

Physics Exam

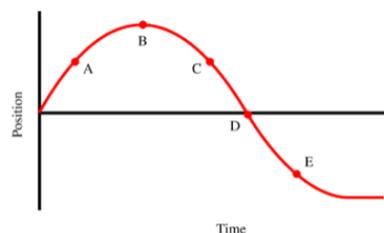
University of Houston Mathematics Contest 2026

Unless otherwise specified, please use $g = 9.80 \text{ m/s}^2$ for the acceleration due to gravity at the surface of the Earth. Let G be the universal gravitational constant. Vectors \hat{x} , \hat{y} , and \hat{z} are unit vectors along x, y, and z, respectively, in a normal Cartesian coordinate system.

Q-01) A sports car completes a quarter-mile drag race in 10.4 s. Assuming the car accelerates from rest at a constant rate, what is its speed at the finish line? Express your answer in km/h (1 mile = 1.61 km)

Q-02) The figure shows a position–time graph for a moving object. At which labeled point is the object moving with the slowest speed?

- A. A
- B. B
- C. C
- D. D
- E. E
- F. The lowest speed occurs at two of the points above.



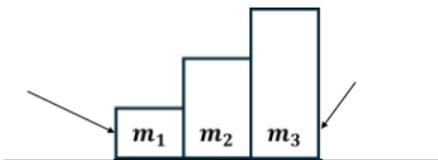
Q-03) A ball starts from rest and moves with a constant acceleration $\vec{a} = 2.97 \text{ m/s}^2 \hat{x} - 2.64 \text{ m/s}^2 \hat{y}$. What is the magnitude of its displacement after 2.50 s?

Q-04) A ball is thrown upward from the ground. A student measuring the time of flight observes that the ball reaches the top of a building 0.450 s after being launched and 1.66 s after launch on its way down. Calculate the height of the building.

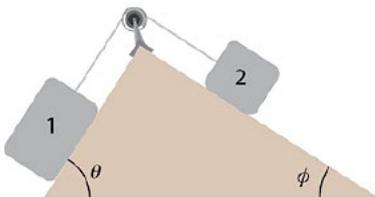
Q-05) A boat travels straight north across a river that flows east at 2.71 m/s. The boat has a speed of 6.95 m/s relative to the water. What is the boat's speed relative to the ground?

Q-06) A 75.2 kg person stands in an elevator that is moving upward and slowing down at a rate of 1.95 m/s². Calculate the person's apparent weight, defined as the normal force exerted by the elevator floor.

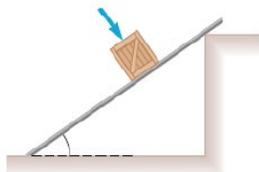
Q-07) Three boxes are initially at rest on a horizontal floor in contact with each other, as shown in the figure. A force $F_1 = 2500$ N is applied to the leftmost box at an angle of 30° below the horizontal, and a force $F_2 = 800$ N is applied to the rightmost box at an angle of 60 degrees below the horizontal, causing all three boxes to accelerate together. Given the masses of the boxes, from left to right, are $m_1 = 20.0$ kg, $m_2 = 80.0$ kg, and $m_3 = 50.0$ kg, determine the contact force exerted by box 2 on box 3.



Q-08) Two blocks are connected by a light string over a frictionless pulley, as shown. Block 1 has a mass of 5.00 kg and rests on a 45.0° incline, while block 2 has a mass of 3.00 kg and rests on a 30.0° incline. The surfaces are frictionless, and the system is released from rest. What is the magnitude of the acceleration of the blocks?

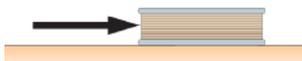


Q-09) The figure shows a crate with a mass of 2.65 kg on a ramp inclined at an angle of 35.0° . The coefficient of static friction between the crate and the ramp is 0.330. Determine the minimum magnitude of the force \vec{F} , pushing perpendicular to the ramp, required to prevent the crate from sliding down.



