CHAPTER 5 Force & Motion – I

Newton's Laws

- ■ **Vertical motion**
- △ **Horizontal motion**
- ◘ **Mixed forces**
- ○ **Contact forces**
- ● **Inclines**
- ◆ **General problems**

■**1.** A 5.0-kg block is lowered with a downward acceleration of 2.8 m/s^2 by means of a rope. What is the force of the block on the rope? (Ans: 35 N, down)

■**2.** An elevator of mass 480 kg is designed to carry a maximum load of 3000 N. What is the tension in the elevator cable at the maximum load when the elevator moves down accelerating at 9.8 m/s^2? (Ans: 0)

■**3.** A 2.00-kg mass is hanging from the ceiling of an elevator accelerating upward at a = 2.50 m/s^2 (see figure 1). What is the tension T in the string? (Ans: 24.6 N)

■**4.** An object is hung from a spring balance attached to the ceiling of an elevator. The balance reads 70 N when the elevator is at rest. What is the reading of the spring balance when the elevator is moving upward with an acceleration of 4.9 m/s^2? (Ans: 105 N)

■**5.** A 70-kg man stands on a spring scale in an elevator that has a downward acceleration of 2.8 m/s^2. What will the scale read? (Ans: 490 N)

■**6.** A monkey hangs vertically from a rope in a descending elevator that decelerates at 2.4 m/s^2. If the tension in the rope is 400 N, find the mass of the monkey. (Ans: 33 kg)

△**7**. Two students are dragging a box (m = 100 kg) across a horizontal frozen lake. The first student pulls with force F_1 = 50.0 N, while the second one pulls with force F_2. The box is moving in the x direction with acceleration a (see figure 2). Assuming that friction is negligible, what is F_2? (Ans: 86.6 N)

△**8**. Only two forces act upon a 5.0-kg box. One of the forces is $\boldsymbol{F}_1 = 6.0\,\hat{\mathbf{i}} + 8.0\,\hat{\mathbf{j}}$ (N). If the box moves with a constant velocity of $\boldsymbol{v} = 1.6\,\hat{\mathbf{i}} + 1.2\,\hat{\mathbf{j}}$ (m/s), what is the magnitude of the second force? (Ans: 10 N)

△**9.** An object of mass M = 10 kg, moving on a frictionless horizontal surface, is subjected to two applied forces as shown in figure 3. In which situation is the object accelerating to the right**?** (Ans: d)

△**10.** A car of mass 1000 kg is initially at rest. It moves along a straight road for 20 s and then comes to rest again. The velocity – time graph for the movement is given in figure 4. What is the magnitude of the net force that acts on the car while it is slowing down to stop from t = 15 s to t = 20 s? (Ans: 2000N)

△**11.** A 20.0-kg block is resting on a frictionless horizontal table. A horizontal string pulls the block. If the tension in the string is 20.0 N, what is the speed of the block after moving 2.0 m? (Ans: 2.0 m/s)

△**12.** A block of mass 2.0 kg is being pushed by a force parallel to the ground, as shown in figure 5. The block is observed to have an acceleration of 1.0 m/s^2 down the incline. Assume the incline is frictionless. Calculate the magnitude of the force. (Ans: 9.0 N)

△**13.** In figure 6, a 25-kg box is pushed across a frictionless horizontal floor with a force of 20 N, directed at an angle of 20^o below the horizontal. What is the magnitude of the acceleration of the box? (Ans: 0.75 m/s^2)

□**14.** A 2.0-kg box slides down a frictionless vertical wall while you push on it with a force F at a 30^o angle with the vertical (see figure 7). What is the magnitude of the normal force of the wall on the box if it is to slide down at constant speed? (Ans: 11.3 N)

□**15**. A 2.3-N weight is suspended by a string from a ceiling and held at an angle θ from the vertical by a 4.0-N horizontal force *F*, as shown in figure 8. What is the magnitude of the tension in the string? (Ans: 4.6 N)

■**16.** The weight of an astronaut on Earth is 800 N. What is his weight on planet Mars, where g = 3.76 m/s^2? (Ans: 307 N)

