Physics Exam

University of Houston Mathematics Contest 2025

Exam Instructions: Unless otherwise specified, please use g as the acceleration due to gravity at the surface of the Earth. To simplify calculations, use $g = 10\ m/s^2$. Let G be the universal gravitational constant.

Q-01) A student has 50.0 minutes to travel from home to school, covering a distance of 10.0 miles. During the first 20.0 minutes of the trip, the student maintains an average speed of 12.0 mi/h. What average speed must the student maintain for the remainder of the trip to arrive at school on time?

A. 4 mi/h

B. 6 mi/h

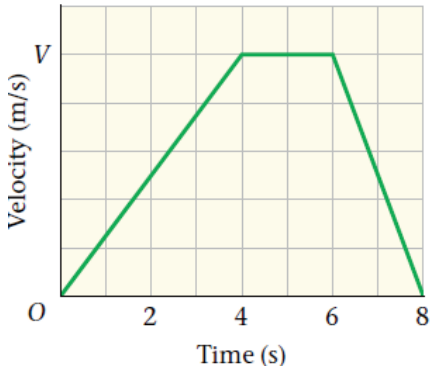
C. 8 mi/h

D. 12 mi/h

E. 16 mi/h

F. None of the above

Q-02) The velocity-time graph shows the velocity of a car over an 8-second interval. The car accelerates from rest, reaching a maximum velocity of 50 m/s at t = 4 seconds. Calculate the total displacement of the 8-second interval.



A. 200 m

B. 250 m

C. 300 m

D. 350 m

E. 400 m

F. None of the above

Q-03) A soccer ball is kicked at an angle of 45 degrees above the horizontal. The ball reaches a maximum height of 5.0 m. How far from the kicker does the ball land?

A. 10 m

B. 15 m

C. 20 m

D. 25 m

E. 30 m

F. None of the above

Q-04) A hot-air balloon ascends vertically at a constant speed of 20 m/s. During the ascent, a sandbag is dropped over the side and lands on the ground at a speed of 60 m/s. How long did it take for the bag to hit the ground after being dropped?

A. 2.0 s

B. 4.0 s

C. 6.0 s

D. 8.0 s

E. 10 s

F. None of the above

Q-05) A solid sphere is suspended from a spring scale. When the sphere is in the air, the scale reads 50 N. What does the scale read when the sphere is submerged in a liquid? The sphere's volume is 5.0×10^{-3} m^3, and the liquid density is 900 kg/m^3.

A. 5.0 N

B. 10 N

C. 15 N

D. 20 N

E. 25 N

F. None of the above

Q-06) An arrow is shot from a height of 2.0 m with an initial velocity of 40 m/s at an angle of 60 degrees above the horizontal toward a cliff 12.0 m tall. The arrow reaches its maximum height and then descends, landing on the top edge of the cliff. What is the arrow's speed just before it reaches the cliff?

A. 30 m/s

B. $30\sqrt{10}$ m/s

C. $10\sqrt{2}$ m/s

D. $30\sqrt{3}$ m/s

E. $10\sqrt{14}$ m/s

F. None of the above

Q-07) You press a book against the wall with your hand. As you get tired, you exert less force, but the book remains in the same spot on the wall. Which of the following statements about the forces acting on the book is true?

A. The force of friction decreases.

B. The force of friction increases.

C. The maximum force of static friction does not change

D. The maximum force of static friction increases

E. The force of gravity changes

F. None of the above

Q-08) A 40 kg block is held at rest on an inclined plane and then released. The angle of the incline is 60 degrees, and the coefficients of static and kinetic friction between the block and the surface are 0.800 and 0.600 respectively. Determine the force of friction acting on the block.

A. 120 N

B. 160 N

C. 200 N

D. $200\sqrt{3/2}$ N

E. $200\sqrt{3}$ N

F. None of the above

Q-09) A physics student, who weighs $w_1 = g \cdot m_1$, hangs from an ideal spring and stretches it by a distance d_1 from its equilibrium position. How far would a second student, weighing $w_2 = g \cdot m_2$, stretch the same spring from its equilibrium position?

A. $(d_1 \cdot m_1) / m_2$

B. $(d_1 \cdot m_2) / m_1$

C. $(d_1 \cdot m_1) / (g \cdot m_2)$

D. $(d_1 \cdot m_2) / (g \cdot m_1)$

E. $g \cdot (d_1 \cdot m_1) / m_2$

F. None of the above

Q-10) An 800 kg race car approaches a turn with a radius of curvature of 40 m. What is the highest speed at which the car can take the turn without sliding? The racing tires have friction coefficients of $\mu_s = 1.5$ and $\mu_k = 0.80$.

A. $8\sqrt{5}$ m/s

B. $10\sqrt{6}$ m/s

C. 16 m/s

D. 20 m/s

E. 48 m/s

F. None of the above

Q-11) A physics student is riding on a Ferris wheel, moving in a vertical circle at a constant speed. Which of the following statements about the forces acting on the student is correct?

