Name______________________________ Essex High School
Physics 200 October 18, 2016

Practice with Forces in 1 Dimension
(up & down, left & right)

Conceptual Questions

3. If the acceleration of an object is zero, are no forces acting on it? Explain.

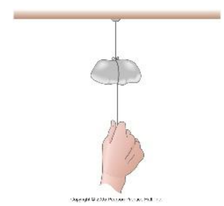
3. If the acceleration of an object is zero, then by Newton's second law, the *net* force must be zero. There can be forces acting on the object as long as the vector sum of the forces is zero.

5. 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?

5. (*a*) A force is needed to bounce the ball back up, because the ball changes direction, and so accelerates. If the ball accelerates, there must be a force.

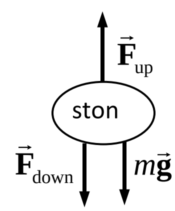
(*b*) The pavement exerts the force on the golf ball.

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.



9. When giving a sharp pull, the key is the suddenness of the application of the force. When a large,
sudden force is applied to the bottom string, the bottom string will have a large tension in it. Because of the stone's inertia, the upper string does not immediately experience the large force. The bottom string must have more tension in it, and will break first.

If a slow and steady pull is applied, the tension in the bottom string increases. We approximate that condition as considering the stone to be in equilibrium until the string breaks. The free-body diagram for the stone would look like this diagram. While the stone is in equilibrium, Newton's 2nd law states that $F_{up} = F_{down} + mg$. Thus the tension in the upper string is going to be larger than the tension in the lower string because of the weight of the stone, and so the upper string will break first.



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?

10. The acceleration of both rocks is found by dividing their weight (the force of gravity on them) by their mass. The 2-kg rock has a force of gravity on it that is twice as great as the force of gravity on the 1-kg rock, but also twice as great a mass as the 1-kg rock, so the acceleration is the same for both.

13. When an object falls freely under the influence of gravity there is a net force *mg* exerted on it by the Earth. Yet by Newton's third law the object exerts an equal and opposite force on the Earth. Why doesn't the Earth move?

13. Let us find the acceleration of the Earth, assuming the mass of the freely falling object is m = 1 kg. If the mass of the Earth is M, then the acceleration of the Earth would be found using Newton's 3rd law and Newton's 2nd law.

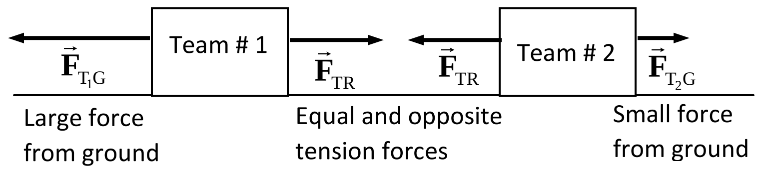
$$F_{\text{Earth}} = F_{\text{object}} \quad \rightarrow \quad Ma_{\text{Earth}} = mg \quad \rightarrow \quad a_{\text{Earth}} = g\, m/M$$

Since the Earth has a mass that is on the order of 10^{25} kg, then the acceleration of the Earth is on the order of $10^{-25} g$, or about $10^{-24}\ \text{m/s}^2$. This tiny acceleration is undetectable.

15. According to Newton's third law, each team in a tug of war (Fig. 4–37) pulls with equal force on the other team. What, then, determines which team will win?

15. In a tug of war, the team that pushes hardest against the ground wins. It is true that both teams have the same force on them due to the tension in the rope. But the winning team pushes harder against the ground and thus the ground pushes harder on the winning team, making a net unbalanced force. The free body diagram below illustrates this. The forces are $\vec{\mathbf{F}}_{\mathrm{T_1G}}$, the force on team 1 from the ground, $\vec{\mathbf{F}}_{\mathrm{T_2G}}$, the force on team 2 from the ground, and $\vec{\mathbf{F}}_{\mathrm{TR}}$, the force on each team from the rope.

Thus the net force on the winning team $\left(\vec{\mathbf{F}}_{\mathrm{T_1G}} - \vec{\mathbf{F}}_{\mathrm{TR}}\right)$ is in the



Problems

1. (I) What force is needed to accelerate a child on a sled (total mass = 60.0 kg) at $1.25\,\mathrm{m/s^2}$?

1. Use Newton's second law to calculate the force.

$$\sum F = ma = (60.0\text{ kg})(1.25\ \mathrm{m/s^2}) = \boxed{75.0\text{ N}}$$

2. (I) A net force of 265 N accelerates a bike and rider at $2.30\,\mathrm{m/s^2}$. What is the mass of the bike and rider together?

