

Newton's Laws

Answers and Explanations

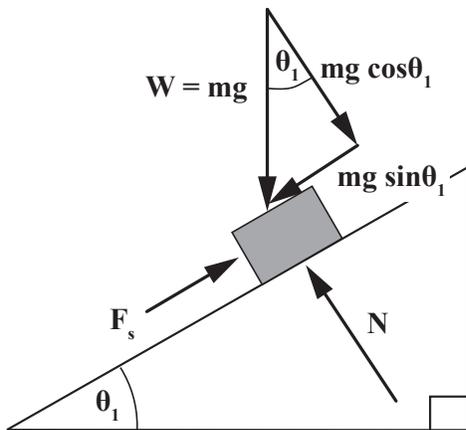
1. C

This is Newton's First Law. An object at rest stays at rest or an object in motion stays in motion with the same constant velocity unless acted upon by a net force.

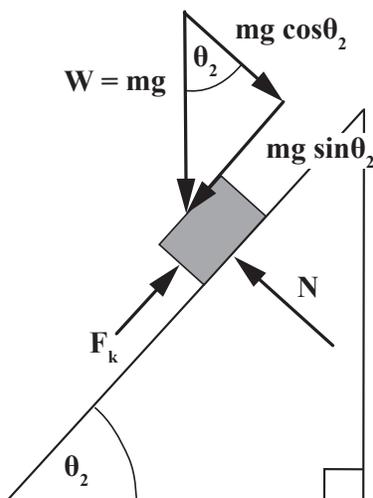
2. A

Let's look at the change in the free body diagram for the block on the inclined plane when we increase the angle of incline and it starts sliding.

Here is the block before the angle of incline is increased:



Here it is afterwards. (Note that static friction force has been replaced with kinetic friction force.)



The normal force, N , must be equal and opposite to the component of the block's weight perpendicular to the plane. As the angle of incline is increased, the component of the weight perpendicular to the plane decreases and so does the normal force.

3. A

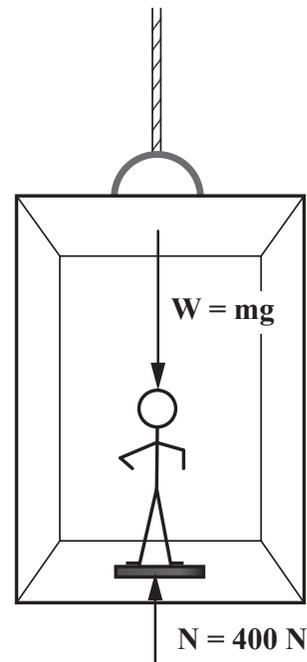
The man is undergoing acceleration due to gravity. For this to be the case, his weight is the only force acting on him. There is no normal force, so the scale registers 0 N.

4. A

In uniform circular motion, a centripetal force is the force that makes a body follow the circular path. Its direction is always perpendicular to the motion of the body and towards the center of the circle.

5. D

With this type of problem, it's a good idea to start with a free body diagram and feel your way.



Above is a free body diagram corresponding for the man on the elevator. We can derive an expression for the net force on the man from this free body diagram and use Newton's 2nd Law to relate this net force

to his acceleration. The acceleration the man undergoes is the result of this net force acting on his mass. (Note we are calling the upward direction negative because it feels clearer mentally. It's okay to do it either way as long as you're consistent.):

$$\Sigma F = ma$$

$$mg - 400N = m (6 \text{ m/s}^2)$$

$$m(10 \text{ m/s}^2) - m (6 \text{ m/s}^2) = 400N$$

$$m(4 \text{ m/s}^2) = 400N$$

$$m = 100\text{kg}$$

$$mg = 1000N$$

6. C

Through Newton's 2nd Law, we know that to determine the force on the object we need to compute the acceleration it is undergoing. The acceleration is the rate of change of the velocity:

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} = \frac{v - v_0}{\Delta t} \\ &= \frac{25 \text{ m/s} - 5 \text{ m/s}}{10 \text{ s}} = 2 \text{ m/s}^2 \end{aligned}$$

