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Forces and Dynamics

Study Guide — Forces & Dynamics

Pre-med/IB-style questions on forces and Newtonian dynamics: free-body diagrams, net force, action–reaction, friction, tension/connected bodies, apparent weight (elevators/orbit), drag/terminal velocity, and circular motion (including banked curves). Difficulty increases gradually and focuses on conceptual traps.

75 items — Study Guide with Answers

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1 A block rests on a smooth (frictionless) horizontal table while a horizontal force pulls it to the right. Which set of forces should appear on the block's free-body diagram?

- A Only the weight (mg) downward
- B Weight (mg) downward and the applied force to the right
- C Weight (mg) downward, normal force upward, and the applied force to the right ✓
- D Weight (mg) downward, normal force upward, applied force to the right, and friction to the left
- E Normal force upward and friction to the left only

► **Explanation:** A free-body diagram includes only forces acting ON the block. On a frictionless table there is no friction, but there is still weight downward and a normal force upward, plus the applied pull.



2 A glider moves in a straight line at constant velocity on a frictionless air track. Which statement about the net force on the glider is correct?

- A The net force must point in the direction of motion.
- B The net force must point opposite the direction of motion.
- C The net force is zero. ✓
- D The net force equals the glider's weight.
- E The net force depends on how fast it is moving.

► **Explanation:** Constant velocity means acceleration is zero. By Newton's 2nd law ($\Sigma F = ma$), zero acceleration implies the net force is zero (even though individual forces like weight/normal may exist).



3 An object has acceleration 0. Which of the following must be true?

- A No forces act on the object.





- B Only one force acts on the object.
- C **The net (resultant) force on the object is zero. ✓**
- D The object must be at rest.
- E The object must be moving in a circle.

► **Explanation:** Acceleration 0 means $\Sigma F = 0$. Forces can still act (e.g., weight and normal), but they must balance. The object can be at rest OR moving with constant velocity.

4 A person pushes on a wall with a horizontal force. Which is the Newton's 3rd law reaction force to the push on the wall?



- A The wall's weight acting downward
- B The friction force on the person's shoes
- C **The wall pushes on the person with equal magnitude in the opposite direction ✓**
- D The normal force on the wall from the ground
- E The person's weight acting downward

► **Explanation:** Newton's 3rd law pairs are equal and opposite forces acting on different objects. If the person pushes on the wall, the wall pushes back on the person with equal magnitude and opposite direction.

5 A block is at rest on a rough incline and would slide down if friction were absent. The static friction force on the block points:



- A Down the slope
- B **Up the slope ✓**
- C Perpendicular to the slope, away from the surface
- D Perpendicular to the slope, into the surface





- E Always vertically upward

► **Explanation:** Static friction opposes the tendency of relative motion. Here gravity's component along the slope tends to pull the block down the slope, so static friction acts up the slope to prevent slipping.

6 On a frictionless surface, a constant net force F produces acceleration a on a mass m . If the net force becomes $2F$ (same m), the acceleration becomes:



- A $a/2$
- B a
- C $2a$ ✓
- D $4a$
- E It depends on the object's speed

► **Explanation:** Newton's 2nd law gives $a = F/m$. Doubling F while keeping m constant doubles the acceleration.

7 Two forces of equal magnitude F act on an object, one east and one north. The magnitude of the net force is:



- A 0
- B F
- C $\sqrt{2} F$ ✓
- D $2F$
- E $F/\sqrt{2}$

► **Explanation:** Perpendicular vectors add via Pythagoras: $|F_{\text{net}}| = \sqrt{(F^2 + F^2)} = \sqrt{2} F$. It must be larger than F but smaller than $2F$.





8 A 10 N force acts east and a 10 N force acts west on an object. The object is initially moving east. What can you conclude about its acceleration at that instant?



- A It accelerates east because it is moving east.
- B It accelerates west because friction must exist.
- C **Its acceleration is zero because the net force is zero.** ✓
- D Its acceleration equals g .
- E It must stop immediately.

► **Explanation:** Equal and opposite forces cancel, so $\Sigma F = 0$ and $a = 0$. Motion can continue at constant velocity even with zero acceleration.

9 Which statement best defines an object's weight?



- A The amount of matter in the object
- B **The gravitational force acting on the object** ✓
- C The object's resistance to acceleration
- D The object's momentum divided by time
- E The object's volume

► **Explanation:** Weight is a force caused by gravity (near Earth, approximately mg). Mass measures amount of matter/inertia and does not change with location.





