR KINETIC FRICTION :** The frictional force, which is effective when two surfaces in contact with each other are in relative motion with respect to each other, is known as dynamic friction.
- **ROLLING FRICTION :** The frictional force, which is effective when a body rolls or rotates on a surface is known as rolling friction.

  It is due to deformation at the point of contact.



LAWS OF FRICTION :

- Friction opposes relative motion between two surfaces in contact and is always tangential to the surface of contact.
- Friction depends on the nature of the two surfaces in contact i.e., nature of materials, surface finish etc.
- Friction is independent of the area of contact between the two surfaces
- Friction is directly proportional to the normal reaction acting on the body.
- $F \alpha R \Rightarrow F = \mu R$

  Where μ = coefficient of friction
- Coefficient of static friction $(\mu_s) = \frac{F}{R}$
- Coefficient of static friction (μ_s) depends on the nature of the two surfaces in contact and is independent of area of the contacting surfaces.
- Coefficient of kinetic friction $(\mu_k) = \frac{F_K}{R}$
- Coefficient of kinetic friction (μ_k) is independent of velocity.
- Coefficient of rolling friction $(\mu_R) = \frac{F_K}{R}$
- Rolling friction depends on area of the surfaces
- Note : $\mu_S > \mu_K > \mu_R$

NORMAL REACTION (R) :

When a body rests on another, the force acting on the bottom surface of the body is called the normal reaction. This is always perpendicular to the surface.

- When the body lies on a horizontal surface

  $R = W = mg$
- When the body lies on an inclined surface

  $R = W\cos\theta = mg\cos\theta$.

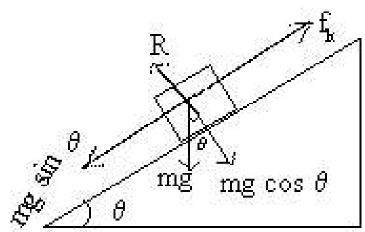
  Normal force always gives rise to frictional force in the direction opposite to the tendency of motion.
- The angle between the normal reaction R and the resultant of F and R is called the angle of friction
- If θ is angle of friction and μ is the coefficient of friction then $\mu = \text{Tan}\theta$
- When a body is moving on a rough inclined plane

which makes an angle θ with the horizontal the frictional force acting on it is

$$F = \mu_k mg\cos\theta$$

MOTION OF A BODY DOWN THE ROUGH INCLINED PLANE :

Let a body of mass m be sliding down a rough inclined plane of angle of inclination θ and coefficient of kinetic friction μ_k.



- Normal reaction $R = mg\cos\theta$
- Frictional force $f_k = \mu_k mg\cos\theta$ (up the plane)
- Net force down the plane
  $F = mg(\sin\theta - \mu_k\cos\theta)$
- Acceleration down the plane
  $a = g(\sin\theta - \mu_k\cos\theta)$
  This is independent of the mass of the body
- Minimum force required to prevent the body sliding down
  $= mg(\sin\theta - \mu_k\cos\theta)$ (in the direction up the plane)
- If the body starts from rest from the top of the inclined plane of length l, time taken to reach the bottom of the plane

$$t = \sqrt{\frac{2l}{g(\sin\theta - \mu_k\cos\theta)}}$$

- Velocity of the body at the bottom of the plane.
  $v = \sqrt{2gl(\sin\theta - \mu_k\cos\theta)}$
- Work done against the frictional force
  $= \mu_k mgl\cos\theta$
- Network done on the body
  $= mgl(\sin\theta - \mu_k\cos\theta)$
  = Gain in the K.E. of the body

MOTION OF A BODY DOWN THE IN CLINED PLANE UNDER DIFFERENT CONDITIONS

ANGLE OF REPOSE (α) : Angle of repose is the minimum angle of the rough inclined plane for which body placed on it may just start sliding down.

Let θ be the angle of inclination of a rough inclined plane α be the angle of repose, m be the mass of the body and

μ be the coefficient of friction.

- If $\theta < \alpha$, the body is at rest on the plane.
  Frictional force $= mg\sin\alpha$ (Self adjusting force)
- If $\theta = \alpha$, the body just tends to slide down the plane
  Frictional force $= mg\sin\theta = \mu_s mg\cos\theta$
- If $\theta > \alpha$, the body slides down with acceleration
  Frictional force $= \mu_k mg\cos\theta$

MOTION OF A BODY UP THE INCLINED PLANE

- When a body is just dragged upwards along a inclined plane then
  - acceleration $a = -g(\sin\theta + \mu_k\cos\theta)$
  - Time of travel $t = \sqrt{\dfrac{2l}{g(\sin\theta + \mu_k\cos\theta)}}$
  - Work done by the driving force
    $W = (mg\sin\theta + \mu_k mg\cos\theta)L$
  - Force required to drag with an acceleration 'a' is $F = \mu_k mg\cos\theta + mg\sin\theta + ma$

SMOOTH INCLINED PLANE

- When a body is sliding down a smooth inclined plane
  1. $a = g\sin\theta$ 2. $v = u + g\sin\theta\, t$
  3. $s = ut + \frac{1}{2}g\sin\theta\, t^2$ 4. $v^2 = u^2 + 2g\sin\theta.s$
- When a body is moving up a smooth inclined plane
  1. $a = -g\sin\theta$ 2. $v = u - g\sin\theta t$
  3. $s = ut - \frac{1}{2}g\sin\theta\, t^2$
  4. $v^2 = u^2 - 2g\sin\theta.s$

MOTION ON A HORIZONTAL ROUGH SURFACE

When a body of mass m on a horizontal rough surface is pulled or pushed with a horizontal force F,

- If the body does not move, the frictional force is equal to the applied force in backward direction.

- If the body is about to move. Then the Friction force = $\mu_s R = \mu_s mg$
- If the applied force $f > \mu_s mg$, the body moves forward.

  Then the frictional force = $\mu_K mg$

  The body moves forward with an acceleration

  $$a = \frac{F - \mu_k\ mg}{m}$$
- If a minimum force, required to move the body is applied and it is further continued, the body moves with an acceleration. $a = (\mu_s - \mu_k)g$

PULLING/PUSHING A BODY :

If a body is pulled at an angle θ (greater than angle of friction α) with the horizontal then the minimum force required is

$$F = \frac{\mu mg}{\cos\theta + \mu_k \sin\theta} = \frac{mg\ \sin\alpha}{\cos(\theta - \alpha)}$$

Similarly, in pushing a body the minimum force required is

$$F = \frac{\mu\ mg}{\cos\theta - \mu_k \sin\theta} = \frac{mg \sin\alpha}{\cos(\theta + \alpha)}$$

APPLICATION OF FRICTIONAL FORCE :

Let us suppose that a car is running with a velocity 'u'. If its engine is stopped then

- Car stops due to friction
- Frictional force on the tyres of car is $F = \mu_k\ mg$
- Acceleration of the car $a = \frac{F}{m} = -\mu_k g$
- Time taken to come to rest $t = \frac{u}{\mu_k g}$
- Distance travelled before coming to rest

  $$S = \frac{u^2}{2\mu_k g}$$
- In case of a car taking a turn of radius 'r' on a horizontal level road, safe maximum speed is $V_{max} = \sqrt{\mu_s gr}$ and maximum angular velocity is $W_{max} = \sqrt{\mu_s g/r}$.
- A block is placed on a truck moving along the horizontal with an acceleration 'a'. Then acceleration of the block is $a' = a - \mu g$ in the backward direction
- A chain of length L is placed on rough table such that minimum length 'l' is hanging over the edge so that the chain doesn't slip off. Then fractional length hanging over the edge is $\frac{l}{L} = \frac{\mu}{\mu + 1}$
- In a death well of radius 'r' a motor cyclist is moving on the wall in a circular path. Then the safe minimum speed v, then $v = \sqrt{\frac{gr}{\mu}}$
- A block of mass m is pressed against a wall without falling, by applying minimum horizontal force F. Then $F = \frac{mg}{\mu}$
- A block is pressed between two hands without falling, by applying minimum horizontal force 'F' by each hand. Then $F = \frac{mg}{2\mu}$
- A block is placed against the vertical side of a truck moving along the horizontal, with an acceleration 'a' without falling. Then $a = \frac{g}{\mu}$
- A block placed on the top of an incline just comes to rest at the bottom. If 1/nth of the length of the incline is rough then $\mu = n\tan\theta$.
- A body released on a rough incline to reach the bottom takes time, 'n' times taken by it when it is released on the top of the same incline when it is smooth. If angle of the incline is θ then $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right)$
- Number of blocks of identical masses m each are placed one above the other. Force required to pull out nth block from the top is $F = (2N-1)\ \mu mg$
- An insect is crawling in a hemispherical bowl of radius 'r'. Maximum height upto which it can crawl is

  $$h = r\left(1 - \frac{1}{\cos\theta}\right)$$

  Maximum angular displacement upto which it can crawl is 'θ'. Then $\mu = \tan\theta$.

ADVANTAGE OF FRICTION :

- Friction plays an important role in our daily life. While walking friction between the ground and shoes prevent us from slipping
- Without friction motion cannot be conveyed by belts from motor to machine
- Vehicles will not come to rest even if the brakes are applied when there is no friction between tyres and the road.
- When there is no friction knots cannot be tied.
- Nails and screws do not hold the boards together without friction.

DISADVANTAGES OF FRICTION :

- Friction causes wear and tear of moving parts of the machinery.
- Friction generates heat in machine parts which damages the machinery.

METHODS OF REDUCING FRICTION :

- **POLISHING :** Friction can be reduced by making the surface in contact polished and smooth. This will remove the irregularities of the surfaces thereby breaking the inter–locking.
- **LUBRICANTS :** Friction can be reduced by using lubricating materials such as grease, oil or graphite on the surfaces. Friction can be reduced by introducing a layer of gases between sliding surfaces. Lubricants should have low density, high viscosity and they should be non volatile.
- **BALL BEARINGS:** By using ball and roller bearings, the sliding friction is converted into rolling friction, thereby the friction is reduced.
- **STREAMLINING :** Automobiles and aeroplanes are streamlined to reduce the friction due to air.

  NOTE : Polishing the surfaces to higher degree leads to increase of friction.

