Practice Problems # 8

1. Which of the following statements is most correct?

(A) The normal force is the same thing as the weight.

(B) The normal force is different from weight, but always has the same magnitude.

(C) The normal force is different from weight, but the two form an action-reaction pair according to Newton's third law.

(D) The normal force is different from the weight, but the two may have the same magnitude in certain cases.

2. Which of the statements is correct about the weight of an object and the force of kinetic friction on that object?

(A) The weight is always greater than the frictional force

(B) The weight is always equal to the frictional force

(C) The weight is less than the frictional force for sufficiently light object

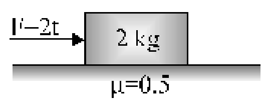
(D) The weight can be more or less than the frictional force

3. Two identical wooden blocks are tied one behind the other and pulled across a rough horizontal surface. The force required to pull them at constant speed is F. If one block is fixed on the top of other block then new force required to pull them at constant speed will be approximately :

(A) F/2 (B) F (C) $\sqrt{2}$ F (D) 2F

For Q. No. 4 to 6

A 2 kg block is kept on a rough horizontal surface and is acted upon by a force 'F' which varies with time t as F = 2t, where F is in N and t is in sec.



4. Motion of block starts at

(A) t = 0 s (B) t = 5 s (C) t = 10 s (D) t = 15 s

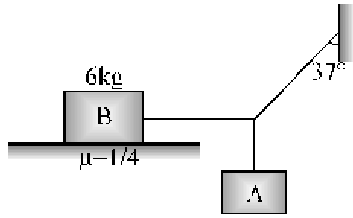
5. Force on the block at t = 3s is :

(A) 16 N (B) 6 N (C) 8 N (D) 10 N

6. Force on the block at t = 10s is :

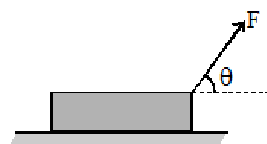
(A) 10 N (B) 6 N (C) 4 N (D) 20 N

7. What is the minimum value of mass of block A so that B starts moving on rough horizontal surface ?



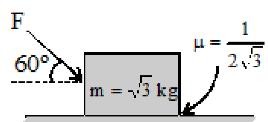
(A) 1 kg (B) 1.5 kg
(C) 2 kg (D) 2.5 kg

8. A wooden block of mass m resting on a rough horizontal table (coefficient of friction = μ) is pulled by a force F as shown in figure. The acceleration of the block moving horizontally is :



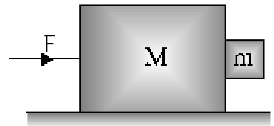
(A) $\frac{F\cos\theta}{m}$ (B) $\frac{\mu F\sin\theta}{M}$ (C) $\frac{F}{m}(\cos\theta+\mu\sin\theta)-\mu g$ (D) none

9. What is the maximum value of the force F such that the block shown in the arrangement, does not move ?



(A) 20N (B) 10N (C) 12N (D) 15N

Illustration 17: In the adjoining figure, the coefficient of friction between the larger block (of mass M) and block (of mass m) is μ. Find the magnitude of horizontal force F required to keep the block stationary with respect to larger block.



Solution : Such problems can be solved with or without using the concept of pseudo force.

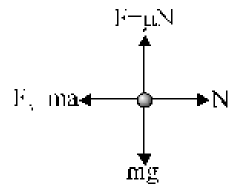
a = acceleration of (wedge + block) in horizontal direction

Non inertial frame of reference (Wedge)

F. B. D. of m with respect to wedge

(real + one pseudo force)

with respect to wedge block is stationary.



$\therefore \sum F_x = 0 = \sum F_y$

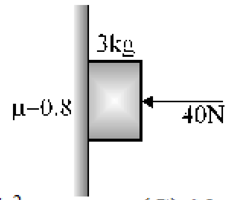
$\therefore$ mg = μN and N = ma

$\therefore a = \dfrac{g}{\mu}$ and F = (M + m)a

$= \mathbf{(M + m)\dfrac{g}{\mu}}$

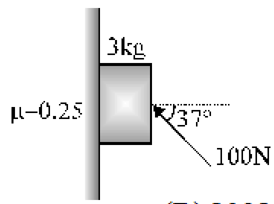
Practice Problems # 9

1. Consider a block pressed against a vertical wall as shown. The magnitude of acceleration of block is :



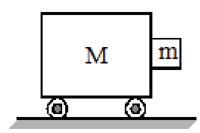
(A) zero (B) 10/3 m/s^2 (C) 10 m/s^2 (D) 40/3 m/s^2