10 An elevator is moving upward but slowing down. Compared with mg , the normal force on a passenger (scale reading) is:

- A Greater than mg
- B Equal to mg
- C Less than mg ✓
- D Zero
- E Negative

► **Explanation:** Moving up but slowing means acceleration is downward. From $N - mg = ma$ (up positive), a is negative, so $N < mg$. You feel lighter.



11 An elevator is moving downward but slowing down. Compared with mg , the normal force on a passenger (scale reading) is:

- A Greater than mg ✓
- B Equal to mg
- C Less than mg
- D Zero
- E It must equal the passenger's mass

► **Explanation:** Moving down but slowing means acceleration is upward. With up positive, $a > 0$, so $N - mg = ma > 0$ and $N > mg$. You feel heavier.



12 A block rests on a rough incline. The maximum possible static friction is $f_{s,max} = \mu_s N$. As the incline angle increases (same block and surface), $f_{s,max}$ generally:





- A Increases because gravity increases
- B Decreases because the normal force decreases ✓**
- C Stays constant because μ_s is constant
- D Becomes equal to mg
- E Becomes equal to $\mu_s mg$ for all angles

► **Explanation:** On an incline, $N = mg \cos \theta$. As θ increases, $\cos \theta$ decreases, so N decreases and thus $f_{s,\max} = \mu_s N$ decreases.

13 A block sits on a horizontal rough surface. If you place an extra mass on top, increasing the normal force, the maximum static friction between block and surface:



- A Increases ✓**
- B Decreases
- C Stays the same
- D Becomes zero because contact area increases
- E Depends only on speed

► **Explanation:** In the basic model, $f_{s,\max} = \mu_s N$. Adding mass increases N , so the maximum possible static friction increases.

14 A block is sliding to the right across a rough horizontal surface. The kinetic friction force on the block points:



- A To the right
- B To the left ✓**
- C Upward





- D Downward
- E Kinetic friction is zero when moving

► **Explanation:** Kinetic friction opposes the direction of relative sliding. If the block slides right relative to the surface, friction on the block acts left.

15 A heavy crate rests on a rough horizontal floor. No horizontal forces act on it. Which is true about the static friction force on the crate?



- A It equals $\mu_s N$ automatically.
- B It equals $\mu_k N$ automatically.
- C It is zero. ✓
- D It points to the left.
- E It points to the right.

► **Explanation:** Static friction adjusts to whatever value is needed to prevent slipping, up to a maximum. With no tendency to move horizontally, the required static friction is 0 (even though the maximum is not 0).

16 Two identical blocks (each mass m) are connected by a light rope on a frictionless surface. A horizontal force F pulls the right block to the right. What is the tension in the rope?



- A F
- B $F/2$ ✓
- C $2F$
- D $F/4$
- E It must be zero because the surface is frictionless





► **Explanation:** The two-block system has total mass $2m$, so $a = F/(2m)$. The left block is pulled only by tension, so $T = m a = m \cdot F/(2m) = F/2$.

17 Two blocks of masses m and $2m$ are connected by a light rope on a frictionless surface. A horizontal force F pulls the **SMALLER** block (m) to the right. What is the rope tension?



- A $F/3$
- B $F/2$
- C $2F/3$ ✓
- D F
- E $3F/2$

► **Explanation:** Total mass is $3m$, so $a = F/(3m)$. The $2m$ block is accelerated only by tension: $T = (2m)a = 2m \cdot F/(3m) = 2F/3$.

18 Two blocks of masses m and $2m$ are connected by a light rope on a frictionless surface. A horizontal force F pulls the **LARGER** block ($2m$) to the right. What is the rope tension?



- A $F/3$ ✓
- B $F/2$
- C $2F/3$
- D F
- E $3F/2$

► **Explanation:** Total mass is still $3m$, so $a = F/(3m)$. Now the smaller block m is pulled only by tension, so $T = m a = m \cdot F/(3m) = F/3$.





19 For the two-block system with masses m and $2m$ on a frictionless surface, the same external force F is applied. In which case is the rope tension larger?



- A Larger when pulling the $2m$ block
- B Larger when pulling the m block ✓
- C The same in both cases
- D Zero in both cases
- E It depends on the blocks' speeds, not masses

► **Explanation:** Pulling the m block gives $T = 2F/3$, while pulling the $2m$ block gives $T = F/3$. Same acceleration occurs, but the tension differs because it must accelerate the "other" block.