A. The net force on the student is zero.

B. The normal force from the seat never equals the student's weight.

C. The normal force from the seat is constant throughout the motion.

D. The student's weight is greater at the bottom of the trajectory than at the top.

E. The acceleration is constant.

F. None of the above.

Q-12) What speed must a satellite have to orbit the Earth at a height equal to the Earth's radius? Express your answer in terms of the satellite's mass (m), the Earth's mass (M), the Earth's radius (R), and the gravitational constant (G).

A. $\sqrt{\frac{Gm}{R}}$

B. $\sqrt{\frac{GM}{R}}$

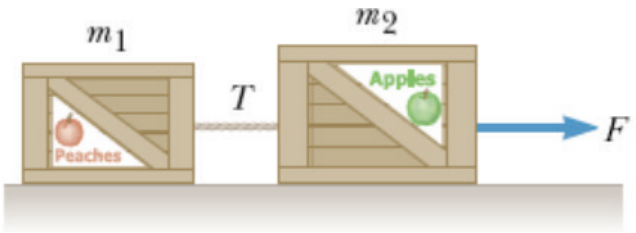
C. $\sqrt{\frac{GmM}{R}}$

D. $\sqrt{\frac{Gm}{2R}}$

E. $\sqrt{\frac{GM}{2R}}$

F. None of the above

Q-13) Two boxes, one with a mass m_1 and the other with a mass m_2, are connected by a rope, as shown in the diagram. The coefficient of kinetic friction between the boxes and the floor is μ_k. When a horizontal force F (in Newtons) is applied to the second box, the two boxes accelerate together. Derive an expression for the tension in the rope.



A. $\left(\frac{m_1}{m_1+m_2}\right)F$

B. $\left(\frac{m_1}{m_1+m_2}\right)F + \mu_k m_1 g$

C. $\left(\frac{m_1}{m_1+m_2}\right)F + \mu_k m_2 g$

D. $\left(\frac{m_1}{m_1+m_2}\right)F + \mu_k (m_1+m_2) g$

E. $\left(\frac{m_1}{m_1+m_2}\right)F + \mu_k (m_1-m_2) g$

F. None of the above

Q-14) A car with a mass of 800 kg is traveling at a speed of 20 m/s when the driver applies the brakes. The car skids for 5.0 s before coming to rest. Assuming constant deceleration, calculate the coefficient of static friction between the tires and the road.

A. 0.3

B. 0.4

C. 0.5

D. 0.6

E. 0.7

F. None of the above

Q-15) Two satellites are in circular orbits around the Earth. Satellite A is at an altitude equal to the Earth's radius, while Satellite B is at an altitude equal to three times the Earth's radius. What is the ratio of their orbital periods, T_A/T_B?

A. 2

B. 3

C. 4

D. 8

E. 9

F. None of the above

Q-16) Which of the following forces is doing zero work?

A. The gravitational force on an apple in free fall.

B. The normal force on a person in an elevator when it is moving up at constant speed.

C. The force of a spring as it is compressed at constant speed.

D. The net force on a block moving along an inclined surface at a constant speed.

E. The weight of a block moving along an inclined surface at a constant speed.

F. None of the above

Q-17) A 2.0 kg block is initially at rest at a height h above the equilibrium position of a vertical spring fixed to the floor. The spring has a spring constant k = 500 N/m. When the block is released and collides with the spring, the spring is compressed at a distance of d= 20 cm before the block comes to rest. Find the initial height h. Ignore any nonconservative force.

A. 10 cm

B. 20 cm

C. 30 cm

D. 40 cm

E. 50 cm

F. None of the above

Q-18) A 5.0 kg cart moves on a rollercoaster at a speed of 2.0 m/s and slides down on a frictionless track. By the time the cart reaches the ground, gravity has done 100 J of work on it. Determine the speed of the cart on the ground.

A. 4.0 m/s

B. 5.0 m/s

C. 6.0 m/s

D. $\sqrt{44}$ m/s

E. $\sqrt{50}$ m/s

F. None of the above

Q-19) An object of mass 5.0 kg slides horizontally across a rough surface and comes to rest after traveling 8.0 m. If the coefficient of kinetic friction between the object and the surface is 0.20, what was the initial speed of the object?

A. 2.0 m/s

B. $\sqrt{8.0}$ m/s

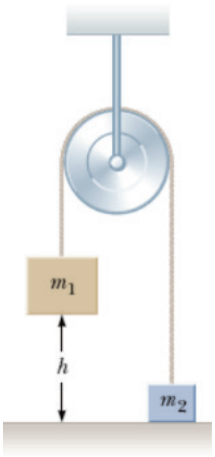
C. 4.0 m/s

D. $\sqrt{32}$ m/s

E. 6.0 m/s

F. None of the above

Q-20) Two blocks are connected by a light string that passes over a frictionless pulley, as shown in the figure. The masses of the blocks are m_1 = 3.0 kg and m_2 = 2.0 kg. The blocks are released from rest, m_1 is at the height h = 2.0 m above the ground, while m_2 starts on the ground. The system accelerates as block m_1 falls. What is the speed of the blocks just before m_1 hits the floor?