Q-10) A 66.1 kg skier starts down from rest and slides down a slope that is 30.0 m long and inclined at an angle of 56.1° above the horizontal. If the coefficient of kinetic friction between the skier and the slope is 0.643, how long does it take the skier to reach the ground?

Q-11) A book with a mass of 2.00 kg rests on a horizontal surface. A horizontal force is applied and gradually increased until the book begins to slide. At that point, the force is held constant, causing the book to accelerate. The coefficients of static and kinetic friction are 0.760 and 0.450, respectively. How far does the book travel in the first 1.25 s after it starts moving?

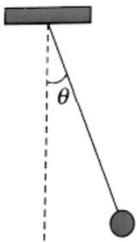


Q-12) At first, a particle is moving with a constant speed along a straight line. Then, it moves at a constant speed along a circular trajectory. What can be said about the net force acting on the particle in each case?

- A. The net force is non-zero in the first case and zero in the second case.
- B. The net force is zero in the first case but non-zero in the second case.
- C. The net force is non-zero in both cases.
- D. The net force is zero in both cases.
- E. The net force is constant in both cases.
- F. The net force is non-constant in both cases.

Q-13) NASA wants to design a centrifuge to test astronauts' reactions to accelerations equal to seven times the gravitational acceleration g . How many revolutions per minute should the centrifuge make if its radius is 12.0 m?

Q-14) A ball attached to a light string of length 1.20 m swings in a vertical plane. When the ball passes through the lowest point of its motion, its speed is 3.50 m/s. Assuming no air resistance, what angle θ in degrees does the string make with the vertical at the highest point of the motion?



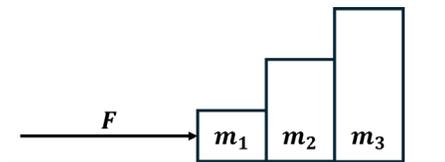
Q-15) A 602 kg elevator is moving upwards at a speed of 5.35 m/s and slows down at a rate of 0.815 m/s^2 . How much work is done by the net force on the elevator during the first 3.22 s of this deceleration?

Q-16) A woman weighing 648 N steps on a bathroom scale that contains a stiff spring. In equilibrium, the spring is compressed 0.711 cm under her weight. Find the work done on the spring during the compression.

Q-17) Two blocks, Block A (mass M) and Block B (mass $2M$), are initially at rest on a frictionless horizontal surface. Starting at $t = 0$, an identical constant horizontal force F is applied to each block. Both forces act in the same direction and continue until each block has traveled a fixed distance D . Which of the following expressions is correct:

- A. Block A has more kinetic energy than Block B because it has a higher acceleration.
- B. Block B has more kinetic energy than Block A because it has more mass.
- C. Both blocks have the same kinetic energy, but the force did more work on Block B.
- D. Both blocks have the same kinetic energy, but the power delivered to Block A was greater.
- E. Both blocks have the same kinetic energy and the same momentum.
- F. None of the above.

Q-18) Three boxes are initially at rest on a horizontal, frictionless floor and are in contact with each other, as shown in the figure. A horizontal force $F = 25$ N is applied to the leftmost box, causing all three boxes to accelerate together. The masses of the boxes, from left to right, are $m_1 = 20.0$ kg, $m_2 = 80.0$ kg, and $m_3 = 50.0$ kg. Determine the total work done on the box m_2 after the first 2.2 s after the force was applied?

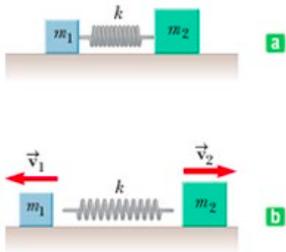


Q-19) A block is pushed up a rough incline by an applied force. The block starts from rest at the bottom and comes to rest at the top of the incline. Which of the following statements is correct?

- A. The work done by friction is equal in magnitude to the change in mechanical energy.
- B. The work done by the applied force is equal in magnitude to the change in mechanical energy.
- C. The change in mechanical energy depends only on the initial and final heights of the block.
- D. The work done by the applied force is equal to the increase in gravitational potential energy.
- E. Mechanical energy is conserved because the block starts and ends at rest.
- F. None of the above.