CONCEPTUAL QUESTIONS

1. To keep a particle moving with constant velocity on a frictionless surface, an external force
   1. should act continuously
   2 should be a variable force
   3. not necessary
   4. should act opposite to the direction of motion
2. Frictional force between two bodies
   1. Adds the motion between the bodies
   2. Destroys the relative motion between the bodies
   3. Sometimes helps and sometimes opposes the motion
   4. Increases the relative velocity between the bodies
3. A good lubricant should be highly
   1. Viscous 2. Non-volatile
   3. Both 4. Transparent
4. Theoretically which of the following are best lubricants
   1. Solids 2.Liquids 3.Gases
   4. All the above.
5. When a moving body is suddenly stopped
   1. Frictional force increases
   2. Roughness is found on the road
   3. Tyres of the vehicles burst
   4. The frictional force reduces to zero as it is a self adjusting force
6. A block 'B' rests on 'A'. A rests on a horizontal surface 'C' which is frictionless. There is friction between A and B. If 'B' is pulled to the right
   1. B moves forward and A to the left
   2. 'B' only moves to the left
   3. 'B' does not move
   4. 'A' and 'B' move together to the right
7. Sand is dusted to the railway tracks during rainy season to
   1. Make it always wet
   2. Increase friction
   3. To reduce consumption of fuel
   4. Make it always dry
8. If an external force and the frictional force acting on a body cancel each other the frictional force is
   1. Rolling friction 2. Sliding friction
   3. Static friction 4. Normal reaction
9. It is easier to pull a lawn roller than to push it because pulling
   1. Involves sliding friction
   2. Involves dry friction
   3. Increases the effective weight
   4. Decreases normal reaction
10. With increase of temperature, the frictional force acting between two surfaces
    1. Increases 2. Decreases
    3. Remains same
    4. May increase or decrease

11. If we imagine ideally smooth surfaces and if they are kept in contact, the frictional force acting between them is
1. Zero 2. A finite value but not zero
3. Very large 4. We can't predict

12. If man is walking, direction of friction is
1. Opposite to direction of motion
2. Same as that of direction of motion
3. Perpendicular to that of direction of motion
4. 45° to the direction of motion

13. A high pressure tyre rolls more easily than a low pressure tyre because
1. Friction is less in high inflated tyre
2. Friction is more in high inflated tyre
3. Friction is zero in high pressure tyre
4. Produces force in the forward direction

14. The limiting friction between two surfaces does not depend
1. on the nature of two surfaces
2. on normal reaction
3. on the weight of the body
4. on volume of the body

15. Aeroplanes are streamlined to reduce
1. fluid friction 2. sliding friction
3. kinetic friction 4. limiting friction

16. An aircraft of mass 'm' travels through a distance 's' on a run way having a coefficient of friction 'μ' takes off with a velocity 'v' in 't' sec. The average power of aircraft is
1. $\frac{1}{2} mv^2$ 2. $\frac{1}{2} mv^2 / t$
3. $(\mu_k mgs + \frac{1}{2} mv^2)/t$ 4. $(mgs + \frac{1}{2} mv^2)/t$

17. The maximum speed of a car on a curved path of radius 'r' and the coefficient of friction μ_k is
1. $v = \sqrt{\frac{\mu_k}{gr}}$ 2. $v = \sqrt{\mu_k gr}$
3. $v = \sqrt{\frac{gr}{\mu_k}}$ 4. $v = \sqrt{\frac{1}{\mu_k gr}}$

18. A lift is moving down with an acceleration equal to the acceleration due gravity. A body of mass M kept on the floor of the lift is pulled horizontally. If the coefficient of friction is μ, then the frictional resistance offered by the body is
1. $\mu_k Mg$ 2. Mg 3. Zero 4. $\mu_k Mg^2$

19. A body is struck to the front part of the truck The coefficient of friction between the body and truck is μ. The minimum acceleration with which the truck should travel so that the body does not fall down is
1. μ / g 2. μg 3. g/μ 4. $\mu^2 g$

20. A block of mass M slides down a rough inclined plane of height h through a slope distances. If F be the force of friction then kinetic energy at the bottom will be
1. Mgh 2. MgS
3. Mgh + FS 4. Mgh – FS

21. A body of mass M is placed on a rough inclined plane of inclination θ and coefficient friction μ_k. A force of $(mg \sin\theta + \mu_k mg\cos\theta)$ is applied in the upward direction, the acceleration of the body is
1. $g\sin\theta$ 2. $g(\sin\theta + \mu_k\cos\theta)$
2. $g(\sin\theta - \mu_k\cos\theta)$ 4. Zero

22. While walking on ice one should take small steps to avoid slipping. This is because smaller steps ensure
1. larger friction 2. smaller friction
3. larger normal force 4. smaller normal force

23. In order to stop a car in shortest distance on a horizontal road, one should
1. apply the brakes very hard so that the wheels stop rotating
2. apply the brakes hard enough to just prevent slipping
3. pump the brakes (press and release)
4. shut the engine off and not apply brakes

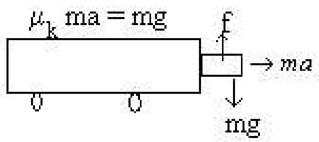
24. A body rests on a rough horizontal plane. A force is applied to the body directed towards the plane at an angle θ with the vertical. The body can be moved along the plane
1. only if θ is greater than the angle of friction
2. only if θ is greater than the angle of friction
3. only if θ is equal to the angle of friction
4. for all values of θ

KEY

1. 3	2. 3	3. 3	4. 3
5. 4	6. 4	7. 2	8. 3
9. 4	10. 2	11. 3	12. 2
13. 1	14. 4	15. 1	16. 3
17. 2	18. 3	19. 3	20. 4
21. 4	22. 3	23. 2	24. 1

HINTS

18. For freely falling body g = 0

19. 

20. P.E. = K.E. + f
K.E. = P.E. – f
= mgh – F.s

21. $a = \dfrac{p - f}{M}$

$(mg \sin\theta + \mu_k\, mg \cos\theta) - mg\,(\sin\theta + \mu_k\, mg \cos\theta)$

LEVEL – I

MOTION OF A BODY ON THE HORIZONTAL SURFACE

1. Brakes are applied to a car moving with disengaged engine, bringing it to a halt after 2s. What is its velocity at the moment when the breaks are applied if the coefficient of friction between the road and the tyres is 0.4?
1. $3.92\ ms^{-1}$ 2. $7.84\ ms^{-1}$
3. $11.2 ms^{-1}$ 4. $19.6\ ms^{-1}$

2. A car running with a velocity 72 kmph on a level road, is stopped after travelling a distance of 30m after disengaging its engine ($g = 10ms^{-2}$). The coefficient friction between the road and the tyres is
1. 0.33 2. 4.5 3. 0.67 4. 0.8

3. If the above car got a stopping distance of 80m on cement road then μ_k is ($g = 10\ m/sec^2$)
1. 0.2 2. 0.25 3. 0.3 4. 0.35

4. A body of mass 6kg. is in uniform motion along a straight line when a force of 12N is acting on it. If $g = 10\ ms^{-2}$, the frictional force acting on the body, is
1. 6 N 2. 12 N 3. 18 N 4. 24 N

5. In the above problem the coefficient of friction between them is
1. 0.01 2. 0.2 3. 0.3 4. Zero

6. A force of 12 N acts on a body of mass 4kg resting on a rough surface (coefficient of friction is 0.2, $g = 10\ ms^{-2}$.) The acceleration of the body in ms^{-2} is
1. 1 2. 0.5 3. 0.25 4. Zero

7. A book sits on horizontal top of a car as the car accelerates horizontally from rest. If the static coefficient of friction between car top and the book is 0.45, the maximum acceleration the car can have for the book not to slip is
1. $3.92\ ms^{-2}$ 2. $4.41\ ms^{-2}$
3. $4.9\ ms^{-2}$ 4. $9.8\ ms^{-2}$

8. The coefficient of friction between a car's wheels and a roadway is 0.5. The least distance in which the car can accelerate from rest to a speed of 72 kmph is $g=10\ ms^{-2}$)
1. 10m 2. 20 m 3. 30 m 4. 40m

9. A car of mass 1000kg moving with a velocity of $10ms^{-1}$ is acted upon by a forward force of 1000 N due to engine and retarding force of 500N due to friction. Its velocity after 10s is
1. $10\ ms^{-1}$ 2. $15\ ms^{-1}$
3. $25\ ms^{-1}$ 4. $20\ ms^{-1}$

10. A body of mass 2kg is placed on a horizontal surface having coefficient of kinetic friction 0.4 and coefficient of static friction 0.5. If a horizontal force of 2.5N is applied on the body, the frictional force acting on the body will be ($g = 10\ ms^{-2}$)
1. 8 N 2. 10 N 3. 20 N 4. 2.5 N

11. In the above problem, the minimum force required to slide the body is
1. 8 N 2. 10 N 3. 20 N 4. 2.5 N

12. In the above problem, during the sliding motion of the body the frictional force is
1. 8 N 2. 10 N 3. 20 N 4. 2.5 N

13. In the above problem the position of the body is
1. rest 2. moving with uniform velocity
3. acclerated motion 4. we cannot say

14. In the above problem, if force applied on the body is 10N, then its acceleration is
1. $5ms^{-2}$ 2. $4\ ms^{-2}$ 3. $1\ ms^{-2}$ 4. $0.5\ ms^{-2}$

15. In the above problem if force applid is 9N its acceleration in ms^{-2} is
1. 4. 5 2. 0.4 3. 0.25 4. Zero

16. A knife with sharp edge is more effective than a blunt knife because
1. the pressure increases due to decrease in surface of contact
2. the force increases due to decrease in surface of contact
3. its velocity ratio decreases
4. it gets blunt due to long use

17. Brakes stop a train in certain distance. When the breaking force is made one fourth, the brakes will stop the train in a distance which is now

1. same 2. four times
3. double 4. half

18. A body of mass 2kg is slipping on a frictionless horizontal table with a velocity of 4 m/s. The necessary force in newton to keep the body moving with the same velocity will be

1. Zero 2.8 3.0.50 4.200

19. The force applied on a body on a rough surface produces an acceleration 'a'. If coefficient of friction between the body and the surface is reduced to $\mu/3$, the acceleration increases by 2 units. The value of μ is

1. 2/3g 2.3/2g 3.3/g 4.1/g

20. The coefficients of static and dynamic friction are 0.7 and 0.4. The minimum force required to create motion is applied on a body and if it is further continued, the acceleration attained by the body in ms^{-2} is

1. 7 2. 4 3. 3 4. Zero

21. The coefficient of static friction between contact surfaces of two bodies is 1. The contact surfaces of one body support the other till the inclination is less than

1. 30º 2. 45º 3.60º 4. 90º

22. A book of weight 20N is pressed between two hands and each hand exerts a force of 40N. If the book just starts to slide down. Coefficient of friction is

1. 0.25 2. 0.2 3.0.5 4. 0.1

23. A 50kg sphere is projected vertically up with a speed of 200 ms^{-1}. It rises to a height of 1500m. The energy used up in overcoming friction is

1. 2.65×10^5 J 2. 5.6×10^5J
3. 20 J 4. Zero

24. An eraser weighing 2N is pressed against the black board with a force of 5N. The coefficient of friction is 0.4. How much force parallel to the black board is required to slide the eraser upwards?

1. 2 N 2.2.8 3.4 N 4. 4.8 N

25. A 10kg mass is resting on a horizontal surface and horizontal force of 80N is applied. If μ = 0.2, the ratio of acceleration with out and with friction is ($g = 10ms^{-2}$)

1. 3/4 2.4/3 3.1/2 4.2/1

26. A train consisting of 30 wagons each of mass 15 tonnes is pulled by an engine of power 90 kW. If the frictional force and air resistive force offered per tonne of the train is 12N the maximum velocity with which the train can travel is

1. 40 kmph 2.60 kmph
3. 80 kmph 4.100 kmph

27. What is the smallest radius of a circle at which a bicyclist can travel if his speed 7m/sec and the coefficient of static friction between the tyres and the road is 0.25?

