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PHY11 HW4

CAUTION

Directions of gravity and the normal force

In Problems involving a slope or an "inclined plane," avoid making errors in the directions of the normal force and gravity. The normal force on an incline is *not* vertical: it is perpendicular to the slope or plane. And gravity is *not* perpendicular to the slope—gravity acts vertically downward toward the center of the Earth.

Summary

Newton's three laws of motion are the basic classical laws describing motion.

Newton's first law (the **law of inertia**) states that if the net force on an object is zero, an object originally at rest remains at rest, and an object in motion remains in motion in a straight line with constant velocity.

Newton's second law states that the acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass:

$$\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}. \qquad (4\text{–}1)$$

Newton's second law is one of the most important and fundamental laws in classical physics.

Newton's third law states that whenever one object exerts a force on a second object, the second object always exerts a force on the first object which is equal in magnitude but opposite in direction:

$$\vec{\mathbf{F}}_{AB} = -\vec{\mathbf{F}}_{BA} \qquad (4\text{–}2)$$

where $\vec{\mathbf{F}}_{BA}$ is the force on object B exerted by object A.

The tendency of an object to resist a change in its motion is called **inertia**. **Mass** is a measure of the inertia of an object.

Weight refers to the **gravitational force** on an object, and is equal to the product of the object's mass m and the acceleration of gravity $\vec{\mathbf{g}}$:

$$\vec{\mathbf{F}}_G = m\vec{\mathbf{g}}. \qquad (4\text{–}3)$$

Force, which is a vector, can be considered as a push or pull; or, from Newton's second law, force can be defined as an action capable of giving rise to acceleration. The **net force** on an object is the vector sum of all forces acting on that object.

When two objects slide over one another, the force of friction that each object exerts on the other can be written approximately as $F_{fr} = \mu_k F_N$, where F_N is the **normal force** (the force each object exerts on the other perpendicular to their contact surfaces), and μ_k is the coefficient of **kinetic friction**. If the objects are at rest relative to each other, then F_{fr} is just large enough to hold them at rest and satisfies the inequality $F_{fr} < \mu_s F_N$, where μ_s is the coefficient of **static friction**.

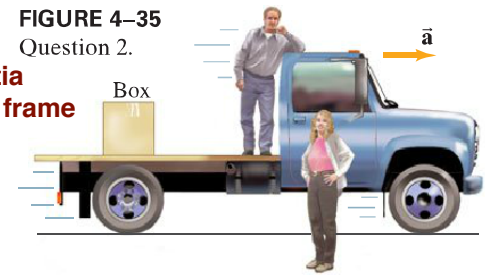
For solving problems involving the forces on one or more objects, it is essential to draw a **free-body diagram** for each object, showing all the forces acting on only that object. Newton's second law can be applied to the vector components for each object.

Questions

1. Why does a child in a wagon seem to fall backward when you give the wagon a sharp pull forward? **Inertia**
2. A box rests on the (frictionless) bed of a truck. The truck driver starts the truck and accelerates forward. The box immediately starts to slide toward the rear of the truck bed. Discuss the motion of the box, in terms of Newton's laws, as seen (*a*) by Mary standing on the ground beside the truck, and (*b*) by Chris who is riding on the truck (Fig. 4–35).

FIGURE 4–35
Question 2.

a) Inertia
b) Bad frame



3. If an object is moving, is it possible for the net force acting on it to be zero? Explain. **Yes. Uniform velocity.**
4. If the acceleration of an object is zero, are no forces acting on it? Explain. **No net force, but may be forces.**
5. Only one force acts on an object. Can the object have zero acceleration? Can it have zero velocity? Explain. **No. Yes.**
6. When a golf ball is dropped to the pavement, it bounces back up. (*a*) Is a force needed to make it bounce back up? (*b*) If so, what exerts the force? **Yes. Ground.**
7. If you walk along a log floating on a lake, why does the log move in the opposite direction? **Force from you.**
8. (*a*) Why do you push down harder on the pedals of a bicycle when first starting out than when moving at constant speed? (*b*) Why do you need to pedal at all when cycling at constant speed? **Static friction. Kinetic friction.**
9. A stone hangs by a fine thread from the ceiling, and a section of the same thread dangles from the bottom of the stone (Fig. 4–36). If a person gives a sharp pull on the dangling thread, where is the thread likely to break: below the stone or above it? What if the person gives a slow and steady pull? Explain your answers.