O17. A constant force *F* of magnitude 20 N is applied to block *A* of mass *m* = 4.0 kg, which pushes block *B*, as shown in figure 9. The block slides over a frictionless flat surface with an acceleration of 2.0 m/s^2. What is the net force on block *B*? (Ans:12 N, to the right)

O18. Three equal mass blocks each of mass 2.0 kg move together over a horizontal frictionless surface. Two forces, $\boldsymbol{F}_1 = 40\,\hat{\mathbf{i}}$ (N) and $\boldsymbol{F}_2 = -10\,\hat{\mathbf{i}}$ (N) are applied on the three-mass system (see figure 10). What is the net force on the middle mass? (Ans: $10\,\hat{\mathbf{i}}$ N)

△**19.** Figure 11 shows block A of mass 6.0 kg and block B of mass 8.0 kg connected by a rigid rod of negligible mass. Force $\boldsymbol{F}_a = 16\,\hat{\mathbf{i}}$ (N) acts on block A and force $\boldsymbol{F}_b = -30\,\hat{\mathbf{i}}$ (N) acts on block B. What is the tension in the rod? (Neglect friction) (Ans: 22 N)

O20. Two blocks are in contact on a frictionless table. A horizontal force is applied to block m_2, as shown in figure 12. If m_1 = 3 kg, m_2 = 2 kg, and *F* = 5 N, find the magnitude of the force between the two blocks.
(Ans: 3 N)

△**21.** Two blocks of masses m_1 = 2.0 kg and m_2 = 3.0 kg are connected as shown in figure 13. Find the tension T_2 if T_1 = 50 N. (Ans: 30 N)

□**22.** In the system shown in figure 14, a horizontal force $\boldsymbol{F}$ acts on the 8.0-kg object. The horizontal surface is frictionless. What is the magnitude of $\boldsymbol{F}$ if the 5.0-kg object has a downward acceleration of 1.0 m/s^2?
(Ans: 54 N)

△**23.** A 2.0-kg mass has a velocity of $(2.0\,\hat{\mathbf{i}} + 2.0\,\hat{\mathbf{j}})$ m/s at one instant. Four seconds later, its velocity is $(2.0\,\hat{\mathbf{i}} + 14\,\hat{\mathbf{j}})$ m/s. Assuming that the object is under the influence of a single constant force, find this force.
(Ans: $6.0\,\hat{\mathbf{j}}$ N)

O24. Three books (X, Y, and Z) rest on a table as shown in figure 16. The weight of each book is also indicated in the figure. What is the magnitude of the force of book Z on book Y? (Ans: 9 N)

●**25.** A 4.0-kg block is pushed up a 30° inclined frictionless plane with a constant horizontal force *F* (figure 17). If the block moves with constant speed, find the magnitude of the force *F*. (Ans: 23 N)

●**26**. A 3.0-kg block slides on a frictionless 37° incline plane. A vertical force of 15 N is applied to the block (see figure 18). What is the acceleration of the block? (Ans: 2.9 m/s^2 down the incline)

●**27.** A block with m_1 = 5.7 kg on a frictionless 30° inclined plane is connected by a cord over a massless frictionless pulley to a second block with m_2 = 3.5 kg hanging vertically as shown in figure 19. What is the acceleration of m_2? (Ans: 0.69 m/s^2 downward)

●**28.** When a 40-N force, parallel to an incline and directed up the incline, is applied to a crate on a frictionless incline that is 30^o above the horizontal, the acceleration of the crate is 2.0 m/s^2, down the incline. Find the mass of the crate. (Ans: 14 kg)

●**29.** Two boxes, one of mass m = 5.00 kg and the other with an unknown mass M, are connected with a string passing over a massless frictionless pulley and are placed on frictionless planes, as shown in figure 20.What must be the mass M, if it goes down the plane with an acceleration of a = 2.45 m/s^2? (Ans: 19.1 kg)

●**30.** Two equal-mass blocks rest on frictionless surfaces, as in figure 21. Assuming the pulleys to be light and frictionless, find the time required for block A to move 0.5 m down the incline, starting from rest. (Ans: 0.64 s)