1. 10 m 2.20 m 3.5 m 4.15 m

MOTION OF A BODY ON THE INCLINED PLANE :

28. The angle of inclination of an inclined plane is 60º. Coefficient of friction between 10kg body on it and its surface is 0.2, $g = 10\ ms^{-2}$. The acceleration of the body down the plane in ms^{-2} is

1. 5.667 2. 6.66 3. 7.66 4.Zero

29. In the above problem the resultant force on the body is

1. 56.6 N 2. 66.6 N
3. 76.7 N 4. 86.6 N

30. In the above problem, the frictional force on the body is

1. Zero 2.5 N 3.7.5 N 4.10 N

31. In the above problem, the minimum force required to pull the body up the inclined plane

1. 66.6 N 2. 86.6 N
3. 96.6 N 4. 76.6 N

32. In the above problem, if the length of the inclined plane 10m then the work done to pull it to the top is

1. 666 J 2.766 J 3.866 J 4. 966 J

33. A body is sliding down an inclined plane forming an angle 30º with the horizontal. If the coefficient of friction is 0.3, then acceleration of the body is

1. 1.25 ms^{-2} 2. 2.35 ms^{-2}
3. 3.4 ms^{-2} 4. 4.9 ms^{-2}

34. In the above problem its velocity after 3 seconds in ms^{-2} is

1. 7.05 2. 14.7 3. 29.4 4. Zero

35. In the above problem its displacement after 3 seconds is

1. 78.4 m 2.44.15m 3.10.575 m 4.Zero

36. It is found that a body on an inclined plane just starts sliding down if inclination is 3 in 5 the angle of repose (friction) is

1. $\sin^{-1} 3/5$ 2. $\sin^{-1} 3/4$
3. $\tan^{-1} 3/5$ 4. $\tan^{-1} 3/4$

37. When a body slides down an inclined plane with coefficient of friction as μ_k, then its acceleration is given by

1. $g(\mu_k \sin\theta + \cos\theta)$ 2. $g(\mu_k \sin\theta - \cos\theta)$
3. $g(\sin\theta + \mu_k \cos\theta)$ 4. $g(\sin\theta - \mu_k \cos\theta)$

38. Work done in moving a body up an inclined rough plane (μ) of length S will be

1. mg ($\sin\theta + \mu_k \cos\theta$)S 2. mg($\mu_k \sin\theta + \cos\theta$)S
3. mg($\mu_k \sin\theta - \cos\theta$)S 4. mg ($\sin\theta - \mu_k \cos\theta$)S

39. A body slides down a rough inclined plane of angle of inclination 30° and takes time twice as great as the time taken in slipping down a identical frictionless plane. The coefficient of friction between the body and the plane is

1. $\sqrt{3}/4$ 2. $\sqrt{3}$ 3. 4/3 4. 3/4

40. A body slides down a smooth inclined plane of height h and angle of inclination 30° reacting the botom with a velocity v. Without changing the height, if the angle of inclination is doubled, the velocity with which it reaches the bottom of the plane is

1. v 2. v/2 3. 2v 4. $\sqrt{2}$ v

41. A body is allowed to slide down on a smooth inclined plane. For a given base length, the time taken by the body to reach the bottom will be minimum if the angle of the inclined plane is

1. 30° 2. 45° 3. 60° 4. 75°

KEY

1. 2	2. 3	3. 2	4. 2	5. 2
6. 1	7. 2	8. 4	9. 2	10. 4
11. 2	12. 1	13. 1	14. 3	15. 4
16. 1	17. 2	18. 1	19. 3	20. 3
21. 2	22. 1	23. 1	24. 3	25. 2
26. 2	27. 2	28. 3	29. 3	30. 4
31. 3	32. 4	33. 2	34. 1	35. 3
36. 1 & 4		37. 4	38. 1	39. 1
40. 1	41. 4			

HINTS

1. $t = \dfrac{u}{\mu_K g} \Rightarrow u = t\mu_k g$

2. $s = \dfrac{u^2}{2\mu_K g} \Rightarrow \mu_K = \dfrac{u^2}{2sg}$

4. $F = f_K$

5. $f_K = \mu_K mg \Rightarrow \mu_K = \dfrac{fK}{mg}$

6. $a = \dfrac{F - \mu_K mg}{m}$

7. $a = \mu_K . g$

8. $s = \dfrac{u^2}{2\mu_K g}$

9. $F^1 = F - f$

$a = \dfrac{F^1}{m}$

$V = at$

10. $F < f_s(\max)$

Then $f_s = F = 2.5N$

11. $f_s = \mu_s mg$

12. $f_K = \mu_K mg$

F

14. $a = \dfrac{F}{m} - \mu_k g \;\; \mu_k^2 \;\; m\mu_k^2 \quad 1$

17. $s\alpha \dfrac{1}{F}$

19. $a = \mu_K g$

$a + 2 = \dfrac{\mu_K}{3} g$

20. $a = (\mu_s - \mu_K) g$

21. $\mu = \tan\theta$

22. $\mu = \dfrac{fs}{R} = \dfrac{mg}{F}$

23. energy spent = K.E - P.E

24. $\mu = \dfrac{mg}{F}$

$F^1 = f_s + mg = \mu_s . F + mg$

25. $\dfrac{a_1}{a_2} = \dfrac{\frac{F}{m}}{\frac{F - \mu_K mg}{m}}$

26. $p = f.v$

27. $v = \sqrt{\mu r g}$

28. $a = g(\sin\theta - \mu_K \cos\theta)$

29. $F = ma$

30. $f = \mu_K mg\cos\theta$

31. $f = mg\left(\sin\theta + \mu_K \cos\theta\right)$

32. $W = F.S$

33. $a = g\left(\sin\theta - \mu_K \cos\theta\right)$

34. $v = a.t$

35. $s = \frac{1}{2}at^2$

36. $\mu = \tan\theta$

37. $F = mg\sin\theta - \mu_k mg\cos\theta$

$a = g(\sin\theta - \mu_k\cos\theta)$

38. $W = Fs = mg(\sin\theta + \mu_k\cos\theta)S$

39. $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right)$

40. $V = \sqrt{2gh}$

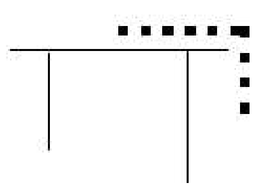
and V does not depends on θ when h=con

41. For given base if angle of inclination is more, shorter will be the time of travel.

LEVEL – II

MOTION OF A BODY ON THE HORIZONTAL SURFACE

1. A chain of length L starts sliding down from the horizontial surface of a table, if the hanging length is 'l', the coefficient of friction between the table and chain is



1. $\frac{l}{L}$ 2. $\frac{L}{l}$ 3. $\frac{l}{L-l}$ 4. $\frac{L-l}{l}$

2. A rope lies on a table so that a part of it is hanging. The rope begins so slide when the length of the hanging part is 25% of the entire length. What is the coefficient of friction between the rope and the table

1. 0.2 2.0.33 3.0.5 4.0.75

3. An aeroplane requires for take off a speed of 108 kmph the run on the ground being 100m. Mass of the plane is 10^4kg and the coefficient of friction between the plane and the ground is 0.2. Assuming the plane accelerates uniformly the minimum force required is

1. 2×10^4 N 2.2.43×10^4 N
3. 6.5×10^4 N 4. 8.86×10^4 N

4. An aeroplane requires for take off speed of 72 kmph, the run on the ground being 100m. The mass of the plane is 10,000kg and the coefficient of friction between the plane and the ground is 0.2. Assume that the plane accelerates uniformly during the take off, the minimum force required by the engine of the plane to take off is

1. 2×10^4 N 2.1.96×10^4 N
3. 0.04×10^4 N 4.3.96×10^4 N

5. A block weighing 10kg is at rest on a horizontal table. The coefficient of static friction between the block and the table is 0.5. If a force acts down at 60º from the horizontal, how large can it be without causing the block to move? ($g = 10ms^{-2}$)

1. 346 N 2.446 N 3.746 N 4.846 N

6. A body moves along a circular path of radius 10m and the coefficient of friction is 0.5. What should be its angular velocity in rad/s if it is not to slip from the surface? ($g=9.8ms^2$)

1. 0.4 2. 0.3 3.0.5 4.0.7

7. A boy pulls a 5kg block along a 20m long horizontal surface at a constant velocity by applying a horizontal force F. If the coefficient of kinetic friction is 0.2, how much work does the boy do on the block? ($g=10ms^{-2}$)

1. 100J 2. 300J 3.200J 4.400 J

8. A train of mass 10^4kg is moving on a level track at a uniform speed of 72km/hr. If the resistance due to friction is 0.25 gmwt per kg, find the power of its engine ($g=9.8\ m/s^2$)?

1. 980 W 2. 490 W 3. 245 W 4. 790 W

9. A block is placed on a rough floor and a horizontal force F is applied on it. The force of friction f by the floor on the block is measured for different values of F and a graph is plotted between them.

1. The graph is a straight line of slope 1
2. the graph is a straight line parallel to the F–axis
3. The graph is a straight line of slope 1 for small F and a straight line parallel to the F–axis for large F.
4. There is a small kink on the graph

10. Read the following two statements and then identify the correct choice of the given answers.
A : The frictional force acting on a body of mass m which is at rest on a horizontal surface of coefficient of static friction μ_s is μ_s mg in the absence of external force
R : The frictional force acting on a body of mass m which is at rest on a rough inclined surface of angle of inclination θ is mg $\sin\theta$.
1. A is true and B is false
2. A is false and B is true
3. Both A and B are true
4. Both A and B are false

11. 70% of the power of a car is used in accelerating it from the rest and the remaining 30% of power is used in overcoming friction. If the acceleration of the car is $5ms^{-2}$, the coefficient of friction between the road and the car is nearly
1. 0.2 2. 0.8 3. 0.7 4. 1.2

12. Two boxes of same material start moving on a rough horizontil surface, one with a velocity of $10ms^{-1}$ and the other with a velocity V. If the ratio of stopping times for the two boxes is 1:3, then the value of V is
1. $3.3ms^{-1}$ 2. $10ms^{-1}$ 3. $30ms^{-1}$ 4. $50ms^{-1}$

13. A 20kg box is on the floor of a truck the coefficient of static friction between the box and the truck floor is 0.3 and the coefficient of sliding friction is 0.2. The magnitude and direction of the frictional force acting on the box, when the truck is accelerating at $2ms^{-2}$ is
1. 99.2 N back ward 2. 99.2 N forward
3. 39.2 N forward 4. 39.2 N backward

14. A a body is pulled through a distance of 5m on a rough surface. If the mass of the body is 5kg and $\mu = 0.2$, then the heat energy developed as a result of friction is
1. 49 joule 2. 4.9 joule
3. 0.9 calorie 4. 4.9 calorie

15. A body of mass 'm' is thrown vertically up with velocity 'u'. If the resistance force due to air is 'f', the time of ascent of the body is
1. $\dfrac{u}{g+f}$ 2. $\dfrac{mu}{mg+f}$
3. $\dfrac{u}{g-f}$ 4. $\dfrac{mu}{mg-f}$

16. A vehicle of mass M is moving on a rough horizontal road with a momentum P. If the coefficient of friction between the tyres and the road is μ, then the stopping distance is
1. $\dfrac{P}{2\mu \mathrm{Mg}}$ 2. $\dfrac{P^2}{2\mu \mathrm{Mg}}$ 3. $\dfrac{P^2}{2\mu \mathrm{M^2g}}$ 4. $\dfrac{P}{2\mu \mathrm{M^2g}}$

17. A force of 150N produces an acceleration of $2ms^{-2}$ in a body and a force of 200N produces an acceleration of $3ms^{-2}$. The mass of the body and the coefficient of kinetic friction are
1. 50kg, 0.1 2. 25kg, 0.1
3. 50kg, 0.5 4 50kg, 0.2

MOTION OF A BODY ON AN INCLINED PLANE

18. A body takes n times as much time to slide down an identical 45° rough incline as it takes to slide down a smooth 45° incline. The coefficient of friction is
1. $1-\dfrac{1}{n^2}$ 2. $\dfrac{1}{1-n^2}$ 3. $\sqrt{1-\dfrac{1}{n^2}}$ 4. $\dfrac{1}{\sqrt{1-n^2}}$

19. The coefficient of friction between a body and an inclined plane is $\dfrac{1}{\sqrt{3}}$. If the body is just ready to slide down, the angle of inclination is
1.75° 2.60° 3.45° 4.30°

20. A wooden block of mass 20kg slides without acceleration down a rough inclined plane which makes angle of 20° with the horizontal. Find the acceleration of the block when the inclination of a plane is increased to 30°
1. $1.81\ ms^{-2}$ 2. $3.62ms^{-2}$
3. $0.90\ ms^{-2}$ 4. $0.45\ ms^{-2}$