20 Two blocks m_1 and m_2 are connected by a light rope on a frictionless surface. A horizontal force F is applied to either block to pull the system. The system's acceleration magnitude is:



- A Different depending on which block is pulled
- B Always F/m_1
- C Always F/m_2
- D $F/(m_1 + m_2)$ ✓
- E Zero because internal forces cancel

► **Explanation:** Treat both blocks as one system: the net external horizontal force is F and total mass is $(m_1 + m_2)$, so $a = F/(m_1 + m_2)$. Internal tension forces cancel within the system.





21 A sled on a rough horizontal surface is pulled by a rope at an upward angle. Compared with pulling with the same tension horizontally, the normal force on the sled is:

- A Larger
- B Smaller ✓
- C Unchanged
- D Zero
- E Always equal to mg

► **Explanation:** An upward component of the pull partially supports the sled, reducing the normal force. In the basic model, smaller N usually means smaller possible friction.



22 A block rests on a table. You pull straight upward on the block with a force equal to its weight mg , and the block is not glued to the table. The normal force from the table on the block is:

- A mg
- B $2mg$
- C 0 ✓
- D $mg/2$
- E Cannot be determined without the table mass

► **Explanation:** For vertical equilibrium while in contact, $N + F_{\text{up}} - mg = 0$. With $F_{\text{up}} = mg$, this gives $N = 0$, meaning it is just about to lose contact (no support force needed).



23 An astronaut in orbit is described as "weightless" because the normal force on them is nearly zero. Which statement is correct about gravity acting on them?





- A Gravity is zero in orbit, so no forces act.
- B Gravity still acts, but the astronaut and spacecraft are in free fall together, so there is little/no support force. ✓**
- C The astronaut's mass becomes zero, so gravity cannot act.
- D Gravity reverses direction, balancing the normal force.
- E Weightless means acceleration is zero.

► **Explanation:** Weightlessness refers to zero apparent weight (support/normal force), not zero gravity. In orbit, gravity provides the centripetal acceleration while everything falls together.

24 A skydiver reaches terminal velocity while falling. Which statement is correct?



- A Drag is greater than weight, so the diver speeds up.
- B Drag equals weight, so acceleration is zero and speed is constant. ✓**
- C Weight becomes zero at terminal velocity.
- D Acceleration equals g at terminal velocity.
- E Speed must be zero at terminal velocity.

► **Explanation:** Terminal velocity means net force is zero: drag upward balances weight downward. With $\Sigma F = 0$, acceleration is zero and speed is constant (not necessarily zero).

25 A ball is thrown straight upward. During the upward motion, air resistance acts opposite the motion. Compared with g , the magnitude of the ball's acceleration is:



- A Less than g
- B Equal to g
- C Greater than g ✓**





- D Zero until it reaches the top
- E Greater than g only if the ball is heavy

► **Explanation:** While moving upward, both gravity and air resistance point downward, so the net downward force is greater than mg . Therefore the downward acceleration magnitude is greater than g .

26 A ball is dropped and falls downward through air. Before reaching terminal velocity, compared with g , the magnitude of its acceleration is typically:



- A Greater than g
- B Equal to g
- C **Less than g** ✓
- D Always zero
- E Independent of drag

► **Explanation:** When falling downward, gravity acts downward but air resistance acts upward, reducing the net downward force below mg . So acceleration magnitude is less than g (approaching 0 at terminal velocity).

27 A parachutist is moving downward but has just opened a parachute, greatly increasing drag. Which combination could be true immediately after opening?



- A Velocity downward, acceleration downward
- B **Velocity downward, acceleration upward** ✓
- C Velocity upward, acceleration downward
- D Velocity upward, acceleration upward
- E Velocity zero, acceleration zero





► **Explanation:** The parachutist can still be moving downward while experiencing an upward net force (drag > weight), giving upward acceleration that reduces the downward speed (a deceleration).

28 A car moving in a circle on a flat road suddenly encounters an icy patch (friction = 0). Immediately after reaching the ice, the car's path (relative to the ground) is best described as:



- A Continuing in the same circular path
- B Spiraling inward
- C Moving approximately in a straight line tangent to the circular path ✓**
- D Stopping immediately
- E Moving radially outward from the center

► **Explanation:** Without friction there is no centripetal force, so there is no inward acceleration. The car continues in the direction of its instantaneous velocity, which is tangent to the circle.

29 Which statement about "centripetal force" is correct?



- A It is a new kind of force that appears only in circles.
- B It is the net inward (toward-center) force required for circular motion, supplied by real forces like tension, friction, or gravity. ✓**
- C It always equals the object's weight mg .
- D It points tangentially along the motion.
- E It must be provided by a centrifugal force.