□**31.** Two blocks of masses m_1 = 4.00 kg and m_2 = 2.00 kg are connected by a string passing over a massless and frictionless pulley and placed on a frictionless horizontal table, as shown in figure 22. A force of F = 10.0 N at an angle of 60.0° with the horizontal is applied to m_1. What is the magnitude of the acceleration of the system? (Ans: 2.43 m/s^2)

●**32**. Two blocks of masses m_1 = 5.0 kg and m_2 = 10 kg are connected by a massless rod and slide on a frictionless 30° incline as shown in figure 23. What is the tension in the rod? (Ans: zero)

■**33.** Two masses m_1 = 2 kg and m_2 = 4 kg are connected by a light string that passes over a frictionless and massless pulley (see figure 24). Find the magnitude of the acceleration of the masses. (Ans: 3.27 m/s^2)

△**34.** Two forces, $\boldsymbol{F_1}$ and $\boldsymbol{F_2}$, are acting on a 3.0-kg box in the xy plane. Figure 25 shows only $\boldsymbol{F_1}$ and the acceleration $\boldsymbol{a}$ of the box. Find $\boldsymbol{F_2}$. (Ans: -72 $\hat{\mathbf{i}}$ +24 $\hat{\mathbf{j}}$ N)

△**35.** A 25.0-kg crate is pushed across a frictionless horizontal floor with a force of 200 N, directed 20below the horizontal. What is the magnitude of the normal force of the floor on the crate? (Ans: 313 N)

△**36.** Figure 27 shows the force versus time graph of a force acting on a 5.0-kg object moving in the x direction along a frictionless one-dimensional track. At t = 0, the object is moving in the negative direction of the x axis with a speed of 2.0 m/s. What are the speed and direction of the object at t = 7.0 s?
(Ans: 7.0 m/s in the positive x direction)

O37. A force $\boldsymbol{F}$ = 10 N is applied to block 1, as shown in figure 29. The masses of blocks 1, 2, and 3 are 5 kg, 3 kg, and 2 kg, respectively. What is the magnitude of the force exerted by block 2 on block 1? Assume the surface is frictionless. (Ans: 5 N)

□**38.** A mass is suspended by a string from the ceiling of a train accelerating horizontally at 2.5 m/s^2. What is the angle that the string makes with the vertical? (Ans: 14^o)

△**40.** Two *horizontal* forces perpendicular to each other act at the same time on a 5.0-kg box on a horizontal frictionless floor. One force is 6.0 N and the other is 8.0 N in magnitude. What is the magnitude of the acceleration of the box? (Ans: 2.0 m/s^2)

A B C D E Conceptual Problems ❶❷❸❹❺

△**1.** Three blocks, (A,B,C), each having mass *M*, are connected by strings, as shown in figure 15. Block C is pulled to the right by a force *F* that causes the entire system to accelerate. Neglecting friction, what is the tension T_1 between blocks B and C?

A. 2F/3
B. F/2
C. F/3
D. F
E. 4F/3

◆**2.** Acceleration is always in the direction:

A. of the net force.
B. of the initial velocity.
C. of the final velocity.
D. of the displacement.
E. opposite to the frictional force.

◆**3.** Consider a particle in motion while the net external force on it is zero. Which of the following statements is correct in this case?

A. The particle must be moving at a constant velocity.
B. The particle must be moving at a constant speed in a circle.
C. The particle will come to rest after some time.
D. The velocity of the particle is always perpendicular to the direction of the motion.
E. The particle has an acceleration of 9.8 m/s^2.

■**4.** To measure your weight, you stand on a spring scale on the floor of an elevator. Among the following situations, select the one that gives the highest reading on the scale:

A. The elevator moves upward with increasing speed.
B. The elevator moves upward with decreasing speed.
C. The elevator remains stationary.
D. The elevator moves downward with increasing speed.
E. The elevator moves downward at constant speed.

●**5.** Two boxes *A* and *B* (m_A = 3.0 kg, and m_B =1.0 kg) are in contact on a horizontal frictionless surface, and move along the *x* axis (see figure 26). A horizontal force $\boldsymbol{F}$ = 10.0 $\hat{\mathbf{i}}$ (N) is applied on box *A*. The net force acting on *A* is $\boldsymbol{F_1}$ and on *B* is $\boldsymbol{F_2}$. Which one of the following statements is correct?