21. A body projected from the bottom of a smooth inclined plane with a velocity 9.8 m/sec. The angle of inclination of the plane is 30°. If it comes to rest after reaching the top of the plane, then the time of ascent is
1. 2 sec 2.1 sec 3. 0.5 sec 4.1.5 sec

22. The time taken by a body to slide down a smooth inclined plane is 4 sec. The time taken by the body to slide, the first 1/4th of the length of the plane is

1. 1 sec 2. 2 sec 3. $\sqrt{3}$ sec 4. 0.25 sec

23. A block of mass 1 kg is kept on a rough inclined plane making an angle of 30° with the horizontal. If $\mu_s = 0.5$ and $\mu_k = 0.4$, the frictional force on the block is

1. $1.96\sqrt{3}$ N 2. $0.4 \times 9.8\ \sqrt{3}$N
3. $9.8 \times \sqrt{3}$ N 4. 0.4×9.8 N

24. The coefficient of friction between a hemispherical bowl and an insect is $\sqrt{0.44}$ and the radius of the bowl is 0.6m. The maximum height to which an insect can crawl in the bowl will be

1. 0.4m 2. 0.2m 3. 0.3m 4. 0.1m

25. The power that the engine must develop in order to take the vehicle of mass 2000kg up an inclined plane of slope 1 in 10 at constant speed of $10ms^{-1}$, if the frictional force is 200N will be ($g = 10ms^{-2}$)

1. 22kW 2. 220kW
3. 22000kW 4. 2200 kW

26. A block slides down a rough inclined plane of slope angle θ with a constant velocity. It is then projected up the same plane with an initial velocity v. The distance travelled by the block up the plane before coming to rest is

1. $\frac{v^2}{4g\sin\theta}$ 2. $\frac{v^2}{2g\sin\theta}$ 3. $\frac{v^2}{g\sin\theta}$ 4. $\frac{4gv^2}{\sin\theta}$

27. A wooden block sliding down from the top of a smooth inclined plane starting from rest takes t_1 seconds to reach the bottom of the plane and attains velocity v_1. Another block of twice the mass falling freely in air from the same height takes t_2 seconds to reach the bottom of the plane and attains velocity v_2. If the angle of inclination of the plane is 30°, then

1. $v_1 = v_2$ and $t_1 = t_2$ 2. $v_1 = v_2$ and $t_1 = 2t_2$
3. $v_1 > v_2$ and $t_1 > t_2$ 4. $v_1 = v_2$ and $2t_1 = t_2$

28. The lengths of smooth and rough inclined planes of 45° inclination are same. Times of sliding of a body on two surfaces are t_1 and t_2, and μ = 0.75, then $t_1 : t_2$ =

1. 2 : 1 2. 2 : 3 3. 1 : 2 4. 1 : 1

29. A body of mass 2kg is sliding down on an inclined plane of θ = 53°. What is the time taken by the body to reach the ground if the length of the inclined plane is 10m ?

($g = 10ms^{-2}$ and $\mu_k = 0.5$)

1. 2 sec 2. 4 sec 3. 3sec 4.5 sec

KEY

01. 3	02. 2	03. 3	04. 4	05. 3
06. 4	07. 3	08. 2	09. 3, 4	10. 2
11. 1	12. 3	13. 3	14. 1	15. 2
16. 3	17. 1	18. 1	19. 4	20. 3
21. 1	22. 2	23. 1	24. 4	25. 1
26. 1	27. 2	28. 3	29. 1	

HINTS

1. $\mu = \frac{1}{L - 1}$

4. $f = \mu ma$

$= \mu m \left(\frac{v^2 - u^2}{2s}\right)$

5. $F = \frac{\mu mg}{\cos\phi - \mu \sin\phi}$

6. $\mu mg = mr\omega^2$

7. $F = \mu mg$, $w = f \times s$

8. $P = f \times v$

10. A. In the absence of external force, the body continues to be at rest i.e.; there is not relative motion between the body and the surface.

So, the frictional force is zero but not μ_s mg

B. When a body is at rest on an inclined plane, the frictional force is self adjusting force = mgsin θ

11. $\mu_s = \frac{F - ma}{mg}$

$f_K = \mu_K mg$

12. $a = g\left(\sin\theta - \tan\alpha\cos\theta\right)$

13. $F_k = \mu_k mg + ma$

15. $t_a = \frac{u}{g + a} = \frac{u}{g + \frac{f}{m}}$

16. $P = mV$; $V = P/m$

$s = \frac{v^2}{2\mu_k g}$

17. $150 - 2\mu = 200 - 3\mu$

20. $f = p\sin\theta + mg$; $R = p\cos\theta$

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

21. F_{ext} x $t = mv - mu \Rightarrow mg\sin\theta xt = -mu$

$t = u/g\sin\theta = \frac{9.8}{9.8x1/2} = \sec$

22. $F = (2N-1)\mu mg$

23. $V_G = \frac{M_B V_B}{M_G}$; $a = \frac{V^2}{2s}$

$F = ma$

24. $mg\sin\theta = F_{fr} = \mu mg$; $mg\cos\theta = N = mg$

$\therefore \mu = \tan\theta = \frac{F_{fr}}{N}$

$\mu^2 = \frac{r^2 - (r-h)^2}{(r-h)^2}$; $(r-h) = \sqrt{\frac{r^2}{\mu^2+1}}$;

$h = r\left[1 - \frac{1}{\sqrt{\mu^2+1}}\right]$

$= 0.6 \text{ x } \left[1 - \frac{1}{\sqrt{1+0.44}}\right] = 0.1\text{m}$

25. $F = Fk + mg\sin\theta + 0$

$P = F.V$

26. $a = g(\sin\theta - \mu_k\cos\theta)$

as $a = 0$; $\mu = \tan\theta$; But, $s = \frac{v^2}{2a}$

$= \frac{v^2}{2g(\sin\theta + \mu_k\cos\theta)}$

$= \frac{v^2}{2g(\sin\theta + \tan\theta\cos\theta)}$

27. $t = \sqrt{\frac{2s}{a - \mu g}}$

28. $a = \frac{F - f_K}{m} = \frac{mg - \frac{mg}{2}}{m} = \frac{g}{2}$

$s = \frac{1}{2}at^2 = \frac{gt^2}{4}$

29. $W = (F - \mu_K mg).s$

30. $M_B.V_B = (M_B + M^1{}_B).V^1$

$s = \frac{V^{12}}{2\mu_K g}$

31. $Q = W = P.t$

$= F.vt$

$= \mu mgvt$

33. $P = mg(\sin\theta + \mu_K\cos\theta).v$

35. $f_s = mg\sin\theta$

36. $mg\sin\theta.l = \mu mg.s$

37. $W = mg(\sin\theta + \mu_K\cos\theta).S$

$\therefore W^1 = W + maS$

38. $F = mg\sin\theta + f + ma$

39. $a = g\tan\theta$

40. $l = ut = \frac{h}{\sin\theta}$

$\sin\theta = \frac{h}{ut} \Rightarrow \theta = \sin^{-1}\left(\frac{h}{ut}\right)$

LEVEL – III

MOTION OF A BODY ON THE HORIZONTAL SURFACE

1. The rear side of truck is open and a box of mass 50kg is placed at 3.2m away from the open end. The coefficient of friction between the box and the surface is 0.2. If the truck starts from rest and moves on a straight road with acceleration 2.1 ms^{-2}, the box falls off the truck after a time ($g = 10ms^{-2}$)

   1. $\frac{8}{\sqrt{41}}$ s 2. 4s 3. 8 s 4. $\sqrt{8}s$

2. A wooden box is placed on the back part of lorry moving with an acceleration of $6ms^{-2}$. If $\mu_k = 0.5$. The acceleration of the box relative to lorry in ms^{-2} is

   1.1 2.1.1 3. 1.2 4. Zero

3. A bullet of mass 300grams moving with velocity v strikes a wooden block of mass 2.7kg and gets embedded in it. If the system travels the distance of 20m on the surface and comes to rest, the velocity v is (coefficient of kinetic friction = 0.25 and $g = 10ms^{-2}$)

   1. 200 ms^{-1} 2. 300 ms^{-1}
   3. 100 ms^{-1} 4. 50 ms^{-1}

4. A rear side of a truck is open and a box of mass 20kg is placed on the floor of the truck at a distance of 5m away from the open end. If the truck starts from rest and moves on a straight road with acceleration, the box falls off the truck after 10 seconds. The acceleration of the truck is ($\mu_k = 0.4$ and $g = 10ms^{-2}$)

1. 4.1 ms^{-2} 2. 2.2 ms^{-2}
3. 3.2 ms^{-2} 4. 1.8ms^{-2}

5. If an ice block of mass 42kg moves on a rough surface μ_k= 0.1. If the initial velocity of block is 4 m/sec, then the amout of ice melted as a result of friction before the block comes to rest in gm is

1.0.5 2.1 3.80 4. 16

6. A small coin is placed on a flat, horizontal turn table. The turntable is observed to make three revolutions in 3.14 sec. What is the coefficient of static friction between the coin and turntable if the coin is observed to slide off the turntable when it is greater than 10cm from the centre of turntable?

1. 0.45 2. 0.6 3. 0.5 4. 0.37

7. The expression for acceleration of a particle in S.H.M. on a rough surface of $\mu_k = 0.4$ is 'a = 8A'. where A is amplitude. Then the maximum amplitude of the particle without sliding on surface is

1. 0.2m 2. 0.3m 3. 0.49 m 4. 0.4m

8. A wooden block of mass M resting on a rough horizontal surface is pulled with a force T at an angle θ to the horizontal. If μ is coefficient of kinetic friction between the block and the surface, the acceleration of the block is

1. $\frac{T\cos\theta}{M} - \mu g$

2. $\frac{T}{M}(\cos\theta - \sin\theta) - \mu g$

3. $\frac{T}{M}(\cos\theta + \mu\sin\theta) - \mu g$

4. $\frac{\mu T\cos\theta}{M} - \mu g$

MOTION OF A BODY ON AN INCLINED PLANE

9. A body is sliding down on a rough inclined plane of inclination 45º. The time taken by it to slide down on the rough inclined plane is 3 times greater than the time taken by the body to slide down the smooth inclined plane of same inclination. The coefficient of friction between rough inclined plane and the body is

1. 1/3 2. 2/3 3. 1/9 4. 8/9

10. A body slides down a rough plane inclined to the horizontal at 30º. If 70% of the initial potential energy is dissipated during the descent, the coefficient of sliding friction is

1. 0.7 2. $\sqrt{\frac{0.7}{2}}$ 3. $\frac{0.7}{\sqrt{3}}$ 4. $\frac{0.7}{\sqrt{2}}$

11. A man pushes a 4kg block with a force of 12N and finds that it starts with an acceleration of 2 ms^{-2}. After sometime, he finds that to keep the block in motion with uniform velocity 4 ms^{-1}, he needs only a constant force of 2N. If $g = 10ms^{-2}$, find the coefficients of static and dynamic frictions.

1. 0.1, 0.05 2. .5, .05
3. .25, .2 4. 2, .1

12. A body is sliding down a rough inclined plane of inclination 60º. If the angle of repose is 30º, find the acceleration of the body. ($g=10ms^{-2}$) in m/s^2.

1. 2.33 2. 3.46 3. 4.5 4. 5.77

13. The force of friction acting on a body when velocity is 4 ms^{-1} is 8N. The force of friction when the velocity is 8ms^{-1} is

1. 4 N 2. 8 N 3. 16 N 4. 32 N

14. An iron block of sides 5cm x 8cm x 15cm has to be pushsed along the floor. The force required will be minimum when the surface in contact with the ground is

1. 8 cm x 15 cm surface 2. 5 cmx15cm surface
3. 8 cm x 5cm surface
4. force is same for all surfaces

15. A boy of mass M is applying a horizontal force to slide a box of mass M^1 on a rough horizontal surface. The coefficient of friction between the shoe of the boy and the floor is μ and that between the box and the floor is 'μ^1' in which of the following cases is it certainly not possible to slide the box?