2. In the given problem, the frictional force on block is :



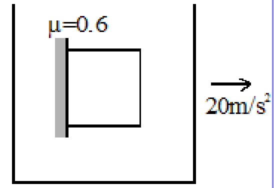
(A) 20 N downward (B) 20 N upward
(C) 30 N upward (D) 30 N downward

3. A cart of mass M has a block of mass m attached to it as shown in the figure. Co-efficient of friction between the block and cart is μ. What is the minimum acceleration of the cart so that the block m does not fall?



(A) μg (B) μ/g (C) g/μ (D) none

4. Car is accelerating with acceleration = 20 m/s^2. A box that is placed inside the car, of mass m = 10kg is put in contact with the vertical wall as shown. The friction coefficient between the box and the wall is $\mu = 0.6$.



(A) The acceleration of the box will be 20m/sec^2

(B) The friction force acting on the box will be 100N

(C) The contact force between the vertical wall and the box will be $100\sqrt{5}$ N

(D) The net contact force between the vertical wall and the box is only electromagnetic in nature.

5. A block of mass 2kg is placed on the floor. The coefficient of static friction is 0.4. If a force of 2.8 N is applied on the block parallel to floor, the force of friction between the block and floor (taking g = 10 m/s^2) is

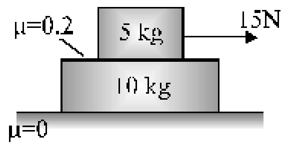
(A) 2.8 N (B) 8 N (C) 2 N (D) zero

6. A heavy body of mass 25 kg is to be dragged along a horizontal plane ($\mu = 1/\sqrt{3}$). The least force required is (Take g = 10 m/s^2)

(A) 250 N (B) 25 N (C) 125 N (D) $250/\sqrt{3}$ N

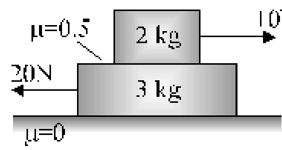
Practice Problems # 10

1. The frictional force between the blocks is :



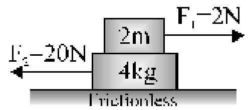
(A) 5 N (B) 10 N (C) 8 N (D) 6 N

2. The frictional force on block of mass 2kg is :



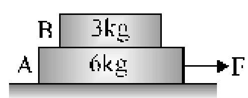
(A) 8 N (B) 10 N (C) 18 N (D) 6 N

3. In the arrangement shown in figure, coefficient of friction between the two blocks is $\mu = 1/2$. The force of friction acting between the two blocks is :



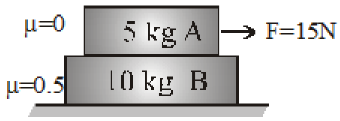
(A) 8 N (B) 10 N (C) 6 N (D) 4 N

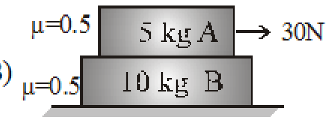
4. Two blocks A and B of masses 6 kg and 3 kg rest on a frictionless horizontal surface as shown in the figure. If coefficient of friction between A and B is 0.4, the maximum horizontal force which can make them move without separation is

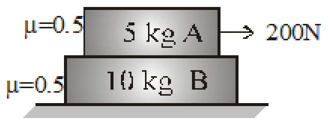


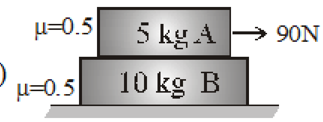
(A) 72 N (B) 40 N (C) 36 N (D) 20 N

5. Find the accelerations and the friction forces involved :

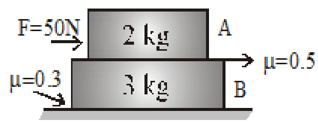
(A) 

(B) 

(C) 

(D) 