A) $\vec{F}_1 = 7.5\,\hat{i}\ N$ and $\vec{F}_2 = 2.5\,\hat{i}\ N$
B) $\vec{F}_1 = 5.0\,\hat{i}\ N$ and $\vec{F}_2 = -5.0\,\hat{i}\ N$
C) $\vec{F}_1 = 2.5\,\hat{i}\ N$ and $\vec{F}_2 = 7.5\,\hat{i}\ N$
D) $\vec{F}_1 = 0\,N$ and $\vec{F}_2 = 0\,N$
E) $\vec{F}_1 = 2.5\,\hat{i}\ N$ and $\vec{F}_2 = -2.5\,\hat{i}\ N$

◆**6.** Which of the following is NOT an example of accelerated motion?

A. The horizontal component of a projectile motion.
B. The vertical component of a projectile motion.
C. A circular motion at constant speed.
D. A swinging pendulum.
E. The Earth's rotation about the sun.

◆**7.** A 1000-kg airplane moves in straight horizontal flight at constant speed. The force of air resistance is 1800 N. The net force on the plane is:

A. zero
B. 11800 N
C. 1800 N
D. 9800 N
E. none of these

◆**8.** An object is being accelerated in the absence of friction by a 100-N force. A second force of 100-N is then applied to the object in a direction opposite to the direction of motion. The object with these two forces acting on it will

A. Move at a constant velocity
B. Slow down
C. Move in a circle
D. Stop rapidly
E. Move backward

◆**9.** Figure 28 shows four possible choices for the direction of **ONE force** of magnitude *F* to be applied to a block on an inclined plane of angle 30. The directions are either horizontal or vertical. (for all choices, we assume that the block remains on the inclined plane). Rank the choices according to the magnitude of **the normal force** on the block from the plane, **greatest first**.

A. choice 4, choice 3, choice 1, choice 2
B. choice 3, choice 4, choice 1, choice 2
C. choice 1, choice 3, choice 4, choice 2
D. choice 2, choice 3, choice 1, choice 4
E. (choice 3 and choice 4) tie, (choice 1 and choice 2) tie

■**10.** A 13-N weight and a 12-N weight are connected by a massless string over a massless, frictionless pulley. The 13-N weight has a downward acceleration equal to:

A. g/25
B. g/12
C. g/13
D. g
E. (13/25)g

■**11.** A 100-kg man standing on a scale in a moving elevator reads his weight as 490 N. The acceleration of the elevator is:

A. 4.9 m/s^2 downward
B. 4.9 m/s^2 upward
C. 9.8 m/s^2 upward
D. 9.8 m/s^2 downward
E. zero

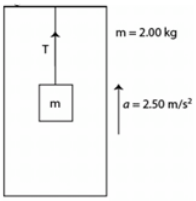


Figure 1

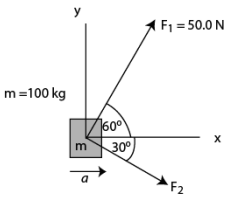


Figure 2

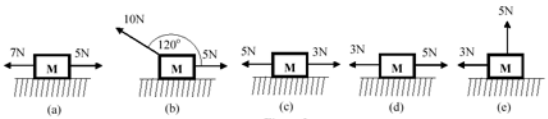


Figure 3

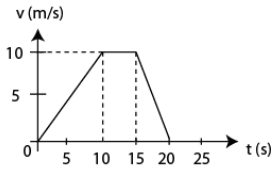
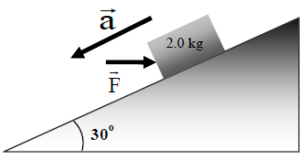


Figure 4



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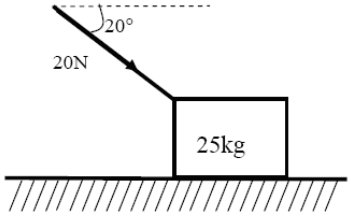

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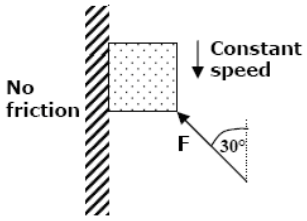