1. $\mu < \mu^1$; $M < M^1$ 2. $\mu > \mu^1$; $M > M^1$
3. $\mu < \mu^1$; $M > M^1$ 4. $\mu > \mu^1$; $M < M^1$

16. A block of mass m and surface area A just begins to slide down an inclined plane when the angle of inclination is $\pi/5$. Keeping the mass of the block same, if the surface area is doubled, the inclination of the plane at which the block starts sliding will be

1. $\pi/5$ 2. $\pi/10$ 3. $2\pi/5$ 4. $\pi/5\sqrt{2}$

17. The angle between force of friction and instantaneous velocity of the body moving over a rough surface is

1. Zero 2. $\pi/2$ 3. π 4. Insufficient data

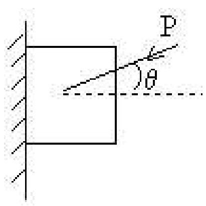
18. A body slides down a rough inclined plane of inclination θ with constant velocity v. If it is projected up the plane with velocity 2v, then it moves up the plane with

1. constant velocity 2. retardation $g\sin\theta$
3. retardation $2g\sin\theta$ 4. acceleration $g\sin\theta$

19. A body moves on a rough horizontal surface with acceleration 'a' when it is subjected to a horizontal force. If the applied force is doubled, it moves with acceleration

1. equal to 2a 2. less than 2a
3. greater than 2a 4. equal to a

20. A block of mass m is pressed against a vertical wall by applying a force P at an angle θ to the horizontal as shown. As a result, if that block is prevented from falling down and μ is coefficient of static friction between the block and the wall, the value of P=



1. $\dfrac{mg}{(\mu\sin\theta-\cos\theta)}$ 2. $\dfrac{mg}{(\mu\sin\theta+\cos\theta)}$

3. $\dfrac{mg}{(\mu\cos\theta-\sin\theta)}$ 4. $\dfrac{mg}{(\mu\cos\theta+\sin\theta)}$

21. Two trolleys of masses m_1 and m_2 are connected by a spring. They are compressed and released on a horizontal surface. Then they move in opposite directions and come to rest after covering distances d_1 and d_2 respectively. If the coefficient of friction is same for both on that surface, $d_1 : d_2$ =

1. (m_1/m_2) 2. (m_2/m_1) 3. $(m_1/m_2)^2$ 4. $(m_2/m_1)^2$

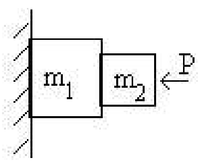
22. A number of blocks each of mass 0.4 kg are placed one over the other. The minimum horizontal force required to pull the eighth block from the top without disturbing the remaining 10N. If $g = 10\ ms^{-2}$, the coefficient of static friction between any two block is

1. 1/3 2. 1/4 3. 1/6 4. 1/8

23. When a person walks on a rough surface

1. The frictional force exerted by the surface keeps him moving
2. reaction of the force applied by the man on the surface keeps him moving
3. the force applied by the man keep him moving
4. weight of the man keeps him moving

24. Consider the situation as shown. Surface of m_1 and m_2 in contact are rough. There is no friction between wall and m_1. Then



1. Friction on m_2 is in the upward direction and m_1 is in equilibrium
2. Friction on m_2 is in the down ward direction and m_1 is in equilibrium
3. friction on m_2 is zero and m_2 is in equilibrium
4. the system can not remain in equilibrium

25. A gun of mass 50kg fires a bullet of mass 0.5kg with velocity of $200ms^{-1}$. If the gun moves through 1m back before coming to rest, the frictional force on the gun is

1. 50 N 2. 100N 3. 200N 4. Zero

26. The horizontal force required to drag a wooden cube of a side 'a' on a rough horizontal surface is F. Another cube of the same wood but of side '2a' is dragged on the same surface. Then the force required if the cube is dragged with constant speed in both the cases

1. F 2. 2 F 3. 8 F 4. 16F

27. A body is placed at the middle of a plank of length 'l' coefficient of friction between the body and the plank is μ. If the body starts with an acceleration 'a', the time after which the body leaves the plank is

1. $\sqrt{\dfrac{1}{(a-\mu g)}}$ 2. $\sqrt{\dfrac{1}{(a+\mu g)}}$ 3. $\sqrt{\dfrac{2l}{(a-\mu g)}}$ 4. $\sqrt{\dfrac{2l}{(a+\mu g)}}$

28. A force equal to the weight of the body acts on a body for 't' seconds. If the frictional force is equal to half the weight of the body the distance travelled in 't' seconds is

1. $s = g^2t^2/4$ 2. $S = gt^2/4$
3. $gt/4$ 4. $g^{-1}t^{-1}/4$

29. When a force of 120N acts on a body of mass 20kg and moves is through a distance of 10m, the kinetic energy gained by the body is 400J. Then coefficient of kinetic friction between the body and the surface on which it is moving is ($g = 10ms^{-2}$)

1. 0.2 2. 0.4 3. 0.8 4. None

30. A bullet of mass 1×10^{-2}kg moving horizontal with a velocity of 2×10^2 ms^{-1} strikes the block of mass 1.99kg and gets embedded into it. If the coefficient of kinetic friction of the block and the horizontal surface is 0.25. Then the distance moved by the block with the bullet is before coming to rest is

1. 0.4m 2. 0.8m 3. 0.6 m 4. 0.2 m

31. A body of mass 2kg moves with a uniform velocity of $2ms^{-1}$ on a horizontal plane of coefficient of friction 0.2. If joule's constant J is 4.2 J/cal and $g = 9.8$ ms^{-2}. Then the amount of heat generated in 5 second is

1. 9.33 cal 2. 93.3 cal
3. 18.66 cal 4. 18.6 cal

32. A smooth wooden plank is kept inclined to a vertical wall such that a body left at its top takes minimum time to reach the bottom. If the foot of the plank is at a horizontal distance of 19.6 m from the wall, the minimum time is

1. 2 s 2. $2\sqrt{2}\,s$ 3. 4 s 4. $\frac{1}{\sqrt{2}}s$

33. An engine of 1000kg is moving up an inclined plane 1 in 2 at the rate of $20ms^{-1}$. If the coefficient of friction is $\frac{1}{\sqrt{3}}$, power of the engine is

1. 98 KW 2. 196 KW
3. 392 KW 4. 49 KW

34. A body of mass 4kg is kept on an inclined plane of 1 in 2. When it is pulled directly up the plane by a force of 6kg wt, it moves with acceleration of $2ms^{-2}$. If a force of 3kg wt is applied down the plane, it moves with this acceleration ($g=10ms^{-2}$)

1. 1 ms^{-2} 2. 2ms^{-2} 3. 3.5ms^{-2} 4. 4.5ms^{-2}

35. A body of mass m is kept on an inclined plane of inclination 30° to the horizontal. If the angle of repose is 45° static friction on the body is

1. $\frac{mg}{\sqrt{2}}$ 2. $\frac{mg}{2}$ 3. mg 4. $\sqrt{2}$ mg

36. A smooth inclined plane of length 4m is making an angle 30° with the rough horizontal plane. A body is released from the top of the smooth inclined plane travels a distance of 8m on the horizontal surface and comes to rest. The coefficient of friction is

1. 0.025 2. 0.0025 3. 0.25 4. Zero

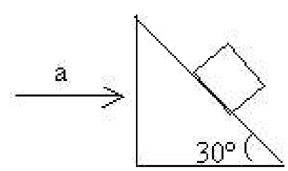
37. Length of an inclined plane is 5m and it is inclined at 30° to the horizontal. Work done to move the block up the plane with uniform velocity is 100J. Then work done to move the block up the plane with uniform acceleration of $4ms^{-2}$ is ($\mu = 1/\sqrt{3}$)

1. 140J 2. 400J 3. 300J 4. 100J

38. A body of mass 2kg is on an inclined plane inclined at 30° to the horizontal. The force applied on it parallel to the plane so that it moves up that slope with acceleration of $2ms^{-2}$ against a frictional force of 5N.

1. 5 N 2. 9 N 3. 14N 4. 18.8 N

39. A block is kept on a wedge of inclination 30° to the horizontal as shown. With what acceleration the wedge should be moved so that the block does not move relative to the wedge?



1. g 2. $g/\sqrt{3}$ 3. $\sqrt{3}\,g$ 4. $g/\sqrt{2}$

40. A body is released from the top of a smooth inclined plane at height h above the ground. Simultaneously another body is pushed up with a velocity V from the bottom. If they meet after time t, inclination of that inclined plane to the horizontal is

1. $\sin^{-1}\left(\frac{t}{hu}\right)$ 2. $\cos^{-1}\left(\frac{t}{hu}\right)$
3. $\sin^{-1}\left(\frac{h}{ut}\right)$ 4. $\cos^{-1}\left(\frac{hu}{t}\right)$

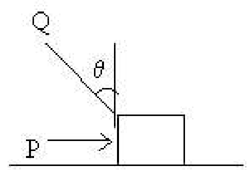
41. A block of mass 1kg lies on a horizontal surface in a truck. The coefficient of friction between the block and the surface is 0.6. If the acceleration of the truck is $5ms^{-2}$, the frictional force acting on the block is

1. 5N 2.10N 3.15 N 4. 20N

42. A block A of mass 2kg rests on another block B of mass 8kg which rests on a horizontal floor The coefficient of friction between A and B is 0.2, while that between B and the floor is 0.5. When a horizontal force of 25N is applied on B, the force of friction between A and B is

1. Zero 2.3.9 N 3.5.0 N 4.49.0N

43. A block of mass, lying on a rough horizontal plane is acted upon by a horizontal force P and another force Q, inclined at an angle θ to vertical. The block will remain in equilibrium, if coefficient of friction between it and surface is



1. $\frac{(P+Q\sin\theta)}{(mg+Q\cos\theta)}$ 2. $\frac{(P\cos\theta+Q)}{(mg-Q\sin\theta)}$

3. $\frac{(P+Q\cos\theta)}{(mg+Q\sin\theta)}$ 4. $\frac{(P\sin\theta-Q)}{(mg-Q\cos\theta)}$

44. A body of mass 100g is sliding from an inclined plane of inclination 30º. What is the frictional force experience if μ = 0.7?

1. $0.7\frac{\sqrt{3}}{2}$ 2. $\frac{1}{2}$ 3. $\frac{\sqrt{3}}{2}$ 4.0.35

45. A block of mass M is pulled along a horizontal rough surface by a rope of mass m by applying a force F at one end of the rope. f is the friction between block and the surface. The force which the rope exerts on the block is

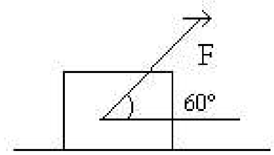
1. $\frac{FM}{m+M}+f$ 2. $\frac{mF}{m+M}-f$

3. $\frac{mF+fM}{M-m}$ 4. $\frac{MF-fm}{M-m}$

46. An insect crawls up a hemispherical surface. The coefficient of friction between the insect and the surface is 1/3. If the line joining the centre of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is given by

1. cot α = 3 2. tan α = 3
3. sec α = 3 4. cosec α = 3

47. A block of mass $\sqrt{3}$ kg is kept on a frictional surface with $\mu = 1/2\sqrt{3}$. The minimum force to be applied (as shown) to move the block is



1. 5 N 2.20N 3.10N 4.20/3 N

48. A block rests on a rough inclined plane making an angle of 30º with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10N, the mass of the block (in kg) is [$g= 10ms^{-2}$]

1. 2.0 2. 4.0 3. 1.6 4. 2.5

49. A small block sides without friction down an inclined plane starting from rest. Let S_n be the distance travelled from time t = n – 1 to t = n.