6. From the figure shown, find out acceleration of 3kg block.

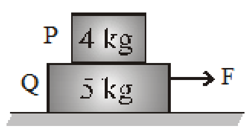


(A) 7 m/s^2 (B) 10 m/s^2 (C) 10/3 m/s^2 (D) none of these

7. In the above question if the external force is applied on 3kg block, then acceleration of the 3kg block will be :

(A) 40/3 m/s^2 (B) $2\frac{25}{3}$ m/s^2 (C) 35/3 m/s^2 (D) none of these

8. The coefficient of friction between 4kg and 5kg block is 0.2 and between 5kg block and ground is 0.1 respectively. Choose the correct statements :



(A) Minimum force needed to cause system to move is 17N

(B) When force is 4N static friction at all surfaces is 4N to keep system at rest

(C) Maximum acceleration of 4kg block is 2m/s^2

(D) Slipping between 4kg and 5kg blocks starts when F is 17 N

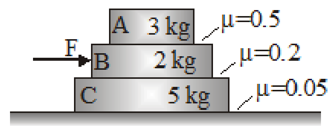
Practice Problems # 11

1. A system of masses is shown in the figure with masses and coefficients of friction indicated. Find the minimum force F required

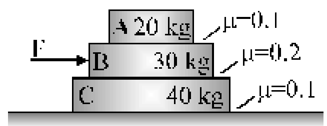
(a) to start slipping at any surface

(b) to start slipping between B and C

(c) to start slipping between A and B



2. A system of masses is shown in the figure with masses and coefficients of friction indicated. The maximum value of F for which there is no slipping anywhere.



(A) 90 N (B) 100 N (C) 80 N (D) none of these

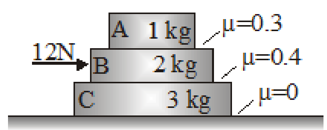
3. In the above question, the minimum value of F for which B slides on C

(A) 100 N (B) 112.5 N (C) 115 N (D) 117.5 N

4. In the question no, the minimum value of F for which A slips on B.

(A) 125 N (B) 150 N (C) 175 N (D) 180 N

5. A system of masses is shown in the figure with masses and coefficients of friction indicated. The frictional force between A and B is :

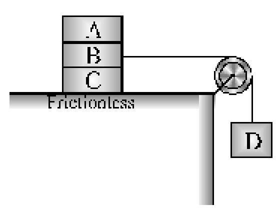


(A) 1 N (B) 2 N (C) 3 N (D) 4 N

6. In the above question, frictional force between B and C is :

(A) 2 N (B) 4 N (C) 6 N (D) 8 N

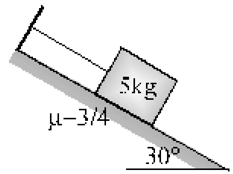
7. Three blocks A, B and C of equal mass m are placed one over the other on a smooth horizontal table as shown in figure. Coefficient of friction between any two blocks A, B and C is 1/2. The maximum value of mass of block D so that the blocks A, B and C more without slipping over each other is



(A) 6 m (B) 5 m (C) 3 m (D) 4 m

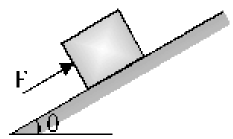
Practice Problems # 12

1. The tension in string is



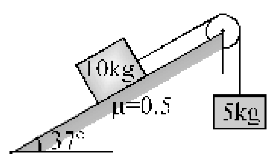
(A) 25 N (B) $\left(\frac{75}{4}\sqrt{3}-25\right)$N (C) $\frac{75}{4}\sqrt{3}$ N (D) zero

2. A block placed on a rough inclined plane of inclination ($\theta = 30°$) can just be pushed upwards by applying a force F as shown. If the angle of inclination of the inclined plane is increased (to $\theta = 60°$), the same block can just be prevented from sliding down by application of a force of same magnitude. The coefficient of friction between the block and the inclined plane is



(A) $\frac{\sqrt{3}+1}{\sqrt{3}-1}$ (B) $\frac{2\sqrt{3}-1}{\sqrt{3}+1}$ (C) $\frac{\sqrt{3}-1}{\sqrt{3}+1}$ (D) none of these

3. The frictional force acting on 10kg block is



(A) 10 N down the plane (B) 40 N up the plane
(C) 10 N up the plane (D) None

5. A block of mass 5kg and surface area $2m^2$ just begins to slide down an inclined plane when the angle of inclination is 30°. Keeping mass same, the surface area of the block is doubled. The angle at which this starts sliding down is