► **Explanation:** "Centripetal force" is not an extra force—it's the name for the resultant inward force (ΣF toward the center) required to produce centripetal acceleration.





30 A ball attached to a string moves in a vertical circle. At the very top of the circle, which forces act on the ball (ignoring air resistance)?



- A Only tension downward
- B Only weight downward
- C Both tension and weight downward ✓
- D Tension upward and weight downward
- E Only a horizontal centripetal force

► **Explanation:** At the top, the center is below the ball, so tension (if taut) points downward toward the center. Weight also points downward, so both act downward.

31 In the same vertical-circle motion, what is the tension in the string at the very top when the ball is moving at the minimum speed needed to keep the string just taut?



- A 0 ✓
- B mg
- C $2mg$
- D It cannot be zero at the top
- E It is always larger than mg at the top

► **Explanation:** At the minimum speed for a taut string at the top, the string is just about to go slack. Then tension is zero and weight alone supplies the needed inward (centripetal) force.

32 At the bottom of a vertical circle for a ball on a string moving fast enough to stay taut, which statement about tension T and weight mg is correct?



- A $T = mg$





- B $T < mg$
- C $T > mg$ ✓
- D $T = 0$
- E T must be negative

► **Explanation:** At the bottom, the centripetal direction is upward toward the center. Net upward force must be mv^2/r , so $T - mg = mv^2/r > 0$, giving $T > mg$.

33 A car goes over the top of a rounded hill (convex) of radius r at speed v . Ignoring air resistance, as v increases the normal force N from the road:



- A Increases
- B Decreases ✓
- C Stays equal to mg
- D Becomes larger than mg
- E Must be zero for any speed

► **Explanation:** At the top, inward (centripetal) direction is downward. The net downward force is $mg - N = mv^2/r$, so $N = mg - mv^2/r$. Increasing v increases mv^2/r , so N decreases and can reach 0 (loss of contact).

34 A car goes through the bottom of a dip (concave upward) of radius r at speed v . Ignoring air resistance, as v increases the normal force N from the road:



- A Decreases
- B Increases ✓
- C Stays equal to mg
- D Becomes zero





- E Must equal mv^2/r only

► **Explanation:** At the bottom, inward (centripetal) direction is upward. Net upward force is $N - mg = mv^2/r$, so $N = mg + mv^2/r$. Increasing v increases N .

35 Which is the best rule for drawing a free-body diagram for an object?



- A Include forces the object exerts on other things, because they affect its motion.
- B **Include only forces acting ON the object, and label their directions.** ✓
- C Include acceleration arrows as forces.
- D Include only the largest force, since smaller ones are negligible.
- E Include only weight and normal; ignore friction and tension.

► **Explanation:** A free-body diagram shows forces acting on the object of interest only. Forces the object exerts on others belong on other objects' diagrams. Acceleration is not a force.

36 A person standing on roller skates pushes a wall to the right. The person rolls to the left. The best explanation is:



- A The person's force on the wall is larger than the wall's force on the person.
- B **The wall exerts an equal and opposite force on the person, accelerating them left.** ✓
- C Gravity pulls them left because they are moving left.
- D The normal force from the ground points left.
- E The person moves left because friction always acts left.

► **Explanation:** Newton's 3rd law: the wall pushes back on the person with equal magnitude opposite direction. With low friction (roller skates), this horizontal force can accelerate the person left.





37 Two skaters at rest push off each other on frictionless ice. Skater A has smaller mass than skater B. Immediately after pushing, which is true?



- A Skater A experiences a larger force.
- B Skater B experiences a larger force.
- C They experience equal and opposite forces, but skater A has a larger acceleration.
- D They have equal accelerations because the forces are equal.
- E Skater A cannot move because it is lighter.

► **Explanation:** Forces are equal and opposite (3rd law). Accelerations are $a = F/m$, so the smaller mass has the larger acceleration for the same force.

38 A car travels at constant speed on a level road. The engine provides a forward driving force. What can you infer about resistive forces (air drag + rolling resistance)?



- A Resistive forces are zero.
- B Resistive forces are smaller than the driving force.
- C Resistive forces are larger than the driving force.
- D Resistive forces equal the driving force in magnitude (net force zero).
- E Resistive forces must be upward.

► **Explanation:** Constant speed means zero acceleration, so net force is zero. Therefore the forward driving force must be balanced by equal total resistive forces backward.