Then $\frac{S_n}{S_{n+1}}$ is

1. $\frac{2n-1}{2n}$ 2. $\frac{2n+1}{2n-1}$ 3. $\frac{2n-1}{2n+1}$ 4. $\frac{2n}{2n+1}$

50. A smooth inclined plane makes an angle of 30º to the horizontal. The constant force applied parallel to the plane to produce a 10kg block to slide up the plane with an acceleration of $1ms^{-2}$ is

1. 39 N 2.42 N 3.49 N 4.59 N
4. the system can not remain in equilibrium

51. A block X kept on an inclined surface just begins to slide if the inclination is θ_1. The block is replaced by another block Y and it is found that it just begins to slide if the inclination θ_2 is ($\theta_2 > \theta_1$). Then

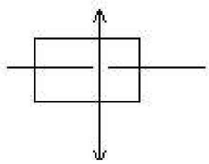
1. Mass of X = mass of Y
2. Mass of X < mass of Y
3. Mass of X > mass of Y
4. All the three are possible

KEY

1. 3	2. 2	3. 3	4. 1	5. 2
6. 4	7. 3	8. 3	9. 4	10. 3
11. 1	12. 4	13. 2	14. 4	15. 1
16. 1	17. 3	18. 3	19. 3	20. 3
21. 4	22. 3	23. 1	24. 4	25. 2
26. 3	27. 1	28. 2	29. 2	30. 4
31. 1	32. 2	33. 1	34. 4	35. 2
36. 3	37. 1	38. 4	39. 2	40. 3
41. 1	42. 1	43. 1	44. 2	45. 1
46.1	47. 2	48. 1	49. 3	50. 4
51. 4				

HINTS

1. $a_{box} = a_{truck} - \mu_k . g$
2. $s = ut + \frac{1}{2} at^2$ (but) $u = 0$
3. Common velocity after collision



$= \dfrac{m_1 u}{m_1 + m_2} \qquad = \dfrac{0.3V}{3}, \quad = \dfrac{V}{10}$

$\dfrac{1}{2} m \left(\dfrac{V}{10}\right)^2 = \mu_k$ mg x 20

4. Resultant acceleration of the box $a_1 = \dfrac{2s}{t^2}$

$= \dfrac{2x5}{100} = \dfrac{1}{10}$ ms^{-2}

If a is the acceleration of the truck and 'm' is the mass of the box

$ma - \mu_k mg = ma_1; \qquad a = a_1 + \mu g$

5. $m' L = \dfrac{1}{2} mu^2 - \dfrac{1}{2} mv^2$ (v=0)

($L = 0.336x10^{-6}$J/kg)

6. $mr\,\omega^2 = \mu_k$ mg
7. $a = 8A = \mu_k$ g;
   R = mg – T sin
8. $F_k = \mu_k R <$ > $T\cos\theta$
   mg

$$a = \frac{T\cos\theta - \mu_k R}{m}$$

9. $\dfrac{t_1}{t_2} = \sqrt{1 - \mu_k \cot\theta} = \dfrac{1}{3} = \sqrt{1 - \mu_k \cot 45^o}$

10. Frictional energy = Initial potential energy $x \dfrac{70}{100}$

NEW TYPE QUESTIONS

1. Match List I with List II from the combinations below

List – I	**List – II**
a. non–conservative froce	e. depends on mass
b. conservative force	f. workdone independent of path
c. deceleration due to friction on rough horizontal surface	g. workdone depends on path
d. accelerating force on a smooth inclined surface	h. independent of mass

The correct match is
1. a → g; b → h; c → f; d → e
2. a → f; b → e; c → h; d → g
3. a → g; b → f; c → h; d → e
4. a → e; b → g; c → h; d → f

2. Match the following

List – I	**List – II**
a. Static friction	e. constant for a given pair of surfaces
b. Limiting friction	f. independent of area of contact
c. Kinetic friction	g. self adjusting
d. Rolling friction	h. has the least magni tude for a given normal reaction

1. a → e; b → f; c → g; d → h
2. a → h; b → f; c → e; d → g
3. a → g; b → e; c → f; d → h
4. a → g; b → h; c → f; d → e

3. Match the following

List – I	List – II
a. Frictional force	e. Zero
b. Gravitational force	f. Electromagnetic force
c. When a body on rough inclined plane is just to move, then the net force acting on the body is	g. mg sin θ
d. The force acting on a body placed on a smooth inclined plane is	h. conservative force

The correct match is

1. a → h; b → f; c → g; d → e
2. a → f; b → h; c → e; d → g
3. a → e; b → g; c → f; d → h
4. a → g; b → e; c → h; d → f

4. Match the following

List – I	List – II
a. frictional force	e. reduction of friction
b. rolling friction	f. adhesive force
c. ball bearing	g. deformation at the point of contact
d. excessive polishing	h. increase of friction
	i. conservative force

The correct match is

1. a → i; b → e; c → h; d → f
2. a → f; b → f; c → e; d → g
3. a → f; b → g; c → e; d → h
4. a → i; b → f; c → h; d → e

5. Match the following

List – I	List – II
a. two rotating discs are brought in contact coaxially	e. generated friction is equal to applied external force
b. contact force on a body placed on rough surface	f. loss of rotational KE is transformed partly into heat
c. To continue a motion is easier than to initiate the motion	g. the resultant of normal reaction and friction
d. for a static friction less than limiting friction	h. kinetic friction is less than static friction

The correct match is

1. a → f; b → g; c → h; d → e
2. a → g; b → f; c → e; d → h
3. a → h; b → e; c → f; d → g
4. a → e; b → h; c → f; d → f

6. If μ_s, μ_k and μ_R are the coefficients of limiting, kinetic and rolling frictions between two given surfaces. Arrange them in ascending order

1. μ_R, μ_S, μ_K 2. μ_R, μ_K, μ_s
3. μ_S, μ_K, μ_R 4. μ_K, μ_R, μ_S

7. Three bodies P, Q and R slide down along three different frictionless inclined planes, starting from rest from the respective tops of the planes. If the respective lengths and angles of inclination of the planes are 4m and 30º, 2m and 45º, 2m and 60º and V_P, V_Q and V_R are the respective speeds when they reach the bottoms. Arrange them in decreasing order of magnitude

1. V_R, V_Q, V_P 2. V_P, V_Q, V_R
3. V_P, V_R, V_Q 4. V_Q, V_R, V_P

8. The ratio of time taken to slide down along a rough inclined plane to an identical smooth inclined planes and angle of inclination and coefficient of friction as follows.

S. no.	Ratio of times	Angle of inclinations	Coefficient of frictions
1.	$t_1/t_2=2$	$\theta = 30^o$	μ_1
2.	$t_1/t_2=4$	$\theta = 45^o$	μ_2
3.	$t_1/t_2=3$	$\theta = 30^o$	μ_3

Then the correct relation between μ_1, μ_2, μ_3 is

1. $\mu_1 < \mu_2 < \mu_3$ 2. $\mu_1 > \mu_2 > \mu_3$
3. $\mu_1 < \mu_3 < \mu_2$ 4. $\mu_1 > \mu_3 > \mu_2$

9. Identify the correct order in which the value of normal reaction increases object is placed on rough horizontal surface

a. the object is pushed with the force F at an angle θ with horizontal
b. the object is pulled with the force F at an angle θ with horizontal
c. The object is pushed down with the force F normally
d. The object is pushed up with the force F normally

1. a, b, c, d 2. d, b, a, c
3. a, c, b, d 4. b, d, c, a

10. Three bodies A, B and C of masses 1kg, 2kg and 3kg are at rest on a horizontal surface of coefficient of friction 0.5. If they are pulled with forces 20N, 30N, and 25N respectively, their accelerations a_A, a_B and a_C will be in ascending order as follows.

1. a_A, a_B, a_C 2. a_C, a_B, a_A
3. a_B, a_A, a_C 4. a_B, a_C, a_A

11. The following particles are projected on the same horizontal rough surface.

S.NO.	Mass	K.E.
1	10gm	20J
2	20gm	40J
3	40gm	100J
4	50gm	200J

Which of the above particles are stopped in the same time due to friction.

1. 10gm, 20gm 2. 10gm, 40gm
3. 20gm, 50gm 4. 10gm, 50gm

A : Assertion R : Reason
A: Both A and R are true. R is correct explanation of A
B. Both A and R are true. But R is not correct explanation of A
C. A is true. R is false
D. Both A and R are false.

12. A : On polishing the surface the friction decreases upto certain limit but increases beyond that
R : On polishing the surface, the irregularities are cut off
1. A 2. B 3. C 4. D

13. A: When a bicycle is being pedaled, the friction on the front wheel is in a direction opposite to the motion of bicycle
R : The rear wheel while being pedalled, pushes the front wheel on rough road due to which the friction opposes the relative motion
1. A 2. B 3. C 4. D

14. A : It is difficult to move a bike with its breaks on
R : sliding friction is greater than rolling friction
1. A 2. B 3. C 4. D

15. A : On a rainy day, it is difficult to drive a car or bus at high speed.
R: The value of coefficient of friction is lowered on wetting the surface.
1. A 2. B 3. C 4. D

16. A horse has to pull a cart harder during the first few steps of his motion
R: The first few steps are always difficult
1. A 2. B 3. C 4. D

17. A : Pulling a lawn roller is easier than pushing it
R : pulling increases the apparent weight as the vertical component of the puling force acts upward
1. A 2. B 3. C 4. D

18. A : More force is required to push a body up a rough inclined plane than that to move the same body down the same plane
R : The friction always acts parallel to inclined plane downwards
1. A 2. B 3. C 4. D

19. A : When a body tends to slide down an inclined plane, force of friction acts up the plane
R : Friction always opposes the relative motion
1. A 2. B 3. C 4. D

20. A : A body on an inclined plane just tends to slide down if the angle of inclination is equal to angle of friction
R : When the angle of inclination is equal to the angle of friction, the compound of weight parallel to the plane is just sufficient to overcome the frictional force
1. A 2. B 3. C 4. D

21. A : An object projected with same velocity on the paths of different rough surfaces are brought to rest in different distances
R : The workdone against the friction depends on the path travelled by the object
1. A 2. B 3. C 4. D

22. A : Frictional force is independent of the velocity of the body.
R : Friction is due to surface irregularities
1. A 2. B 3. C 4. D

23. A : The acceleration of a body sliding down a smooth plane of inclination 30º is $5ms^{-2}$
R : $a = g \sin\theta = 10 \sin 30^\circ = 5ms^{-2}$.
1. A 2. B 3. C 4. D

24. A : The acceleration of a body moving up a rough inclined plane, when it is pulled up by a force, depends on its mass
R : Frictional force acts down the plane when the body moves up the plane
1. A 2. B 3. C 4. D

25. A : When external force acting on a body moving on a rough horizontal surface is doubled, the acceleration of the body is doubled.
R : The acceleration of a body moving on a rough horizontal surface is proportional to the resultant force acting on it.
1. A 2. B 3. C 4. D

26. A : The time of ascent for a body projected to move up a rough inclined plane is less than the time of descent
R : The retardation for upward motion is more than the acceleration for down motion
1. A 2. B 3. C 4. D

27. A : Work done in moving a body over a smooth inclined plane does not depend upon slope of inclined plane, provided its height is same
R : W = mgh = mgl sin θ
1. A 2. B 3. C 4. D