Q-20) A 12,000 kg car accelerates from rest to 66.0 km/h in 14.0 s. What is the average power delivered by the engine? Neglect friction and air resistance, and express your answer in megawatts (MW).

Q-21) Two objects with masses $m_1 = 0.540$ kg and $m_2 = 0.760$ kg are placed on a horizontal frictionless surface. A spring with force constant 306 N/m is placed between them as in Figure (a). The spring is massless and not attached to either object, and it is compressed by 9.48 cm. The objects are released from rest. Find the magnitude of the final velocity v_1 of mass m_1 , shown in Figure (b).



Q-22) A soccer ball of mass 0.420 kg is initially moving horizontally to the right at a speed of 18.0 m/s. The ball is then struck, after which it moves at an angle of 35.0° above the horizontal to the left with a speed of 26.0 m/s. Determine the magnitude of the average net external force, assuming the contact time is 0.0120 s.

Q-23) A bullet of mass 0.0101 kg moves horizontally toward a block of mass 2.10 kg that is initially at rest on a horizontal table. The bullet has an initial speed of 150 m/s and embeds itself in the block. After the collision, the bullet–block system slides together across the table. The coefficient of kinetic friction between the bullet–block system and the table is 0.525 . How far does the bullet–block system slide before coming to rest?

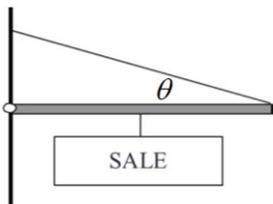
Q-24) A $6,000$ kg truck moving at 9.00 m/s collides head-on with a $2,500$ kg car moving at 14.0 m/s. After the collision, the two vehicles stick together and move as a single object. Find the kinetic energy of the cars after the collision? Express your answer in kJ.

Q-25) A flywheel rotating at 85.0 rad/s slows down at a constant rate due to friction. After 4.20 s, its angular speed has dropped to 62.0 rad/s. Calculate the total number of complete revolutions the flywheel makes during this time interval.

Q-26) Which of the following statements about rotational motion is correct?

- A. If angular momentum is conserved, then rotational kinetic energy must also be conserved.
- B. A system with zero net torque must have zero angular acceleration and zero angular velocity.
- C. If angular momentum is constant, the rotational kinetic energy must remain constant as well.
- D. If no external torque acts, a decrease in moment of inertia causes an increase in rotational kinetic energy.
- E. If the net external torque on a system is zero, then its rotational kinetic energy cannot change.
- F. Angular momentum depends only on angular speed and not on the geometry or distribution of mass.

Q-27) A rod extends horizontally from a wall. It is attached to the wall by a bolt at one end and a wire at the other, at an angle of 31.0 degrees, as shown in the figure. A "SALE" sign hangs from the center of the rod. The rod has a weight $W_{\text{rod}} = 235 \text{ N}$ and a length of 3.00 m. The sign has a weight $W_s = 65.0 \text{ N}$. Find the magnitude of the force on the bolt.



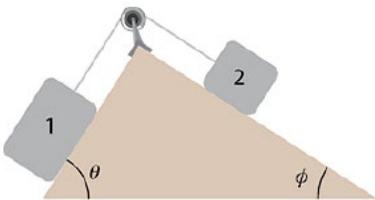
Q-28) A constant tangential force is applied to the rim of a hoop ($I_{\text{hoop}} = MR^2$) with a mass of 7.79 kg and a radius of 6.20 m. The force increases the hoop's angular velocity from 3.55 rad/s to 6.20 rad/s over a time interval of 2.50 s. Determine the magnitude of the applied force.

Q-29) Which of the following statements about rotational motion is correct?