39 On a frictionless surface, a force F produces acceleration a on mass m . If both the force and the mass are doubled, the acceleration is:

- A $2a$
- B a ✓
- C $a/2$
- D $4a$
- E 0

► **Explanation:** Acceleration is $a = F/m$. If both F and m double, a becomes $(2F)/(2m) = F/m = a$.



40 A block of mass m slides on a horizontal surface with coefficient of kinetic friction μ_k . It is pulled by a constant horizontal force F and accelerates at a . If both F and m are doubled while μ_k stays the same, the new acceleration is:

- A $2a$
- B a ✓
- C $a/2$
- D 0 (it must move at constant speed)
- E It depends on the initial speed

► **Explanation:** Net force is $F - \mu_k mg$. Doubling gives $2F - \mu_k(2m)g = 2(F - \mu_k mg)$. Acceleration is $a = F_{\text{net}}/m$, so $a_{\text{new}} = [2(F - \mu_k mg)]/(2m) = (F - \mu_k mg)/m = a$.



41 A crate is pulled across a rough horizontal floor at constant speed. Which statement is correct about horizontal forces on the crate?

- A The pulling force is larger than kinetic friction, so it speeds up.





- B** The pulling force equals kinetic friction, so the net horizontal force is zero. ✓
- C Kinetic friction must be zero because it is moving at constant speed.
- D The net force must point forward because it is moving forward.
- E The net force must point backward because friction exists.

► **Explanation:** Constant speed implies zero acceleration, so the net horizontal force is zero. Therefore the forward pull must balance the backward kinetic friction.

42 A block of mass m rests at rest on a rough incline of angle θ . It does not slip. If static friction is not at its maximum, the magnitude of the static friction force is:



- A $\mu_s mg \cos \theta$
- B $\mu_k mg \cos \theta$
- C** $mg \sin \theta$ ✓
- D $mg \cos \theta$
- E 0

► **Explanation:** For equilibrium along the plane, static friction must balance the component of weight down the plane, which is $mg \sin \theta$. It only equals $\mu_s N$ at the threshold of slipping.

43 A block rests on a rough incline. The angle is increased slowly until the block is just about to start sliding. At that instant, which relation is correct?



- A $mg \sin \theta = \mu_k mg \cos \theta$
- B** $mg \sin \theta = \mu_s mg \cos \theta$ ✓
- C $mg \cos \theta = \mu_s mg \sin \theta$
- D $mg = \mu_s mg$





- E Static friction must be zero at the slipping point

► **Explanation:** At impending motion, static friction reaches its maximum: $f_{s,max} = \mu_s N = \mu_s mg \cos$. Equilibrium along the plane gives $mg \sin = f_{s,max}$, so $mg \sin = \mu_s mg \cos$ (equivalently $\tan = \mu_s$).

44 A block is pressed against a vertical wall with a horizontal force F . Coefficient of static friction between block and wall is μ_s . Which condition must be satisfied for the block to be able to remain at rest without sliding down?



- A $\mu_s F \geq mg$ ✓
- B $\mu_s mg \geq F$
- C $F \geq \mu_s mg \cos$
- D $F = mg$ always
- E The block can never be held by friction on a wall

► **Explanation:** The push provides the normal force: $N = F$. Maximum static friction is $\mu_s N = \mu_s F$ upward. To prevent sliding down, friction must be able to balance weight: $\mu_s F \geq mg$.

45 In the wall-friction setup (block pressed with force F , coefficient μ_s), if the pushing force is doubled to $2F$, the maximum possible static friction becomes:



- A Half as large
- B The same
- C Twice as large ✓
- D Four times as large
- E Zero





► **Explanation:** Maximum static friction is $f_{s,\max} = \mu_s N = \mu_s F$. Doubling F doubles N , so $f_{s,\max}$ doubles.

46 A car turns left on a flat road at constant speed. Which horizontal force acts on the passenger to make them follow the curved path?



- A A real outward (rightward) centrifugal force
- B A leftward force from the seat/door on the passenger ✓**
- C A rightward force from gravity
- D No force because speed is constant
- E A forward driving force from the engine acting directly on the passenger

► **Explanation:** To move in a curve, the passenger needs an inward (leftward) centripetal force. The car provides it via contact forces (seat/door) pushing the passenger toward the center of the turn.