MULTI CORRECT TYPE QUESTIONS

28. Let F, FN and f denote the magnitude of the contact force, normal force and the friction extended by one surface on the other kept in contact. If none of these is zero
a. $F > F_N$ b. $F > f$
c. $F_N > f$ d. $F_N - f < F < F_N + f$
1. a & c are correct 2. b & c are correct
3. a, b & d are correct 4.only a & b are correct

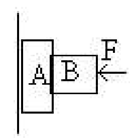
29. An object of mass 10kg moving with a velocity of $5.6ms^{-1}$ on a surface comes to rest after travelling a distance of 16m. Then
a. coefficient of friction is 0.1
b. workdone against the friction is 156.8J
c. retardation of the body is 8.4 ms^{-2}.
d. the block comes to rest in1 sec
1. a & b are correct 2. b & c are correct
3. c & d are correct 4. a, b & c are correct

30. A horizontal force of 20N is applied to a block of mass 4kg resting on a rough horizontal table. What can be said about the coefficient of static friction between the block and the table $[g = 10ms^{-2}]$
a. $\mu_s > 0.5$ b. $\mu_s = 0.5$ c. $\mu_s = 0$ d. $\mu_s < 0.5$

31. A block slides down an inclined plane of angle 45º with constant velocity. If it is then projected up the same plane with velocity $10ms^{-1}$, then $[g = 10ms^{-2}]$
a. the retardation while going up is $10\sqrt{2}$ ms^{-2}
b. it comes to rest after moving up for $\frac{1}{\sqrt{2}}$ s
c. it comes to rest after moving up for $\sqrt{2}$ s
d. coefficient of friction is 0.5
1. a, b & d are correct 2. a, c & d are correct
3. a & b are correct 4. c & d are correct

32. A block is placed on a rough floor and a horizontal force 'F' is applied on it. The force of friction 'f' by the floor on the block is measured for different values of F and a graph plotted between them
a. is a straight line of slope 45º
b. is a straight line of slope less than 45º
c. is a straight line of slope 45º for small F and a straight line parallel to the F–axis for large F.
d. there is a small kinik on the graph
1. b & d are correct 2. a is correct
3. c & d are correct 4. a & b are correct

33. Two blocks A and B are pressed against a vertical wall by applying a horizontal force 'F'. There is no friction between A and B. The
a. Both blocks A and B can be at rest for any magnitude of F
b. B can be at rest A moves down for smaller magnitude of F
c. Both A and B will move down for smaller magnitude
d. A can be at rest and b moves down for larger magnitude of F



1. a & b are correct 2. c & d are correct
3. a & d are correct 4. b & c are correct

34. A block is thrown up an inclined plane with certain velocity to reach the top of it. If the length of the inclined plane is l and its angle of incline is equal to angle of repose, then
a. the retardation is 2g sin θ
b. the retardition is 2g tan θ
c. the time of ascent is $\sqrt{\frac{1}{g\sin\theta}}$
d. the time of ascent is $\sqrt{\frac{1}{2g\tan\theta}}$
1. a & c are correct 2. a & d are correct
3. b & c are correct 4. b & d are correct

35. An object of mass 'm' is projected on the rough horizontal surface of coefficient of friction 'μ' with some initial K.E., The time 't' taken before stopping is
a. $t\alpha\,\mu$ b. $t\alpha\frac{1}{\sqrt{m}}$ c. $t\alpha m$ d. $t\alpha\frac{1}{\mu}$
1. Both a & b are correct
2. Both a & c are correct
3. Both b & d are correct
4. Both b & c are correct

36. Two blocks of masses m and 4m connected by a spring of negligible mass are compressed and released. They move off in opposite direction with velocities V_1 and V_2 immediately after release and come to rest after covering distances S_1 and S_2. Then

a. $\frac{V_1}{V_2} = \frac{4}{1}$

b. $\frac{S_1}{S_2} = \frac{16}{1}$ (if coefficient of friction is same for both blocks)

c. $\frac{S_2}{S_1} = \frac{4}{1}$ (if friction is same for both blocks)

d. $\frac{S_2}{S_1} = \frac{16}{1}$ (if coefficient of friction is same) for both blocks

1. only a & c are correct
2. a, b & c are correct
3. only b & c are correct
4. c & d are correct

KEY

1. 3	2. 3	3. 2	4. 3	5. 1
6. 2	7. 3	8. 3	9. 2	10. 2
11. 1	12. 1	13. 1	14. 1	15. 1
16. 2	17. 3	18. 3	19. 1	20. 1
21. 1	22. 1	23. 1	24. 2	25. 4
26. 1	27. 1	28. 3	29. 1	30. 3
31. 3	32. 3	33. 2	34. 1	35. 3
36. 2				

PREVIOUS EAMCET QUESTIONS

1. A body is moving up on inclined plane of angle θ with an initial kinetic enrgy E. The coefficient of friction between the plane and the body is μ. The workdone against friction before the body comes to rest is **[2002E]**

1. $\frac{\mu \cos\theta}{E\cos\theta + \sin\theta}$ 2. $2\mu E \cos\theta$
3. $\frac{\mu E \cos\theta}{\mu\cos\theta - \sin\theta}$ 4. $\frac{\mu E \cos\theta}{\mu\cos\theta + \sin\theta}$

2. A body is sliding down a rough inclined plane. The coefficient of friction between the body and the plane is 0.5. The ratio of the net force required for the body to slide down and the normal reaction on the body is 1:2. Then, the angle of the inlcined plane is **[2002 E]**

1. 15° 2. 30° 3. 45° 4. 60°

3. A box of mass 50kg is pulled on an inclined plane of 12m along and 2m height by a constant force of 100N from rest. It acquires a velocity of 2m/s when it reaches the top of the plane. The work done against friction in joules is **[2002M]**

1. 50 2. 100 3. 150 4. 200

4. A body moves along a circular path of radius 5m. The coefficient of friction between the surface of the path and body is 0.5. The angular velocity, in rad/s with which the body should move so that it does not leave the path is (g = $10 m/s^2$) **[2002 – M]**

1. 4 2. 3 3. 2 4. 1

5. A body of weight 64 N is pushed with just enough force to start it moving across a horizontal floor and the same force continues to act afterwards. If the coefficients of static and dynamic friction are 0.6 and 0.4 respectively. The acceleration of the body will be (acceleration due to gravity = g) **[2001-E]**

1. $\frac{g}{2}$ 2. 0.64g 3. $\frac{g}{32}$ 4. 0.2g

6. A particle is projected up along a rough plane of inclination 45° with the horizontal. If the coefficient of friction is 0.5, the retardation is (g = acceleration due to gravity) **[2001–E]**

1. $\frac{g}{2}$ 2. $\frac{g}{2\sqrt{2}}$ 3. $\frac{3g}{2\sqrt{2}}$ 4. $\frac{g}{\sqrt{2}}$

7. A block of weight 200N is pulled along a rough horizontal surface at constant speed by a force 100N acting at an angle 30° above the horizontal. The coefficient of kinetic friction between the block and the surface is

1. 0.43 2. 0.58 3. 0.75 4. 0.83

8. Consider the following two statements A and B, and identify the correct choice in the given answer

A. For a body resting on a rough horizontal table, it is easier to pull at an angle than push at the same angle to cause motion

B. A body sliding down a rough inclined plane of inclination equal to angle of friction has non–zero acceleration [2001 – M]

1. Both A & B are true
2. A is true but B is false
3. A is false but B is true
4. Both A & B are false

9. A body of mass m_1 projected vertically upwards with an initial velocity 'u' reaches a maximum height h. Another body of mass m_2 is projected along an inclined plane making an angle 30º with the horizontal and with speed 'u'. The maximum distance travelled along the incline is [2001 – M]

1. 2h 2. h 3. $\frac{h}{2}$ 4. $\frac{h}{4}$

10. A body of mass 5kg rests on a rough horizontal surface of coefficient of friction 0.2. The body is pulled through a distance of 10m by a horizontal force 25N. The K.E. acquired by it is [2000 – E]

1. 200J 2. 150J 3.100J 4.50J

11. A body is sliding down an inclined plane having coefficient of friction 0.5. If the normal reaction is twice that of the resultant downward force along the incline, the angle between the inclined plane and horizontal is [2000 – E]

1. 15º 2. 30º 3. 45º 4. 60º

12. A car is moving on a circular level road of radius of curvature 300m. If the coefficient of friction is 0.3 and acceleration due to gravity is $10m/s^2$. The maximum speed the car can have is [1999 – E]

1. 30 km/h 2. 81 km/h
3. 108 km/h 4. 162 km/h

13. A body takes four–third times as much time to slide down rough inclined plane as it takes to side down an identical but smooth inclined plane if the angle of inclined plane is 45º. The coefficient of friction is **[1999–E]**

1. 7/16 2. 9/16
3. 7/9 4. 3/4

14. Two bodies having the same mass, 2 kg each, have different surface area $50m^2$ and $100m^2$ in contact with a horizontal plane. If the coefficient of friction is 0.2 the forces of friction that come into play when they are in motion, will be in the ratio **[1999 – M]**

1. 1 : 1 2.1:2 3.2: 1 4.1 : 4

15. A van is moving with a speed of 72 kmph on a level road, where the coefficient of friction between tyres and road is 0.5, the minimum radius of curvature, the road must have, for safe driving of van, is $(g=10m/s^2)$ **[1999–M]**

1. 80m 2. 40m 3. 20m 4. 4m

16. The maximum speed with which a car can be driven round a curve of radius 18m without skidding (when $g = 10ms^{-2}$ and coefficient of friction between rubber tyres and the roadway is 0.2) is **[1998 – E]**

1. 36 kmph 2. 18 kmph
3. 21.6 kmph 4. 14.4 kmph

17. A body is projected along a rough horizontal surface with a velocity of 6 m/s. If the body comes to rest after travelling a distance of 9m, the coefficient of sliding friction is $(g=10ms^{-2})$ **[1998 – M]**

1. 0.5 2. 0.6 3. 0.4 4. 0.2

18. A block of mass 10kg is pushed by a force F on a horizontal rough surface moves with an acceleration $5m/s^2$ and when the horizontal froce is doubled, it gets an acceleration of $18m/s^2$. Then the coefficient of friction is (assume $g = 10ms^{-2}$) **[1997 – E]**

1. 0.8 2. 0.2 3. 0.4 4. 0.6

19. A body of mass 10kg lies on a rough horizontal surface. When a horizontal force of F newtons acts on it, it gets an acceleration of $5m/s^2$ and when the horizontal force is doubled, it gets an acceleration of $18 m/s^2$. Then the coefficient of friction between the body and the horizontal surface is (assume $g = 10ms^{-2}$) **[1997 – M]**

1. 0.2 2. 0.8 3.0.4 4.0.6

20. A 30kg box has to move up an inclined slope of 30º to horizontal at a uniform velocity of 5 metres/sec. If the frictional force retarding the motion is 250N the horizontal force in Newtons to move up is $(g=10 m/sec^2)$**[1996 M]**

1. $300\sqrt{2}$ N 2. 300N
3. $300\sqrt{3}$ N/2 4. 300 x 2 / $\sqrt{3}$ N

21. A body of weight 50N is placed on smooth surface. If the force required to move the body on the smooth surface if 30N, the coefficient of friction is **[1996 – M]**

1. 0.6 2. 1.2 3. 0.3 4. 1.67

22. A brick of mass 2kg just begins to slide down on inclined plane at an angle of 45º with the horizontal. The force of friction will be**[1996–M]**

1. 19.6 sin 45º 2. 9.8 sin 45º
3. 19.6 cos 45º 4. 9.8 cos 45º

23. A uniform chain of length 'L' hangs partly from a table which is kept in equilibrium by friction. The maximum length that can stand without slipping is 'l', then the coefficient of friction between the table and the chain is **[1995 – E]**