FIGURE 4–36
Question 9.

10. The force of gravity on a 2-kg rock is twice as great as that on a 1-kg rock. Why then doesn't the heavier rock fall faster? **Twice as much inertia.**

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4. A bear sling, Fig. 4–40, is used in some national parks for placing backpackers' food out of the reach of bears. As the backpacker raises the pack by pulling down on the rope, the force F needed:
(a) decreases as the pack rises until the rope is straight across.
(b) doesn't change.
(c) increases until the rope is straight.
(d) increases but the rope always sags where the pack hangs.

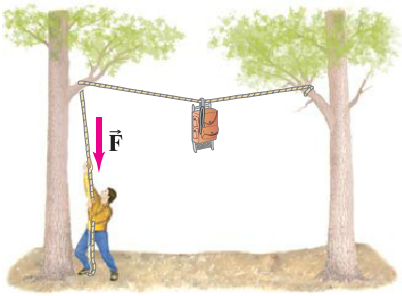

FIGURE 4–40 MisConceptual Question 4.

5. What causes the boat in Fig. 4–41 to move forward?
(a) The force the man exerts on the paddle.
(b) The force the paddle exerts on the water.
(c) The force the water exerts on the paddle.
(d) The motion of the water itself.

FIGURE 4–41 MisConceptual Question 5.

6. A person stands on a scale in an elevator. His apparent weight will be the greatest when the elevator
(a) is standing still.
(b) is moving upward at constant velocity.
(c) is accelerating upward.
(d) is moving downward at constant velocity.
(e) is accelerating downward.

7. When a skier skis down a hill, the normal force exerted on the skier by the hill is
(a) equal to the weight of the skier.
(b) greater than the weight of the skier.
(c) less than the weight of the skier.

8. A golf ball is hit with a golf club. While the ball flies through the air, which forces act on the ball? Neglect air resistance.
(a) The force of the golf club acting on the ball.
(b) The force of gravity acting on the ball.
(c) The force of the ball moving forward through the air.
(d) All of the above.
(e) Both (a) and (c).

9. Suppose an object is accelerated by a force of 100 N. Suddenly a second force of 100 N in the opposite direction is exerted on the object, so that the forces cancel. The object
(a) is brought to rest rapidly.
(b) decelerates gradually to rest.
(c) continues at the velocity it had before the second force was applied.
(d) is brought to rest and then accelerates in the direction of the second force.

10. You are pushing a heavy box across a rough floor. When you are initially pushing the box and it is accelerating,
(a) you exert a force on the box, but the box does not exert a force on you.
(b) the box is so heavy it exerts a force on you, but you do not exert a force on the box.
(c) the force you exert on the box is greater than the force of the box pushing back on you.
(d) the force you exert on the box is equal to the force of the box pushing back on you.
(e) the force that the box exerts on you is greater than the force you exert on the box.

11. A 50-N crate sits on a horizontal floor where the coefficient of static friction between the crate and the floor is 0.50. A 20-N force is applied to the crate acting to the right. What is the resulting static friction force acting on the crate?
(a) 20 N to the right.
(b) 20 N to the left.
(c) 25 N to the right.
(d) 25 N to the left.
(e) None of the above; the crate starts to move.

12. The normal force on an extreme skier descending a very steep slope (Fig. 4–42) can be zero if
(a) his speed is great enough.
(b) he leaves the slope (no longer touches the snow).
(c) the slope is greater than 75°.
(d) the slope is vertical (90°).

FIGURE 4–42 MisConceptual Question 12.

13. To pull an old stump out of the ground, you and a friend tie two ropes to the stump. You pull on it with a force of 500 N to the north while your friend pulls with a force of 450 N to the northwest. The total force from the two ropes is
(a) less than 950 N.
(b) exactly 950 N.
(c) more than 950 N.

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For assigned homework and other learning materials, go to the MasteringPhysics website.

Problems

[*It would be wise, before starting the Problems, to reread the Problem Solving Strategies on pages 30, 60, and 88.*]

4–4 to 4–6 Newton's Laws, Gravitational Force, Normal Force [Assume no friction.]