47 A road is banked with the outer edge higher. A car drives around the curve slower than the "no-friction design speed." If friction is present, the friction force on the tires points:



- A Down the slope (toward the inner lower edge)
- B Up the slope (toward the outer higher edge) ✓**
- C Purely vertical upward
- D Purely horizontal outward
- E Friction must be zero on a banked road

► **Explanation:** At too low speed, the car tends to slide down the bank toward the inner lower edge. Static friction must oppose that tendency, so it acts up the slope.





48 A road is banked with the outer edge higher. A car drives around the curve faster than the "no-friction design speed." If friction is present, the friction force on the tires points:

- A Up the slope (toward the outer higher edge)
- B Down the slope (toward the inner lower edge) ✓**
- C Purely vertical downward
- D Purely horizontal inward
- E Friction must reverse gravity

► **Explanation:** At too high speed, the car tends to slide up the bank toward the outer higher edge. Static friction opposes that tendency, so it acts down the slope.



49 In uniform circular motion, velocity is tangent to the path. The acceleration is:

- A Tangent to the path
- B Radially outward
- C Radially inward (toward the center) ✓**
- D Always zero because speed is constant
- E Always upward

► **Explanation:** Even with constant speed, the velocity direction changes, so acceleration is nonzero. In uniform circular motion it points toward the center (centripetal acceleration).



50 At some instant, the net force on an object is perpendicular to its velocity. At that instant, the object's speed is:

- A Increasing





- B Decreasing
- C Momentarily not changing (only direction changes at that instant) ✓**
- D Becoming zero
- E Impossible to determine

► **Explanation:** The instantaneous rate of change of kinetic energy depends on power: $P = F \cdot v$. If $F \perp v$, then $F \cdot v = 0$, so kinetic energy (and thus speed) is not changing at that instant, though direction can change.

51 In uniform circular motion, why does the centripetal force not change the object's kinetic energy?



- A Because centripetal force is zero
- B Because centripetal force is always parallel to velocity
- C Because centripetal force is perpendicular to the velocity, so it does no work ✓**
- D Because gravity cancels centripetal force
- E Because work is undefined for circular motion

► **Explanation:** Work depends on the component of force along displacement/velocity. In uniform circular motion, the inward force is perpendicular to the tangential velocity, so it does no work and does not change kinetic energy.

52 A block on a frictionless horizontal surface is pulled by a force of fixed magnitude F at an angle θ above the horizontal. As θ increases (keeping F constant), the horizontal acceleration:



- A Increases because the force points more upward
- B Decreases because the horizontal component $F \cos \theta$ decreases ✓**
- C Stays constant because the force magnitude is constant





- D Becomes negative
- E Becomes zero for all angles

► **Explanation:** Only the horizontal component accelerates the block horizontally. As θ increases, $\cos \theta$ decreases, so the horizontal component (and thus horizontal acceleration) decreases.

53 A block is on a frictionless horizontal surface. A force is applied straight upward (vertical). The block's horizontal acceleration is:



- A Zero ✓
- B Equal to g
- C Equal to F/m
- D Larger than F/m because there is no friction
- E Negative

► **Explanation:** A purely vertical force has no horizontal component, so it cannot produce horizontal acceleration on a frictionless horizontal surface.

54 A force of 3 N acts east and 4 N acts north on an object. What is the magnitude of the net force?



- A 1 N
- B 5 N ✓
- C 7 N
- D 12 N
- E 0 N





► **Explanation:** Perpendicular components add by Pythagoras: $\sqrt{(3^2 + 4^2)} = 5$ N. The net must be larger than 4 N but smaller than 7 N, consistent with 5 N.

55 A person of mass m stands on a scale in an elevator accelerating downward with acceleration magnitude $g/2$. Neglecting air resistance, the scale reads:



- A** $mg/2$ ✓
- B** mg
- C** $2mg$
- D** 0
- E** $mg/4$

► **Explanation:** Take upward as positive: $N - mg = ma$. Downward acceleration means $a = -g/2$, so $N = mg + m(-g/2) = mg/2$.

56 In an ideal Atwood machine, masses $2m$ and m hang on a massless rope over a frictionless pulley. The heavier mass ($2m$) moves down. The rope tension T is:



- A** $T = mg$
- B** $T = 2mg$
- C** $mg < T < 2mg$ ✓
- D** $T > 2mg$
- E** $T < mg$

► **Explanation:** For the $2m$ mass accelerating downward, tension must be less than its weight $2mg$. For the m mass accelerating upward, tension must be greater than its weight mg . So $mg < T < 2mg$.