2. Use Newton's second law to calculate the mass.

$$\sum F = ma \quad \rightarrow \quad m = \frac{\sum F}{a} = \frac{265\text{ N}}{2.30\,\mathrm{m/s^2}} = \boxed{115\text{ kg}}$$

4. (I) What is the weight of a 76-kg astronaut (*a*) on Earth, (*b*) on the Moon $\left(g = 1.7\ \mathrm{m/s^2}\right)$, (*c*) on Mars $\left(g = 3.7\ \mathrm{m/s^2}\right)$, (*d*) in outer space traveling with constant velocity?

4. In all cases, $W = mg$, where *g* changes with location.

(*a*) $W_{\text{Earth}} = mg_{\text{Earth}} = (76\text{ kg})(9.8\,\mathrm{m/s^2}) = \boxed{7.4\times10^2\,\mathrm{N}}$

(*b*) $W_{\text{Moon}} = mg_{\text{Moon}} = (76\text{ kg})(1.7\,\mathrm{m/s^2}) = \boxed{1.3\times10^2\,\mathrm{N}}$

(*c*) $W_{\text{Mars}} = mg_{\text{Mars}} = (76\text{ kg})(3.7\,\mathrm{m/s^2}) = \boxed{2.8\times10^2\,\mathrm{N}}$

(*d*) $W_{\text{Space}} = mg_{\text{Space}} = (76\text{ kg})(0\,\mathrm{m/s^2}) = \boxed{0\text{ N}}$

6. (II) What average force is required to stop an 1100-kg car in 8.0 s if the car is traveling at $95\,\mathrm{km/h}$?

6. Find the average acceleration from Eq. 2-2. The average force on the car is found from Newton's second law.

$$v = 0 \qquad v_0 = (95\,\mathrm{km/h})\left(\frac{0.278\,\mathrm{m/s}}{1\,\mathrm{km/h}}\right) = 26.4\,\mathrm{m/s} \qquad a_{avg} = \frac{v - v_0}{t} = \frac{0 - 26.4\,\mathrm{m/s}}{8.0\text{ s}} = -3.30\ \mathrm{m/s^2}$$

$$F_{avg} = ma_{avg} = (1100\text{ kg})(-3.3\ \mathrm{m/s^2}) = \boxed{-3.6\times10^3\,\mathrm{N}}$$

The negative sign indicates the direction of the force, in the opposite direction to the initial velocity.

9. (II) A 0.140-kg baseball traveling $35.0\,\mathrm{m/s}$ 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?

9. The problem asks for the average force on the glove, which in a direct calculation would require knowledge about the mass of the glove and the acceleration of the glove. But no information about the glove is given. By Newton's 3rd law, the force exerted by the ball on the glove is equal and opposite to the force exerted by the glove on the ball. So calculate the average force on the ball, and then take the opposite of that result to find the average force on the glove. The average force on the ball is its mass times its average acceleration. Use Eq. 2-11c to find the acceleration of the ball, with $v = 0$, $v_0 = 35.0\,\mathrm{m/s}$, and $x - x_0 = 0.110\ \mathrm{m}$. The initial direction of the ball is the positive direction.

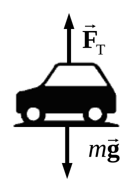
$$a_{avg} = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (35.0\,\mathrm{m/s})^2}{2(0.110\ \mathrm{m})} = -5568\ \mathrm{m/s^2}$$

$$F_{avg} = ma_{avg} = (0.140\ \mathrm{kg})(-5568\ \mathrm{m/s^2}) = \boxed{-7.80\times10^2\,\mathrm{N}}$$

Thus the average force on the glove was 780 N, in the direction of the initial velocity of the ball.

10. (II) How much tension must a rope withstand if it is used to accelerate a 1200-kg car vertically upward at $0.80\,\mathrm{m/s^2}$?

10. Choose up to be the positive direction. Write Newton's 2nd law for the vertical direction, and solve for the tension force.

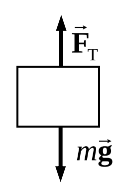


$$\sum F = F_T - mg = ma \quad \rightarrow F_T = m(g + a)$$

$$F_T = (1200\ \mathrm{kg})(9.80\,\mathrm{m/s^2} + 0.80\,\mathrm{m/s^2}) = \boxed{1.3\times10^4\,\mathrm{N}}$$

13. (II) An elevator (mass 4850 kg) is to be designed so that the maximum acceleration is 0.0680*g*. What are the maximum and minimum forces the motor should exert on the supporting cable?