(A) 30° (B) 60° (C) 15° (D) none

6. The force F_1 that is necessary to move a body up an inclined plane is double the force F_2 that is necessary to just prevent it from sliding down, then :

(A) $F_2 = w \sin(\theta - \phi) \sec\phi$ (A) $F_1 = w \sin(\theta - \phi) \sec\phi$

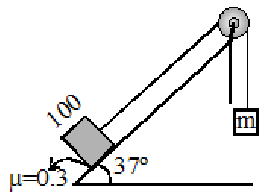
(C) $\tan\phi = 3 \tan\theta$ (D) $\tan\theta = 3 \tan\phi$

where ϕ = angle of friction

θ = angle of inclined plane

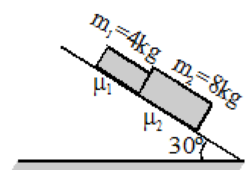
w = weight of the body

7. The value (s) of mass m for which the 100g block remains in static equilibrium is

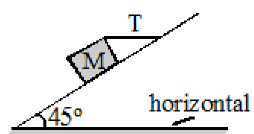


(A) 35 g (B) 37 g (C) 83 g (D) 80 g

8. In the figure shown below the friction between the 4kg block and the incline as μ_1 and between 8kg and incline is μ_2. Calculate the accelerations of the blocks when (a) $\mu_1 = 0.2$ and $\mu_2 = 0.3$ (b) $\mu_1 = 0.3$ and $\mu_2 = 0.2$. (take g = 10 m/s^2)



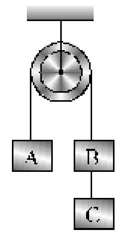
9. A block of mass 16kg is resting on a rough inclined plane as shown in figure. The block is tied up by a a horizontal string which has a tension of 50N. The coefficient of friction between the surfaces of contact is (g = 10 m/s^2)



(A) 1/2 (B) 2/3 (C) 3/4 (D) 1/4

Solved Example Objective

1. Three equal weights A, B and C each of mass 2 kg are hanging on a string passing over a fixed frictionless pulley as shown in figure. The tension in string connecting B and C is



(A) zero (B) 13 N (C) 3.3 N (D) 19.6 N

Ans. ***(B)***

Solution.

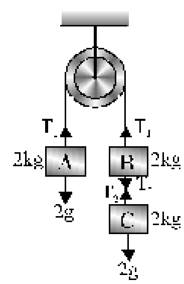
For mass C, resultant force on C = $2g - T_2$

$\therefore \quad 2g - T_2 = 2a$ ...(i)

For mass B, $2g + T_2 - T_1 = 2a$ ...(ii)

For mass A, $T_1 - 2g = 2a$ ...(iii)

Adding (i), (ii) and (iii)



$$a = \frac{2g}{6} = \frac{g}{3}$$

$$\text{Tension, } T_2 = 2g - 2a = 2g - \frac{2g}{3}$$

$$= \frac{4g}{3} = \frac{4 \times 9.8}{3} = 13 \text{ N}$$

$\therefore$ **Answer is (B)**

2. A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from one end where the force is applied?

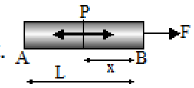
(A) $\frac{FL}{x}$ (B) $\frac{F(L-x)}{L}$

(C) $\frac{FL}{(L-x)}$ (D) $\frac{Fx}{(L-x)}$

***Ans.* (B)**

Solution.

Let AB be a string of length L. Let F be the force pulling the rope to the right.

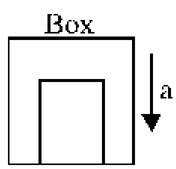


Mass per unit length of rope = $\frac{M}{L}$ where M is the total mass.

Let P be a point at a distance x from B. If T is the tension in the rope at P then for the part AP, the tension is towards right while for the part PB it is towards left. If a is the acceleration produced in the rope, then for part PB

$$F - T = \text{mass of PB} \times a$$

3. With what acceleration 'a' should the box in the figure descend so that a body of mass M placed in it exerts a force $\frac{Mg}{4}$ on the base of the box?



(A) $\frac{3g}{4}$ (B) $\frac{g}{4}$ (C) $\frac{g}{2}$ (D) $\frac{g}{8}$

***Ans.* (A)**

Solution.