57 A car is moving east but experiences a net force due north (e.g., a sudden sideways push). Immediately after the force begins, the car's acceleration points:

- A East
- B West
- C North ✓**
- D South
- E Along the velocity direction (east)

► **Explanation:** Acceleration points in the direction of the net force (Newton's 2nd law). It does not have to point in the direction of motion.



58 A ball is thrown horizontally (ignore air resistance). While it is in flight, which forces act on it?

- A Weight downward and a forward force
- B Weight downward and an upward normal force
- C Only weight downward ✓**
- D Weight downward and kinetic friction forward
- E No forces act because it is moving

► **Explanation:** In ideal projectile motion (no air), the only force is gravity (weight) downward. There is no continued "force of motion" forward.



59 A rocket in deep space produces a constant thrust force. As fuel burns, the rocket's mass decreases. Neglecting external forces, the rocket's acceleration magnitude will generally:

- A Decrease





- B Stay the same
- C Increase ✓**
- D Become zero
- E Reverse direction automatically

► **Explanation:** With thrust approximately constant, $a = F/m$. As m decreases, F/m increases, so acceleration increases (qualitatively).

60 Two horizontal forces act on a crate: 30 N to the right and 20 N to the left. Which is correct about the net force and acceleration?



- A Net force is 50 N right; acceleration right
- B Net force is 10 N right; acceleration right ✓**
- C Net force is 10 N left; acceleration left
- D Net force is 0; acceleration is 0
- E Acceleration depends only on speed, so cannot tell

► **Explanation:** Net force is the vector sum: 30 right – 20 left = 10 N to the right. Acceleration points in the direction of net force.

61 An object is in equilibrium under three concurrent forces (all acting at a point). Which graphical statement is correct?



- A The three forces must have equal magnitudes.
- B The three forces must be parallel.
- C If drawn head-to-tail, the three force vectors can form a closed triangle. ✓**
- D One of the forces must be the weight mg .
- E Equilibrium requires all forces to point upward.





► **Explanation:** Equilibrium means the vector sum is zero. For three forces, that means you can arrange them head-to-tail to form a closed triangle (resultant zero).

62 In the basic kinetic friction model used in many exams, the kinetic friction force magnitude is best approximated by:



- A** $\mu_k N$ ✓
- B** $\mu_s N$
- C** mg
- D** $m v$
- E** It must increase strongly with speed in all cases

► **Explanation:** The standard model gives kinetic friction magnitude $f_k = \mu_k N$. Static friction uses μ_s and adjusts up to $\mu_s N$; real friction can vary, but exams often use this simplified model.

63 In which situation is the normal force on an object on a surface guaranteed to equal its weight mg (assuming no other vertical forces)?



- A** A block at rest on an incline
- B** A person in an elevator accelerating upward
- C** **A block on a horizontal surface with no vertical acceleration** ✓
- D** A car at the top of a rounded hill
- E** A sled being pulled upward at an angle

► **Explanation:** If the surface is horizontal, there are no other vertical forces, and vertical acceleration is zero, then N must balance mg , giving $N = mg$. In many other situations, N differs from mg .





64 A person stands on a scale in an elevator with upward acceleration a (take upward as positive). Which expression best matches the scale reading N ?

- A $N = mg - ma$
- B $N = m(g + a)$ ✓**
- C $N = ma - mg$
- D $N = mg$
- E $N = m(g - a)$ for upward acceleration

► **Explanation:** Newton's 2nd law vertically: $N - mg = ma$. Rearranging gives $N = m(g + a)$ when a is upward (positive).



65 A block rests on a horizontal surface. You push downward on it with an additional force F_{down} while it remains at rest. Compared to its weight mg , the normal force from the surface is:

- A Less than mg
- B Equal to mg
- C Greater than mg ✓**
- D Zero
- E Negative

► **Explanation:** With no vertical acceleration, forces must balance: $N - mg - F_{\text{down}} = 0$, so $N = mg + F_{\text{down}}$, which is greater than mg .



66 A small block sits on top of a larger block. The larger block is pulled so the system accelerates on a horizontal surface. What sets the maximum acceleration so that the top block does not slip relative to the bottom?





- A The mass of the top block only
- B The mass of the bottom block only
- C The maximum static friction between the blocks (so $a_{\max} = \mu_s g$) ✓**
- D The speed of the blocks
- E It is always equal to g

► **Explanation:** The only horizontal force on the top block is static friction, which must equal $m_{\text{top}} a$. Since $f_{s,\max} = \mu_s m_{\text{top}} g$, slipping begins when $m_{\text{top}} a > \mu_s m_{\text{top}} g$, so $a_{\max} = \mu_s g$ (mass cancels).