1. $\frac{l^2}{L-l}$ 2. $\frac{l}{L}$ 3. $\frac{l}{L-l}$ 4. $\frac{L-l}{l}$

24. A block of weight 100N is pushed by a force F on a horizontal rough plane moves with an acceleration 1 m/s^2, when force is doubled its acceleration becomes $10 m/s^2$. The coefficient of friction is ($g=10ms^{-2}$) **[1994 – E]**

1. 0.4 2. 0.6 3. 0.5 4. 0.8

25. A body of mass 60kg is pushed with just enough force to start it moving on a rough surface with $\mu_s = 0.5$ and $\mu_k = 0.4$ and the force continues to act afterwards. The acceleration of the body is **[1993 – M]**

1. 0.98 m/sec^2 2. 3.92m/sec^2
3. 4.90m/sec^2 4. Zero

26. If the coefficient of friction is $\sqrt{3}$, the angle of friction is **[1994 – M]**

1. 30º 2. 60º 3. 45º 4. 37º

27. μ_s, μ_k and μ_r are the coefficient of static, kinetic and rolling friction between two surfaces. In their increasing order of magnitude one can write **[1992, 95 – E]**

1. $\mu_r < \mu_k < \mu_s$ 2. $\mu_r > \mu_k > \mu_s$
3. $\mu_r > \mu_k < \mu_s$ 4. $\mu_r = \mu_k = \mu_s$

28. A cube of 10N rests on rough inclined plane of slope 3 in 5. The coefficient of friction is 0.6. The minimum force necessary to start the cube moving up the plane is [1990–E]

1. 8.8 N 2. 16.2 N 3. 10.8 N 4. 21.6 N

29. Kinetic friction is always ...... than the rolling friction
[1987 – E]

1. Smaller 2. Greater 3. Equal 4. None

30. A pulling force making an angle θ to the horizontal is applied on a block of weight W placed on a horizontal table. If the angle of friction is d, the magnitude of the force required to move the body is equal to [1987-E]

1. $\frac{WCosd}{Cos(\theta-d)}$ 2. $\frac{W\sin d}{Cos(\theta-d)}$
3. $\frac{WTand}{Sin(\theta-d)}$ 4. $\frac{WSind}{Tan(\theta-d)}$

31. A block of ice at 0ºC whose mass initially is 42 kg slides along a horizontal surface (μ=0.1) starts with an initial velocity 4 m/sec. and comes to rest. The ice melted as a result of friction between the block and table is .... gm
[1986 – M]

1. 0.5 g 2.1g 3.80 g 4.16 g

32. The horizontal acceleration that should be given to a smooth inclined plane of angle $\sin^{-1}\left(\frac{1}{l}\right)$ to keep an object stationary on the plane, relative to the inclined plane is
[EAMCET 2003 E]

1. $\frac{g}{\sqrt{l^2-1}}$ 2. $g\sqrt{l^2-1}$ 3. $\frac{\sqrt{l^2-1}}{g}$ 4. $\frac{g}{\sqrt{l^2+1}}$

33. A horizontal force, just sufficient to move a body of mass 4kg lying on a rough horizontal surface is applied on it. The coefficients of static and kinetic friction between the body and the surface are 0.8 and 0.6 respectively. If the force continues to act even after the block has started moving, the acceleration of the block in ms^{-2} is ($g = 10ms^{-2}$) **[EAMCET 2003 E]**

1. 1/4 2. 1/2 3. 2 4. 4

34. The minimum force required to move a body up an inclined plane of inclination 30º is found to be thrice the minimum force required to prevent it from sliding down the plane. The coefficient of friction between the body and the plane is
[EAMCET 2003 E]

1. $1/\sqrt{3}$ 2. $1/2\sqrt{3}$ 3. $1/3\sqrt{3}$ 4. $1/4\sqrt{3}$

35. The minimum force required to move a body up an inclined plane is three times the minimum force required to prevent it from sliding down the plane. If the coefficient of friction between the body and the inclined plane is $\frac{1}{2\sqrt{3}}$, the angle of the inclined plane is
[EAMCET ENG 05]

1. 60º 2. 45º 3. 30º 4.15º

36. A cubical block of mass 'm' rests on a rough horizontal surface 'μ' is the coefficient of static friction between the block and the surface. A force mg acting on the cube at an angle 'θ' with the vertical side of the cube pulls the block. If the block is to be pulled along the surface then the value cot (θ/2) is **(2005 M)**

1. Less than μ 2. Greater than μ
3. *Equal to* μ 4. Not dependent on μ

KEY

1. 4	2. 3	3. 2	4. 4	5. 4
6. 3	7. 2	8. 2	9. 1	10. 2
11. 3	12. 3	13. 1	14. 1	15. 1
16. 3	17. 4	18. 1	19. 2	20. 4
21. 1	22. 1	23. 1	24. 4	25. 1
26. 2	27. 1	28. 3	29. 2	30. 2
31. 2	32. 1	33.3	34. 2	35. 3
36. 2				

HINTS

1. Work energy theorem

$\frac{1}{2}mu^2 - \frac{1}{2}mv^2 = W = F.S$

$a = -(g\sin\theta + \mu_k g\cos\theta)$

$v^2 - u^2 = 2as$

$s = \frac{E}{mg(\sin\theta + \mu_k \cos\theta)}$

$F = \mu_k\ mg\ \cos\theta$

W = F.S.

3. $W = \frac{1}{2}mv^2$

4. $v = \sqrt{\mu_k rg}$

$\omega = \frac{\sqrt{\mu_k g}}{r}$

5. $a = (\mu_s - \mu_k)g$

6. $a = g(\sin\theta + \mu_k\cos\theta)$

7. μ= tan

9. $\mu^2 = 2gh$

$\mu^2 = 2g\,l\sin\theta$

10. Frictional force = μmg

11. $\mu mg\cos\theta \times 2 = mg\sin\theta$

15. $\frac{mv^2}{r} = \mu_k\ mg$

16. $\frac{mv^2}{r} = \mu_k\ mg$

17. $S = \frac{v^2}{2\mu_k gr}$

19. When the applied horizontal force is "F" and the force of friction is 'f', then the resultant force on the body when its acceleration is 5 m/s^2 would be $ma_1 = F - f$

Similarly $ma_2 = 2F - f$

Coefficient of friction $\mu = \frac{f}{R} = \frac{f}{mg}$

20. $F = mg\sin\theta + \mu mg\cos\theta$

Horizontal component of force = $F\cos\theta$

21. N = mg ; $\mu = \frac{f}{N}$

22. Friction force = $mg\sin\theta$

23. Weight on the hanging part = (M/L) lg

weight of part resting on the table = M/L (L–l)g

Friction force = $\mu R = \mu$(M/L) (L–l)g

μ (M/L) (L–l)g = (M/L) lg μ = 1 / L–l

24. mg = 100N $\rightarrow$ m = 10 kg;

a1 = 1m/s^2, a_2 = 10 m/s^2

$F - f = ma_1$, $2F - f = ma_2$

25. Net force acting on the body = $(\mu_s - \mu_k)$ mg

Acceleration = $(\mu_s - \mu_k)$ g = 0.1 x 9.8

= 0.98 m/sec^2

26. μ = Tanθ

28. $F = (mg)\sin\theta + \mu_k mg\cos\theta$

30. $R + P\sin\theta = W$; $R = (W - P\sin\theta)$

$f = \mu_k R = \mu_k (W - P\sin\theta)$,

$\mu_k (W - p\sin\theta) = p\cos\theta$

$\mu_k W = p[(\cos\theta + \mu_k\sin\theta)]$

Substitute = $\mu_k = \tan d = \frac{Sind}{Cosd}$

OTHER COMPETITIVE EXAMINATIONS QUESTIONS

1. Find the distance travelled by a body before coming to rest if it is moving on a rough horizontal surface with a velocity 36 km/hr and the coefficient of friction between the body and the surface is 0.2 (g = 9.8 m/s^2)? **(IIT 77)**

1. 20m 2. 25.5 m 3. 30 m 4.None

2. A block of mass 2kg rests on a rough inclined plane making an angle of 30º with the horizontal. If = 0.7, the frictional force on the block is **(IIT 80)**

1. 9.8 N 2. 0.7 x 0.98 x $\sqrt{3}$ N
2. 9.8 x $\sqrt{3}$ N 4. None

3. A 40kg slab rests on a frictionless floor. A 10kg block rests on the top of the slab. The static coefficient of friction between the block and the slab is 0.6, while the kinetic coefficient of friction is 0.4. The 10kg block is acted upon by a horizontal force of 100N. If g = 9.8 m/s^2, the resultant acceleration of the slab is **(NCERT ' 82)**

1. 0.98 m/s^2 2. 1.47 m/s^2
3. 1.52 m/s^2 4. 1.1 m/s^2

4. A block has been placed on an inclined plane. The slope angle θ of the plane is such that the block slides down the plane at constant speed. The coefficient of kinetic friction is equal to **(CBSE ' 93)**

1. Sin θ 2. Cos θ 3. g 4. Tan θ

5. A long horizontal rod has a bead which can slide along its length and initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ and gravity is neglected, then the time after which the bead starts slipping is

1. $\sqrt{\frac{\mu}{\alpha}}$ 2. $\frac{\mu}{\sqrt{\alpha}}$ 3. $\frac{1}{\sqrt{\mu\alpha}}$
4. Infinitesimal

6. On a rough horizontal surface, a body of mass 2kg is in a velocity of $10ms^{-1}$. If the coefficient of friction is 0.2 and $g = 10ms^{-2}$, the body will cover a distance of **(MP PMT 1999)**

1. 10m 2. 25 m 3. 50m 4. 250m

7. Maximum value of static friction is

1. Limiting friction 2. rolling friction
3. static friction 4. normal reaction

8. When a body of mass 'M' slides down an inclined plane of inclination θ, through a distance 'S', the work done against friction is **(BHU Med-1999)**

1. Mg ($\mu_k \cos\theta - \sin\theta$)S
2. μ_k Mg $\sin\theta$ S
3. μ_k Mg $\cos\theta$ S 4. μ_k Mg $\tan\theta$ S

9. A static friction is

1. Equal to dynamic friction
2. Always less than the dynamic friction
3. Always greater than the dynamic friction
4. Some times equal to dynamic friction

10. On the horizontal surface of a truck a block of mass 1kg is placed ($\mu = 0.6$) and truck is moving with acceleration 5 m/sec^2. The fractional force on block will be

1. 5 N 2. 6 N 3. 5.88 N 4. 8N

11. When a bicycle is in motion, the force of friction excreted by the ground on the two wheels is such that it acts

1. in the backward direction on the front wheel and in the forward direction on the rear wheel
2. in the forward direction on the front wheel and in the backward direction on the rear wheel
3. in the backward direction on both the front and rear wheels
4. in the forward direction on both the front and rear wheels

KEY

1. 2	2. 1	3. 1	4. 4
5. 1			
6. 2	7. 1	8. 3	9. 3
10. 1			
11. 1			

HINTS

4. Downward force must be equal to upward force so mg Sin $\theta = \mu$ mg $\cos\theta$.
Therefore $\mu = \text{Tan}\theta$

5. For equilibrium, $m\omega^2 L = ma\mu$

$$L(\alpha t)^2 = L\,\alpha\,\mu$$

$$t^2 = \frac{\mu}{\alpha} \text{ or } t = \sqrt{\frac{\mu}{\alpha}}$$

6. The covering distance by a body $s = \frac{u^2}{2\mu g}$

$$s = \frac{(10)^2}{2x0.2x10} = 25m$$

8. Work done $w = F.S = \mu_k$ RS

μ_k mg $\cos\theta$. S

9. Because lesser force is required maintain the motion of a body, than the force required to start the body from the rest

10. F = ma = 1 x 5 = 5N

*****