If the box is accelerated downwards, from the frame outside the elevator, equation of motion can be written as

$$Mg - N = Ma$$

Here, $N = \frac{Mg}{4}$

$\Rightarrow$ $a = \frac{3g}{4}$

$\therefore$ **Answer is (A)**

4. An elevator weighing 6000 kg is pulled upward by a cable with an acceleration of 4.9 m/s^2. The tension in the cable is(Take g = 9.8 m/s^2)

(A) 6000 N (B) 6000 gN (C) 9000 N (D) 9000 gN

Ans. ***(D)***

Solution.

For the elevator

$$T - 6000g = 6000a = 6000 \times \frac{g}{2}$$

$\therefore$ T = 9000 gN

$\therefore$ **Answer is (D)**

5. Two bodies of masses m_1 and m_2 are connected by a light string passing over a smooth light fixed pulley. The acceleration of the system is g/7. The ratio of their masses is

(A) 7 : 1 (B) 7 : 2 (C) 4 : 3 (D) 4 : 5

Ans. ***(C)***

Solution.

$$a = \frac{m_1 - m_2}{m_1 + m_2} g = \frac{g}{7}$$

$$7m_1 - 7m_2 = m_1 + m_2$$

$$6m_1 = 8m_2$$

or, $$\frac{m_1}{m_2} = \frac{4}{3}$$

$\therefore$ **Answer is (C)**

Since the body starts from rest, the distance is equal to $\frac{1}{2}at^2$.

Thus, $S = \frac{g}{\sqrt{2}}t_1^2 = \frac{g}{\sqrt{2}}(1-\mu)t_2^2$;

Given $t_2 = \eta t_1 \frac{1-\mu}{1} = \frac{t_1^2}{t_2^2} = \frac{1}{\eta^2}$

$$\mu = \left(1 - \frac{1}{\eta^2}\right)$$

∴ **Answer is (A)**

8. A mass of 0.5 kg is just able to slide down the slope of an inclined rough surface when the angle of inclination is 60°. The minimum force necessary to pull the mass up the incline along the line of greatest slope is ($g = 10\ m/s^2$):

(A) 20.25N (B) 8.65N (C) 100N (D) 1N

Ans. ***(B)***

Solution.

Acceleration down the plane $= g(\sin\alpha - \mu\cos\alpha) = 0$

So, it is given that $\tan\alpha = \tan 60°$

$= \mu = \sqrt{3}$

Minimum force necessary $= mg(\sin\alpha + \mu\cos\alpha) = 0.5 \times 10\left(\frac{\sqrt{3}}{2} + \sqrt{3}\frac{1}{2}\right) = 5\sqrt{3} = 8.66N$

∴ **Answer is (B)**

6. A block can slide on a smooth inclined plane of inclination θ kept on the floor of a lift. When the lift is descending with retardation, a m/s^2 the acceleration of the block relative to the incline will be

(A) $(g-a)\sin\theta$ (B) $(g+a)\sin\theta$ (C) $g\sin\theta$ (D) $g-a$

Ans. ***(B)***

Solution.

When the lift is descending with a retardation of a m/s^2 it is equivalent to an upward acceleration of a m/s^2.

Hence, total acceleration on the lift floor $= (g + a)$

Hence, acceleration of block relative to incline $= (g + a)\sin\theta$

$\therefore$ **Answer is (B)**

7. A given object taken η times as much time to slide down a $45°$ rough incline as it takes to slide down a perfectly smooth $45°$. The coefficient of kinetic friction between object and incline is given by

(A) $\mu = \frac{1}{1-\eta^2}$ (B) $\mu = 1 - \frac{1}{\eta^2}$ (C) $\mu = \sqrt{\frac{1}{1-\eta^2}}$ (D) $\mu = \sqrt{1 - \frac{1}{\eta^2}}$

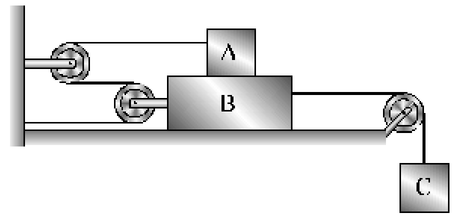
Ans. ***(A)***

Solution.