77N

a) 666.4N
b) 115.6N
c) 251.6N

1452N

0.02N

33.3 m/s
a=3.7 m/s^2
I3.3X10^5 N

1. (I) What force is needed to accelerate a sled (mass = 55 kg) at 1.4 m/s^2 on horizontal frictionless ice?
2. (I) What is the weight of a 68-kg astronaut (*a*) on Earth, (*b*) on the Moon (g = 1.7 m/s^2), (*c*) on Mars (g = 3.7 m/s^2), (*d*) in outer space traveling with constant velocity? **d) 0 N**
3. (I) How much tension must a rope withstand if it is used to accelerate a 1210-kg car horizontally along a frictionless surface at 1.20 m/s^2?
4. (II) According to a simplified model of a mammalian heart, at each pulse approximately 20 g of blood is accelerated from 0.25 m/s to 0.35 m/s during a period of 0.10 s. What is the magnitude of the force exerted by the heart muscle?
5. (II) Superman must stop a 120-km/h train in 150 m to keep it from hitting a stalled car on the tracks. If the train's mass is 3.6 × 10^5 kg, how much force must he exert? Compare to the weight of the train (give as %). How much force does the train exert on Superman? **37.8%**
6. (II) A person has a reasonable chance of surviving an automobile crash if the deceleration is no more than 30 g's. Calculate the force on a 65-kg person accelerating at this rate. What distance is traveled if brought to rest at this rate from 95 km/h? **19,110N v=26.4 m/s 1.2 m**
7. (II) What average force is required to stop a 950-kg car in 8.0 s if the car is traveling at 95 km/h?
8. (II) Estimate the average force exerted by a shot-putter on a 7.0-kg shot if the shot is moved through a distance of 2.8 m and is released with a speed of 13 m/s.
9. (II) A 0.140-kg baseball traveling 35.0 m/s strikes the catcher's mitt, which, in bringing the ball to rest, recoils backward 11.0 cm. What was the average force applied by the ball on the glove?
10. (II) How much tension must a cable withstand if it is used to accelerate a 1200-kg car vertically upward at 0.70 m/s^2?
11. (II) A 20.0-kg box rests on a table. (*a*) What is the weight of the box and the normal force acting on it? (*b*) A 10.0-kg box is placed on top of the 20.0-kg box, as shown in Fig. 4–43. Determine the normal force that the table exerts on the 20.0-kg box and the normal force that the 20.0-kg box exerts on the 10.0-kg box.

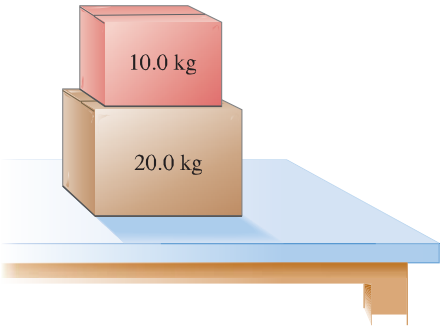

FIGURE 4–43
Problem 11.

12. (II) A 14.0-kg bucket is lowered vertically by a rope in which there is 163 N of tension at a given instant. What is the acceleration of the bucket? Is it up or down?
13. (II) A 75-kg petty thief wants to escape from a third-story jail window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of only 58 kg. How might the thief use this "rope" to escape? Give a quantitative answer.
14. (II) An elevator (mass 4850 kg) is to be designed so that the maximum acceleration is 0.0680g. What are the maximum and minimum forces the motor should exert on the supporting cable?
15. (II) Can cars "stop on a dime"? Calculate the acceleration of a 1400-kg car if it can stop from 35 km/h on a dime (diameter = 1.7 cm). How many g's is this? What is the force felt by the 68-kg occupant of the car?
16. (II) A woman stands on a bathroom scale in a motionless elevator. When the elevator begins to move, the scale briefly reads only 0.75 of her regular weight. Calculate the acceleration of the elevator, and find the direction of acceleration.
17. (II) (*a*) What is the acceleration of two falling sky divers (total mass = 132 kg including parachute) when the upward force of air resistance is equal to one-fourth of their weight? (*b*) After opening the parachute, the divers descend leisurely to the ground at constant speed. What now is the force of air resistance on the sky divers and their parachute? See Fig. 4–44.

FIGURE 4–44
Problem 17.