- A. A system with a larger mass requires a greater torque to achieve the same angular acceleration as a system with a lower mass.
- B. Rotational kinetic energy is always conserved in a rotational collision, even if the bodies stick together.
- C. The moment of inertia of a rigid body is proportional only to its mass, regardless of the distribution.
- D. An object's moment of inertia cannot change unless its total mass changes.
- E. Two bodies with identical mass must have the same moment of inertia.
- F. None of the above.

Q-30) A solid 1.50 kg disk ($I_{disk} = (1/2)MR^2$) with a radius of 20.0 cm rolls without slipping across a horizontal surface. The center of mass moves with a constant velocity, and the disk rotates at a constant rate of 120 rpm. Determine the disk's total kinetic energy.

Q-31) Two blocks are connected by a light string over a frictionless pulley, as shown. Block 1 has a mass of 5.00 kg and rests on a 45.0° incline, while block 2 has a mass of 3.00 kg and rests on a 30.0° incline. The pulley is a uniform solid disk ($I_{disk} = (1/2)MR^2$) with a mass of 2.00 kg and a radius of 0.100 m. What is the magnitude of the acceleration of the blocks? Assuming the surfaces are frictionless and the string does not slip on the pulley, determine the magnitude of the acceleration of the blocks after the system is released from rest.



Q-32) A ceiling fan is modeled as a central cylindrical disk with four thin rods (blades) extending radially from its center. The disk has a mass of 2.40 kg and a radius of 0.200 m. Each of the four rods has a mass of 0.850 kg and a length of 0.640 m. If a constant motor torque of 1.50 N·m is applied, determine the resulting angular acceleration of the fan ($I_{disk} = (1/2)MR^2$, $I_{rod,end} = (1/3)MR^2$, $I_{rod,center} = (1/12)MR^2$).



Q-33) An ice skater is spinning at an angular speed of 0.813 rev/s with her arms extended. Her moment of inertia is $2.34 \text{ kg}\cdot\text{m}^2$ with her arms extended and $0.783 \text{ kg}\cdot\text{m}^2$ with her arms close to her body. What is her angular velocity, in revolutions per second, after she pulls in her arms?

Q-34) An object attached to the end of a spring oscillates in simple harmonic motion. If the amplitude of oscillation is doubled, how are the oscillation period T and the object's maximum speed v_{max} affected?

- A. T and v_{max} both remain the same.
- B. T and v_{max} both double.
- C. T remains the same and v_{max} doubles.
- D. T remains the same and v_{max} increases by a factor of the square root of 2.
- E. T doubles and v_{max} remains the same.
- F. None of the above.

Q-35) A 6.18 kg cart is attached to a horizontal spring with a spring constant of 400 N/m on a frictionless air track. What is the length of a simple pendulum that has the same period as the cart–spring system?

Q-36) A block with a mass of 11.0 kg is attached to a massless spring with a spring constant of 518 N/m. The system rests on a horizontal, frictionless surface. The block is released from rest when the spring is compressed by 11.0 cm. How much time, in seconds, does it take for the block to reach its maximum kinetic energy for the first time?

Q-37) Water is stored in a tank open to the atmosphere (101 kPa). The tank is 12.0 m deep and is completely full. What is the gauge pressure at the bottom of the tank? Express your answer in kPa.

Q-38) Which of the following statements is not true?

- A. The pressure at a particular depth depends on the shape of the container.
- B. The pressure increases as the depth increases.
- C. The pressure is the same in all directions at one point.
- D. The pressure in a liquid is due to the weight of the column of the liquid above.
- E. Pressure exists everywhere in a liquid.
- F. None of the above.

Q-39) A hydraulic lift consists of two pistons. Piston A has a radius of 15.0 cm, and Piston B has a radius of 1.50 m. A 1500 kg car rests on Piston B. Determine the minimum force that must be applied to Piston A to support the car in equilibrium.

Q-40) A bear with a mass of 610 kg is floating in a pool filled with an unknown liquid. One-third of the bear's volume is above the liquid's surface. Assuming the bear's density is 935 kg/m^3 , determine the density of the liquid.