Acceleration without friction $= g\sin\alpha = \frac{g}{\sqrt{2}}$

With friction, the acceleration is $g(\sin\alpha - \mu\cos\alpha) = \frac{g}{\sqrt{2}}(1-\mu)$

9. Given that mass of A is 100 kg and that of B is 140 kg. Pulleys are smooth and friction coefficient between A and B and between B and horizontal surface is $\mu = 0.3 (g = 10 \text{ m/s}^2)$. The maximum value of mass of block C so that neither A nor B moves is :



(A) 210 kg (B) 190 kg (C) 185 kg (D) 162 kg

Ans. ***(D)***

Solution

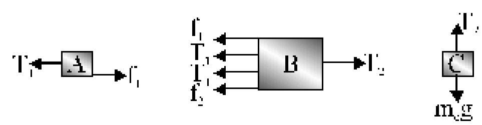
Maximum friction that can be obtained between A and B is

$$f_1 = \mu m_A g = (0.3)(100)(10) = 300\text{N}$$

and maximum friction between B and ground is

$$f_2 = \mu(m_A + m_B)g = (0.3)(100 + 140)(10) = 720 \text{ N}$$

Drawing free body diagrams of A, B and C in limiting case



Equilibrium of A gives

$$T_1 = f_1 = 300\text{N} \quad ...(1)$$

Equilibrium of B given

$$2T_1 + f_1 + f_2 = 0$$

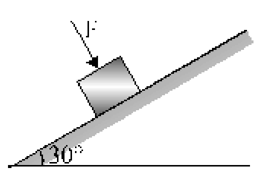
or $T_2 = 2(300) + 300 + 720 = 1620$ N ...(2)

and equilibrium of C given

$$m_C g = T_2 \quad \text{or} \quad 10m_C = 1620 \quad \text{or} \quad m_C = 162 \text{ kg}$$

$\therefore$ **Answer is (D)**

10. A block of mass m = 2 kg is resting on a rough inclined plane of inclination 30° as shown in figure. The coefficient of friction between the block and the plane is m = 0.5. What minimum force F should be applied perpendicular to the plane on the block, so that block does not slip on the plane (g = 10m/^{2})?



(A) zero (B) 6.24 N (C) 2.68 N (D) 4.34 N

Ans. ***(C)***

Solution

Since $mg\sin 30° > \mu mg\cos 30°$

the block has a tendency to slip downwards. Let F be the minimum force applied on it, so that it does not slip. Then

$$N = F + mg\cos 30°$$

$\therefore$ $mg\sin 30° = \mu N = \mu(F + mg\cos 30°)$

or $$F = \frac{mg\sin 30°}{\mu} - mg\cos 30° = \frac{(2)(10)(1/2)}{0.5} - (2)(10)\left(\frac{\sqrt{3}}{2}\right)$$

or $$F = 20 - 17.32 = 2.68\ \text{N}$$

$\therefore$ **Answer is (C)**

PP-8

1. (D)	**2.** (D)	**3.** (B)	**4.** (B)
5. (B)	**6.** (A)	**7.** (C)	**8.** (C)
9. (A)			

PP-9

1. (A)	**2.** (A)	**3.** (C)	**4.** (A) (B) (C) (D)
5. (B)	**6.** (C)		

PP-10

1. (B)	**2.** (B)	**3.** (A)	**4.** (C)

5. **(a)** $a_A = 3ms^2, a_B = 0, f_A = 0, f_B = 0$ **(b)** $a_A = 1ms^{-2}, a_B = 0, f_A = 25N, f_B = 25N$

(c) $f_A = 35m/s^2, a_B = 0, f_A = 25N, f_B = 25N$ **(d)** $a_A = 13ms^{-2}, a_B = 0, f_A = 25N, f_B = 25N$

6. (D)	**7.** (B)	**8.** (C)

PP-11

1. (a) 5N (b) 15N (c) 35N	**2.** (A)	**3.** (B)

4. (B)	**5.** (B)	**6.** (C)	**7.** (C)

PP-12

1. (D)	**2.** (C)	**3.** (C)	**4.** (A)
5. (A)	**6.** (A)	**7.** (B)	

8. **(a)** $2.4m/s^2$ both **(b)** $3.2\ m/s^2, 2.4\ m/s^2$ **9.** (A)