18. (II) The cable supporting a 2125-kg elevator has a maximum strength of 21,750 N. What maximum upward acceleration can it give the elevator without breaking?
19. (III) A person jumps from the roof of a house 2.8 m high. When he strikes the ground below, he bends his knees so that his torso decelerates over an approximate distance of 0.70 m. If the mass of his torso (excluding legs) is 42 kg, find (*a*) his velocity just before his feet strike the ground, and (*b*) the average force exerted on his torso by his legs during deceleration.

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4–7 Newton's Laws and Vectors [Ignore friction.]

20. (I) A box weighing 77.0 N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end (Fig. 4–45). Determine the force that the table exerts on the box if the weight hanging on the other side of the pulley weighs (*a*) 30.0 N, (*b*) 60.0 N, and (*c*) 90.0 N.

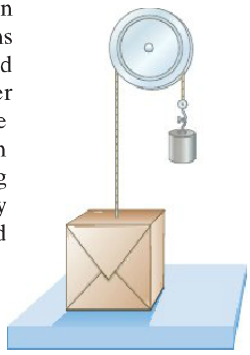


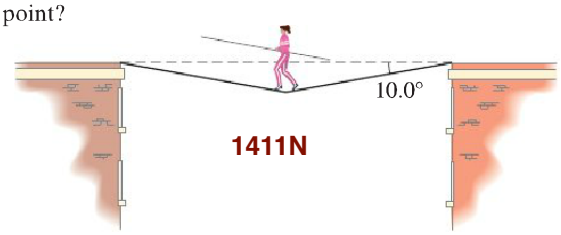
FIGURE 4–45
Problem 20.

21. (I) Draw the free-body diagram for a basketball player (*a*) just before leaving the ground on a jump, and (*b*) while in the air. See Fig. 4–46.

FIGURE 4–46
Problem 21.

22. (I) Sketch the free-body diagram of a baseball (*a*) at the moment it is hit by the bat, and again (*b*) after it has left the bat and is flying toward the outfield. Ignore air resistance.

23. (II) Arlene is to walk across a "high wire" strung horizontally between two buildings 10.0 m apart. The sag in the rope when she is at the midpoint is 10.0°, as shown in Fig. 4–47. If her mass is 50.0 kg, what is the tension in the rope at this point?



1411N

FIGURE 4–47 Problem 23.

24. (II) A window washer pulls herself upward using the bucket–pulley apparatus shown in Fig. 4–48. (*a*) How hard must she pull downward to raise herself slowly at constant speed? (*b*) If she increases this force by 15%, what will her acceleration be? The mass of the person plus the bucket is 72 kg.

FIGURE 4–48
Problem 24.

25. (II) One 3.2-kg paint bucket is hanging by a massless cord from another 3.2-kg paint bucket, also hanging by a massless cord, as shown in Fig. 4–49. (*a*) If the buckets are at rest, what is the tension in each cord? (*b*) If the two buckets are pulled upward with an acceleration of 1.25 m/s^2 by the upper cord, calculate the tension in each cord.

FIGURE 4–49
Problem 25.

26. (II) Two snowcats in Antarctica are towing a housing unit north, as shown in Fig. 4–50. The sum of the forces $\vec{\mathbf{F}}_A$ and $\vec{\mathbf{F}}_B$ exerted on the unit by the horizontal cables is north, parallel to the line L, and $F_A = 4500$ N. Determine F_B and the magnitude of $\vec{\mathbf{F}}_A + \vec{\mathbf{F}}_B$.

FB=4500Sin 48/sin 32
= 6310.7 N
FA+FB=8362.9N

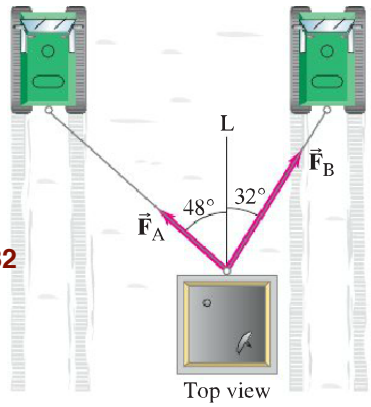


FIGURE 4–50
Problem 26.

27. (II) A train locomotive is pulling two cars of the same mass behind it, Fig. 4–51. Determine the ratio of the tension in the coupling (think of it as a cord) between the locomotive and the first car (F_{T1}), to that between the first car and the second car (F_{T2}), for any nonzero acceleration of the train.