13. In both cases, a free-body diagram for the elevator would look like the adjacent diagram. Choose up to be the positive direction. To find the MAXIMUM tension, assume that the acceleration is up. Write Newton's 2nd law for the elevator.



$$\sum F = ma = F_T - mg \quad \rightarrow$$

$$F_T = ma + mg = m(a + g) = m(0.0680g + g) = (4850\ \mathrm{kg})(1.0680)(9.80\,\mathrm{m/s^2})$$

$$= \boxed{5.08\times10^4\,\mathrm{N}}$$

To find the MINIMUM tension, assume that the acceleration is down. Then Newton's 2nd law for the elevator becomes

$$\sum F = ma = F_T - mg \quad \rightarrow \quad F_T = ma + mg = m(a + g) = m(-0.0680g + g)$$

$$= (4850\ \mathrm{kg})(0.9320)(9.80\,\mathrm{m/s^2}) = \boxed{4.43\times10^4\,\mathrm{N}}$$

14. (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. If the thief were to hang motionless on the sheets, or descend at a constant speed, the sheets would not support him, because they would have to support the full 75 kg. But if he descends with an acceleration, the sheets will not have to support the total mass. A free-body diagram of the thief in descent is shown. If the sheets can support a mass of 58 kg, then the tension force that the sheets can exert is $F_T = (58\text{ kg})(9.8\,\text{m/s}^2) = 570\text{ N}$. Assume that is the tension in the sheets. Then write Newton's 2nd law for the thief, taking the upward direction to be positive.

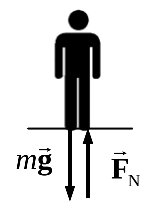
$$\sum F = F_T - mg = ma \;\rightarrow\; a = \frac{F_T - mg}{m} = \frac{570\text{ N} - (75\text{ kg})(9.80\,\text{m/s}^2)}{75\text{ kg}} = -2.2\,\text{m/s}^2$$

The negative sign shows that the acceleration is downward.

If the thief descends with an acceleration of 2.2 m/s^2 or greater, the sheets will support his descent.

15. (II) A person stands on a bathroom scale in a motionless elevator. When the elevator begins to move, the scale briefly reads only 0.75 of the person's regular weight. Calculate the acceleration of the elevator, and find the direction of acceleration.

15. There will be two forces on the person – their weight, and the normal force of the scales pushing up on the person. A free-body diagram for the person is shown. Choose up to be the positive direction, and use Newton's 2nd law to find the acceleration.



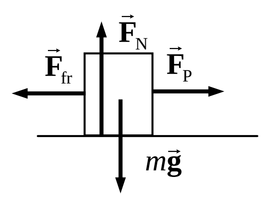
$$\sum F = F_N - mg = ma \;\rightarrow\; 0.75mg - mg = ma \;\rightarrow$$

$$a = -0.25g = -0.25(9.8\,\text{m/s}^2) = \boxed{-2.5\,\text{m/s}^2}$$

Due to the sign of the result, the direction of the acceleration is $\boxed{\text{down}}$. Thus the elevator must have started to move down since it had been motionless.

36. (I) If the coefficient of kinetic friction between a 35-kg crate and the floor is 0.30, what horizontal force is required to move the crate at a steady speed across the floor? What horizontal force is required if μ_k is zero?

36. A free-body diagram for the crate is shown. The crate does not accelerate vertically, and so $F_N = mg$. The crate does not accelerate horizontally, and so $F_P = F_{fr}$. Putting this together, we have

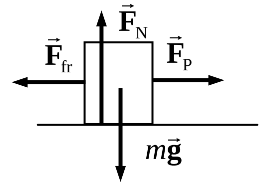


$$F_P = F_{fr} = \mu_k F_N = \mu_k mg = (0.30)(35\text{ kg})(9.8\,\text{m/s}^2) = 103 = \boxed{1.0\times10^2\text{ N}}$$

If the coefficient of kinetic friction is zero, then the horizontal force required is $\boxed{0\text{ N}}$, since there is no friction to counteract. Of course, it would take a force to START the crate moving, but once it was moving, no further horizontal force would be necessary to maintain the motion.

37. (I) A force of 48.0 N is required to start a 5.0-kg box moving across a horizontal concrete floor. (*a*) What is the coefficient of static friction between the box and the floor? (*b*) If the 48.0-N force continues, the box accelerates at $0.70\,\text{m/s}^2$. What is the coefficient of kinetic friction?