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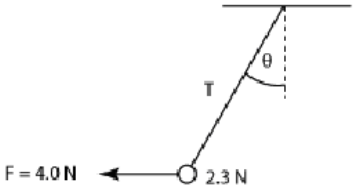
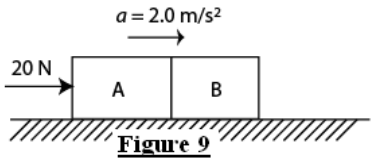


Figure 8



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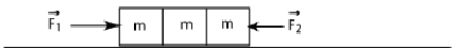
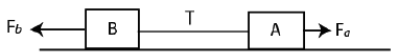


Figure 10



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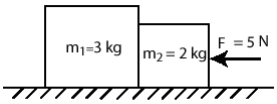

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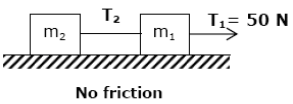

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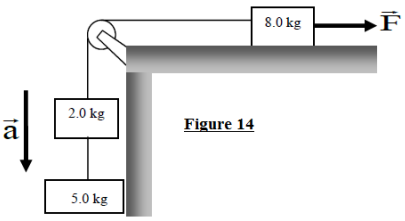

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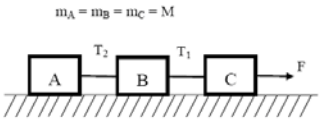

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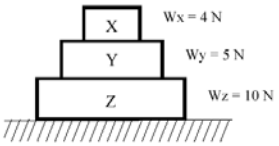

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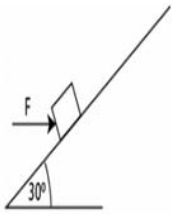

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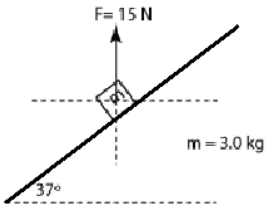
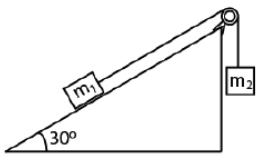


Figure 18



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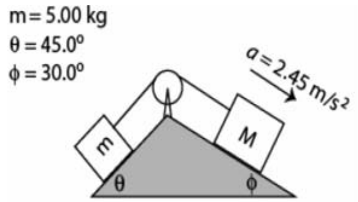

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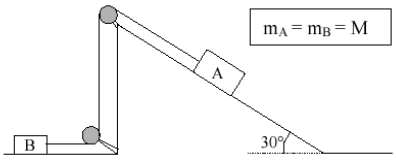

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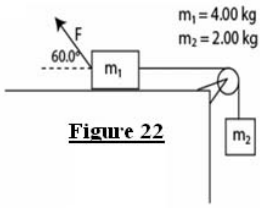

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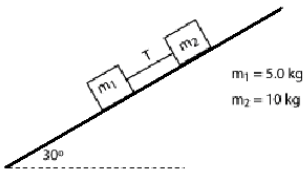

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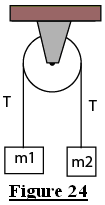
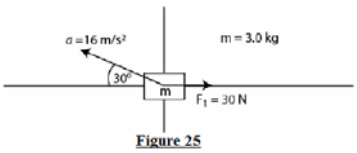


Figure 24



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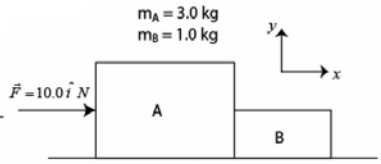
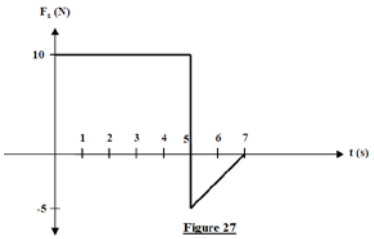


Figure 26



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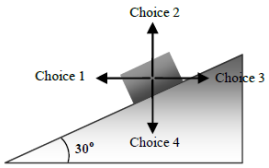

Figure 28

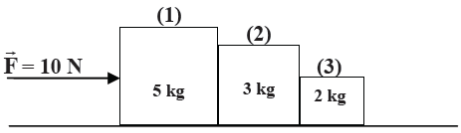

Figure 29