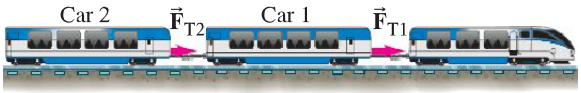


FIGURE 4–51 Problem 27.

28. (II) The two forces $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ shown in Fig. 4–52a and b (looking down) act on an 18.5-kg object on a frictionless tabletop. If $F_1 = 10.2$ N and $F_2 = 16.0$ N, find the net force on the object and its acceleration for (a) and (b).

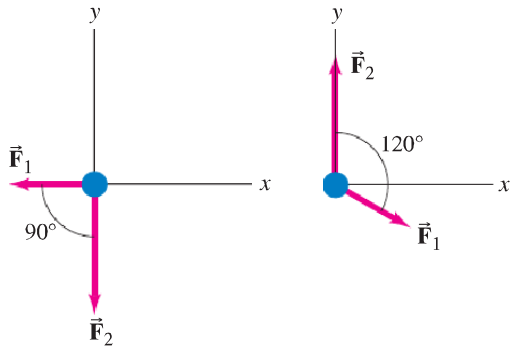


FIGURE 4–52 Problem 28.

PHY11, HW4: Work

1) $F = ma = 55 \times 1.4 = 77\,\mathrm{N}$.

2) $Weight = mg$:
(a) Earth: $68 \times 9.8 = 666.4\,\mathrm{N}$.
(b) Moon: $68 \times 1.7 = 115.6\,\mathrm{N}$.
(c) Mars: $68 \times 3.7 = 251.6\,\mathrm{N}$.
(d) Space (constant vel.): $68 \times 0 = 0\,\mathrm{N}$.

3) Tension $= F = ma = 1210 \times 1.20 = 1452\,\mathrm{N}$.

4) $$v_y = v_{y0} + at \qquad (A)$$

$$0.35 = 0.25 + a \times 0.1$$

So $a = (0.35 - 0.25)/0.1 = 1\,\mathrm{m/s^2}$.
$F = ma = 0.02 \times 1 = 0.02\,\mathrm{N}$.

5) $120\dfrac{\mathrm{km}}{\mathrm{h}} = 120\dfrac{1000\mathrm{m}}{3600\mathrm{s}} = 33.3\,\mathrm{m/s}$. Now use

$$v_y^2 = v_{y0}^2 + 2a(y - y_0) \qquad (C)$$

So $0^2 = 33.3^2 + 2a(150)$,
or $a = -33.3^2/300 = -3.7\,\mathrm{m/s^2}$.
The minus says a is in the opposite direction to v (assumed positive). Then, $|F| = m|a| = 3.6 \times 10^5 \times 3.7 = 1.33 \times 10^6\,\mathrm{N}$.
Force of train on superman is equal and opposite.
Weight of train: $3.6 \times 105 \times 9.8 = 3.53 \times 10^6\,\mathrm{N}$.
Percentage: $\dfrac{1.33 \times 10^6}{3.53 \times 10^6} 100 = 38\%$.

6) $F = ma = 65 \times 30 \times 9.8 = 1.9 \times 10^4\,\mathrm{N}$.
$95\dfrac{\mathrm{km}}{\mathrm{h}} = 95\dfrac{1000\mathrm{m}}{3600\mathrm{s}} = 26.4\,\mathrm{m/s}$. Now use

$$v_y^2 = v_{y0}^2 + 2a(y - y_0) \qquad (C)$$

$0^2 = 26.4^2 + 2(-30 \times 9.8)d$,
or $d = 26.4^2/588 = 1.2\,\mathrm{m}$.

23) The tension T will point along the rope, the vertical component of the tensions on either side will balance the weight:

$$2T \sin 10^\circ = 50 \times 9.8$$

So $T = 490/(2 \sin 10^\circ) = 1411\,\mathrm{N}$.

26) Given the direction of the force, the components perpendicular to the line L must balance:

$$F_A \sin 48^\circ = F_B \sin 32^\circ,$$

or

$$F_B = \frac{F_A \sin 48^\circ}{\sin 32^\circ} = \frac{4500 \sin 48^\circ}{\sin 32^\circ} = 6311\,\mathrm{N}.$$

Magnitude of resultant, is sum of the magnitudes of the components parallel to L:

$$F_A \cos 48^\circ + F_B \cos 32^\circ = 8363\,\mathrm{N}.$$