$\boxed{37.}$ A free-body diagram for the box is shown. Since the box does not accelerate vertically, $F_N = mg$



(*a*) To start the box moving, the pulling force must just overcome the force of static friction, and that means the force of static friction will reach its maximum value of $F_{fr} = \mu_s F_N$. Thus we have for the starting motion,

$$F_P = F_{fr} = \mu_s F_N = \mu_s mg \;\rightarrow\; \mu_s = \frac{F_P}{mg} = \frac{48.0\text{ N}}{(5.0\text{ kg})(9.8\,\text{m/s}^2)} = \boxed{0.98}$$

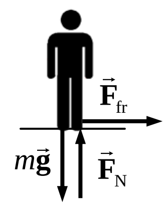
(*b*) The same force diagram applies, but now the friction is kinetic friction, and the pulling force is
NOT equal to the frictional force, since the box is accelerating to the right.

$$\sum F = F_P - F_{fr} = ma \;\rightarrow\; F_P - \mu_k F_N = ma \;\rightarrow\; F_P - \mu_k mg = ma \;\rightarrow$$

$$\mu_k = \frac{F_P - ma}{mg} = \frac{48.0\text{ N} - (5.0\text{ kg})(0.70\,\text{m/s}^2)}{(5.0\text{ kg})(9.8\,\text{m/s}^2)} = \boxed{0.91}$$

38. (I) Suppose that you are standing on a train accelerating at 0.20*g*. What minimum coefficient of static friction must exist between your feet and the floor if you are not to slide?

38. A free-body diagram for you as you stand on the train is shown. You do not accelerate vertically, and so $F_N = mg$. The maximum static frictional force is $\mu_s F_N$, and that must be greater than or equal to the force needed to accelerate you.

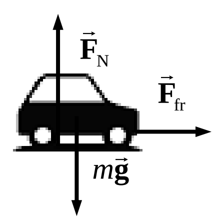


$$F_{fr} \ge ma \;\rightarrow\; \mu_s F_N \ge ma \;\rightarrow\; \mu_s mg \ge ma \;\rightarrow\; \mu_s \ge a/g = 0.20g/g = \boxed{0.20}$$

The static coefficient of friction must be at least 0.20 for you to not slide.

44. (II) Drag-race tires in contact with an asphalt surface have a very high coefficient of static friction. Assuming a constant acceleration and no slipping of tires, estimate the coefficient of static friction needed for a drag racer to cover 1.0 km in 12 s, starting from rest.

44. Assume that the static frictional force is the only force accelerating the racer. Then consider the free-body diagram for the racer as shown. It is apparent that the normal is equal to the weight, since there is no vertical acceleration. It is also assumed that the static frictional force is at its maximum. Thus



$$F_f = ma \;\rightarrow\; \mu_s mg = ma \;\rightarrow\; \mu_s = a/g$$

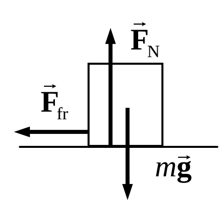
The acceleration of the racer can be calculated from Eq. 2-11b, with an initial speed of 0.

$$x - x_0 = v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; a = 2(x - x_0)/t^2$$

$$\mu_s = \frac{a}{g} = \frac{2(x - x_0)}{gt^2} = \frac{2(1000\text{ m})}{(9.8\,\text{m/s}^2)(12\text{ sec})^2} = \boxed{1.4}$$

47. (II) A box is given a push so that it slides across the floor. How far will it go, given that the coefficient of kinetic friction is 0.20 and the push imparts an initial speed of $4.0\,\text{m/s}$?

47. A free-body diagram for the box is shown, assuming that it is moving to the right. The "push" is not shown on the free-body diagram because as soon as the box moves away from the source of the pushing force, the push is no longer applied to the box. It is apparent from the diagram that $F_N = mg$ for the vertical direction. We write Newton's 2nd law for the horizontal direction, with positive to the right, to find the acceleration of the box.



$$\sum F_x = -F_{\text{fr}} = ma \quad \rightarrow \quad ma = -\mu_k F_{\text{N}} = -\mu_k mg \quad \rightarrow$$
$$a = -\mu_k g = -0.2\left(9.8\,\text{m/s}^2\right) = -1.96\,\text{m/s}^2$$

Eq. 2-11c can be used to find the distance that the box moves before stopping. The initial speed is 4.0 m/s, and the final speed will be 0.

$$v^2 - v_0^2 = 2a\left(x - x_0\right) \quad \rightarrow \quad x - x_0 = \frac{v^2 - v_0^2}{2a} = \frac{0 - \left(4.0\,\text{m/s}\right)^2}{2\left(-1.96\,\text{m/s}^2\right)} = \boxed{4.1\,\text{m}}$$