67 A box rests on the flat bed of a truck that accelerates forward. If the truck's acceleration is too large for static friction, the box will start to slip relative to the truck. Relative to the truck, the box slips:



- A Forward (toward the front)
- B Backward (toward the rear) ✓**
- C Upward
- D Downward
- E It cannot slip on a horizontal surface

► **Explanation:** The truck speeds up forward, but if friction can't provide enough forward force on the box, the box keeps a lower speed (inertia). The truck moves out from under it, so it slides backward relative to the truck.

68 While the box does NOT slip on the accelerating truck bed, the static friction force on the box points:



- A Backward
- B Forward ✓**





- C Upward
- D Downward
- E Zero, because friction only acts when slipping

► **Explanation:** To accelerate forward with the truck, the box needs a net forward force. Static friction provides that forward force (up to its maximum).

69 When a bus accelerates forward suddenly, standing passengers tend to lurch backward relative to the bus mainly because:



- A A backward force from the bus pushes their bodies backward
- B Their bodies tend to keep their original state of motion (inertia) while the bus moves forward under them ✓
- C Gravity tilts backward during acceleration
- D Air resistance pushes them backward strongly
- E A centrifugal force appears in straight-line motion

► **Explanation:** Inertia (Newton's 1st law) means the passenger's body tends to remain at rest while the bus accelerates forward. Relative to the bus, they appear to move backward unless friction/contact forces accelerate them forward.

70 When a car brakes suddenly, passengers tend to lurch forward relative to the car mainly because:



- A A forward force from the brakes pulls them forward
- B Their bodies tend to keep moving forward due to inertia ✓
- C Gravity becomes stronger
- D Friction always points forward inside the car
- E Their mass decreases during braking





► **Explanation:** When the car slows, the passenger's body tends to maintain its forward velocity (Newton's 1st law). Seatbelts provide the backward force needed to decelerate them with the car.

71 A front-wheel-drive car accelerates forward on a dry road without wheel slip. What is the direction of the static friction force exerted by the road on the driven tires?



- A Forward** ✓
- B Backward
- C Upward
- D Downward
- E Zero because the tires roll without slipping

► **Explanation:** The driven tires push the road backward at the contact point (due to engine torque). By Newton's 3rd law, the road pushes the tires forward via static friction, accelerating the car forward.

72 A free (unpowered) cart wheel is pulled forward by a force applied at its axle and rolls without slipping. The direction of the static friction force exerted by the ground on the wheel is:



- A Forward
- B Backward** ✓
- C Upward
- D Downward
- E Zero for any rolling motion

► **Explanation:** A forward pull at the axle tends to translate the wheel forward without providing a clockwise torque. Static friction acting backward at the contact point provides the clockwise torque needed to spin the wheel for rolling without slipping.





73 A block is pushed up a rough incline at constant speed. Which statement about forces along the incline is correct?



- A Applied force equals $mg \sin$ only
- B Applied force equals friction only
- C Applied force equals $mg \sin +$ friction (both oppose the motion up the slope) ✓
- D Net force must point up the slope because it's moving up
- E Friction assists the motion up the slope, so it reduces the needed applied force

► **Explanation:** Constant speed means zero acceleration, so the net force along the slope is zero. Down the slope act $mg \sin$ and friction (opposing upward motion), so the applied force up the slope must balance their sum.

74 A block slides down an incline with kinetic friction. If the coefficient of kinetic friction increases (same angle), the magnitude of the acceleration down the slope:



- A Increases
- B Decreases ✓
- C Stays the same
- D Becomes exactly g
- E Becomes zero for any incline angle

► **Explanation:** Along the slope, net force is $mg \sin - f_k$, where $f_k = \mu_k mg \cos$. Increasing μ_k increases friction, reducing the net downhill force and thus reducing acceleration.





75 A car takes a flat curve where the maximum available static friction sets the maximum centripetal force. If the car's speed is doubled, by what factor must the curve radius increase to keep from skidding (same μ and mass)?

- A 2
- B 4 ✓
- C 1/2
- D 1/4
- E It does not need to change

► **Explanation:** Max centripetal force is $F_{\max} = \mu m g$. The needed centripetal force is $m v^2 / r$. To keep $m v^2 / r = \mu m g$, radius must scale with v^2 . Doubling v requires r to increase by $2^2 = 4$.