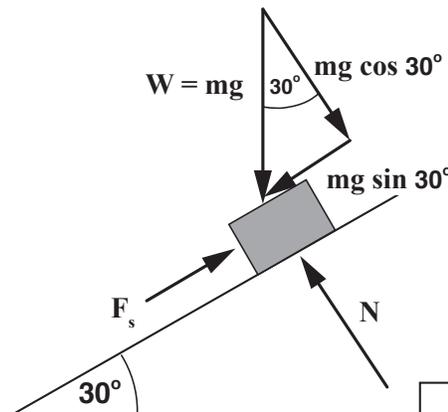
Then applying the 2nd Law:

$$\begin{aligned} F &= ma \\ &= (2 \text{ kg})(2 \text{ m/s}^2) \\ &= 4 \text{ N} \end{aligned}$$

7. D

The block will not slide if the component of the weight of the block down the plane is less than the threshold of static friction. If that case a static friction force

equal and opposite to the component of the weight down the plane will prevent sliding.



The threshold of static friction equals the product of the coefficient of static friction and the normal force. The static friction force which occurs will be less than or equal to this value.

$$F_s \leq \mu_s N$$

The normal force on the inclined plane is equal in magnitude to the component of the weight perpendicular to the plane, so the threshold of static friction can be expressed:

$$F_s \leq \mu_s mg \cos 30^\circ$$

The block won't slide then if the following weight parallel to the plane, which will be met by an equal and opposite static friction force, is less than this threshold.

$$mg \sin 30^\circ \leq \mu_s mg \cos 30^\circ$$

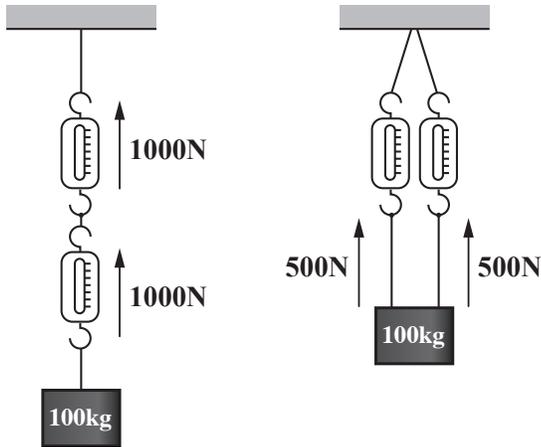
$$0.5 \leq \mu_s 0.87$$

$$\mu_s \geq 0.6$$

Both steel on steel and steel on concrete satisfy this condition. With those materials, the block won't slide.

8. C

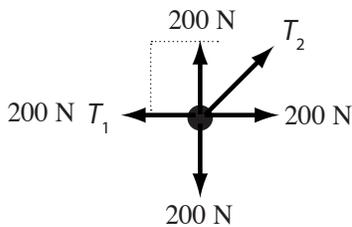
If the two spring scales were sharing the load, they would each show approximately half the weight. But if you hang one below the other, then each feels the full load.



9. C

Solving cord tension problems nearly always begins with construction of a free body diagram. Focusing on where the cords meet, we know that, because net force equals zero, the cord(s) must supply an upward force equal and opposite to the weight.

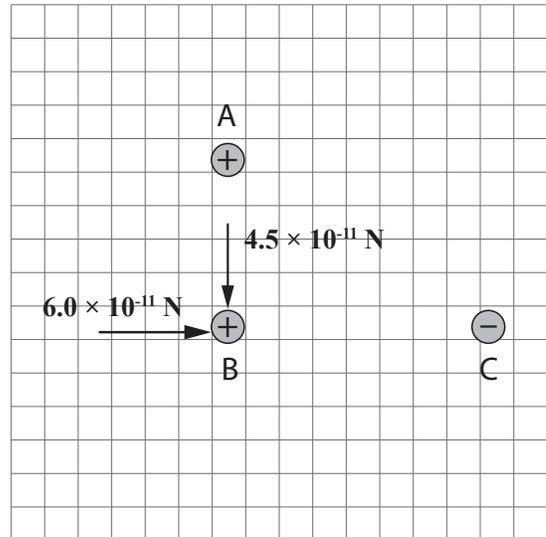
This upward force is supplied solely by the vertical component of T_2 , 200 N. And because the angle of T_2 is 45° , its horizontal and vertical components are equal. If the horizontal component of T_2 also equals 200 N, then the value of T_2 is also 200 N.



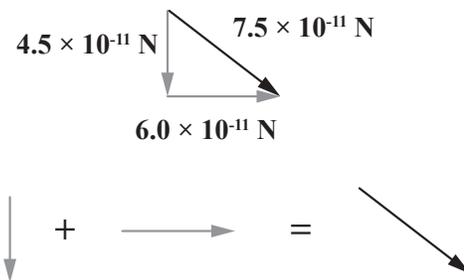
10. D

The question stem provides a bit of help in mentioning that the strength of an electric field can equivalently be thought of in terms of newtons per coulomb or volts per meter. Even though the given information is expressed in volts per meter, straightforwardly thinking about what newtons per coulomb must mean for an electric field leads you to the basic elec-

trostatics formula $F = Eq$. In other words, we simply multiply the field strengths of charges A and C at the location of charge B by the charge in coulombs of B to obtain the respective forces each exerts on B shown in the free body diagram below.



Now we perform vector addition to obtain the net force on B. The ratio of the forces are 3:4 and they are at a right angles, so vector addition will conform to the simple 3:4:5 right triangle ratio. A clue was provided in that the electric field strengths in the question stem have scientific notation coefficients 3 and 4.



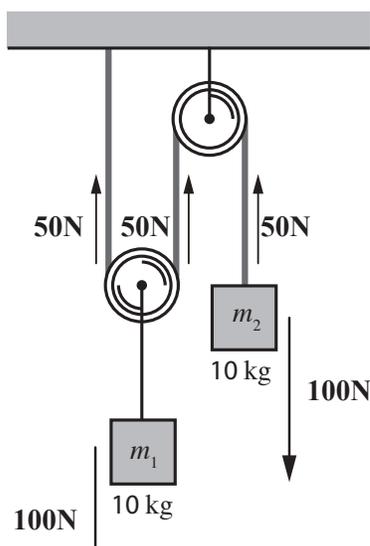
11. A

MCAT passages and question stems will often have a lot of hand-waving with scientific details. It can make an easy question seem a lot more complicated than it is. Always start with the assumption that the question is easy. In this case, this is simply Newton's 3rd Law. If an object A exerts a force on object B, then object B must exert a force of equal magnitude and opposite direction back on object A.

12. B

Sometimes there's a period of uncertainty the moment you first encounter a physics or chemistry problem. It can be like staring into the void, and you don't exactly know what to do. This is natural. It doesn't mean you're in trouble. Be patient and let your mind accommodate to the problem. Play with it a little bit. Be open to your intuition. Write down the given information. Some kinds of problems are convenient in that there are some very useful things to do while your mind adjusts to the problem. In a chemistry problem, you write molarity as moles per liter or molecular weight as grams per mole, for example. You're doing something useful and playing for a little time. Trust yourself. There's no reason to feel stress. Soon the problem will be unfolding, and then you see it.

In this type of problem, a very useful thing to do at the start is construct a free body diagram.



The tension in the rope is 50N to hold up the 10kg mass on the left. This translates as a net upward force of 50N on the mass on the right. Therefore, there is a net downward force of 50N on the 10kg mass. From Newton's 2nd Law, $\mathbf{F} = m\mathbf{a}$, we know then it is undergoing a 5 m/s^2 acceleration downward.

13. A

An object traveling on a curved path with a certain radius of curvature will experience a centripetal force equal to

$$F_r = \frac{mv^2}{r}$$

The threshold of static friction represents the maximum capacity of static friction for two surfaces. If a motion producing force exceeds this value, then sliding will occur. The threshold depends on the coefficient of static friction for the materials and the normal force.

$$F_s \leq \mu_s N$$

At the maximum speed, the centripetal force will have come to equal the threshold of static friction.

$$\frac{mv_{\max}^2}{R} = \mu_s N$$

$$v_{\max}^2 = \frac{\mu_s N R}{m}$$

The normal force between the car and the roadway will be equal in magnitude to the car's weight, mg , so we can simplify the expression:

$$N = mg$$

$$v_{\max}^2 = \mu_s g R$$

$$v_{\max} = \sqrt{\mu_s g R}$$

14. A

We have two positively charged particles with the same magnitude of charge within the same uniform electric field. They both experience the same electrostatic force, $F = Eq$. However, because the helium-3 nucleus has a smaller mass, ie. 3 amu vs 4 amu for the alpha particle, it has less inertia. By Newton's 2nd Law, $F = ma$, the same force on a smaller mass will result in a greater acceleration, so the helium-3 nucleus will strike first.