A. 2.0 m/s

B. $\sqrt{8.0}$ m/s

C. 4.0 m/s

D. $\sqrt{18}$ m/s

E. 6.0 m/s

F. None of the above

Q-21) A 0.2 kg baseball is thrown into a lake. When it enters the water, the ball's speed is 20 m/s. Due to the drag force of the water, its speed decreases to 10 m/s after descending a vertical distance of 5 m. If only the drag force of the water and gravity act on the ball, find the work done by the drag force of the water.

A. -10 J

B. -20 J

C. -30 J

D. -40 J

E. -50 J

F. None of the above

Q-22) Car 1 has twice the mass of car 2, but both cars have the same kinetic energy. How does the linear momentum of car 1 compare to that of car 2?

A. $p_1 = p_2$

B. $p_1 = 2p_2$

C. $p_1 = \sqrt{2}p_2$

D. $p_1 = \frac{1}{2}p_2$

E. $p_1 = \frac{1}{\sqrt{2}}p_2$

F. None of the above

Q-23) An ice skater with a mass of 60 kg is initially at rest on a frictionless ice rink. The skater throws a ball of mass 2.0 kg at a speed of 10 m/s. With what speed does she recoil backward as a result of throwing the ball?

A. 0.20 m/s

B. 0.25 m/s

C. 0.33 m/s

D. 0.40 m/s

E. 0.45 m/s

F. None of the above

Q-24) A 10-gram bullet strikes and embeds itself in a 0.5 kg block that rests on a frictionless, horizontal surface and is attached to a spring with a spring constant of 300 N/m. The impact compresses the spring by 0.20 m. What was the initial speed of the bullet?

A. $20\sqrt{153}$ m/s

B. $20\sqrt{53}$ m/s

C. $200\sqrt{3}$ m/s

D. $20\sqrt{3}$ m/s

E. $20\sqrt{53}$ m/s

F. None of the above

Q-25) A balloon moving upwards with constant acceleration is filled with a gas with a density of 0.80 kg/m^3. The density of air is 1.2 kg/m^3. What is the acceleration of the balloon?

A. 1.0 m/s^2

B. 2.0 m/s^2

C. 3.0 m/s^2

D. 4.0 m/s^2

E. 5.0 m/s^2

F. None of the above

Q-26) A dumbbell-shaped object consists of a 1.0 kg rod (1/2) m long and two (1/3) kg masses attached to each end. What is the moment of inertia of the dumbbell when rotating about its center? Assume the two masses are point particles, and the inertia of the rod rotating about its center is given by (1/12)MR^2, where M is the mass of the rod, and R is its length.

A. (1/4) kg m^2

B. (1/8) kg m^2

C. (1/12) kg m^2

D. (1/16) kg m^2

E.(1/24) kg m^2

F. None of the above

Q-27) A 10 m long ladder leans against a wall so that the bottom of the ladder makes an angle of 60 degrees with the floor. The coefficient of static friction between the floor and the ladder is 0.8, and friction at the top of the ladder against the wall is negligible. The ladder has a mass of 20 kg and is uniform along its length. Also, a worker with a mass of 60 kg stands exactly halfway up the ladder. What is the normal force exerted on the ladder by the wall?

A. $200\sqrt{3}$ N

B. $400\sqrt{3}$ N

C. $200/\sqrt{3}$ N

D. $400/\sqrt{3}$ N

E. $300\sqrt{3}$ N

F. None of the above

Q-28) - A large wind turbine that generates electricity is initially rotating with an angular speed of 5.0 rad/s. Workers apply a brake to slow the turbine down, where the resulting magnitude of angular acceleration is 0.10 rad/s^2. How many complete revolutions does the turbine make within one minute after the brake is applied? (Use the approximate value $\pi = 3.0$).

A. 14

B. 16

C. 18

D. 20

E. 22

F. None of the above

Q-29) A disk with a mass of 2.0 kg starts from rest at a height of 3.0 m above the ground on an inclined plane. The disk rolls without slipping toward the ground. If the disk has a radius of 10 cm, what is its angular speed when it reaches the ground? The inertia of the disk about its center is given by (1/2)MR^2, where M is the mass of the disk, and R is its radius.

A. 20 rad/s

B. $20\sqrt{10}$ rad/s

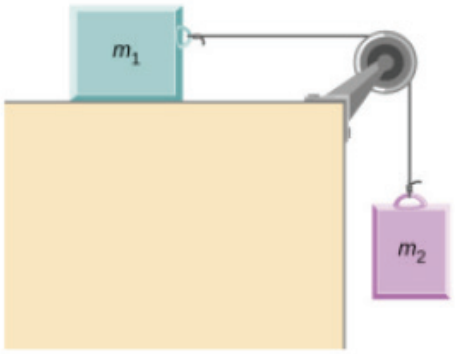
C. 40 rad/s

D. $40\sqrt{10}$ rad/s

E. 80 rad/s

F. None of the above

Q-30) A block with a mass m_1 = 2.0 kg and a block with a mass m_2 = 4.0 kg are connected by a light string that passes over a pulley, as shown in the diagram. The coefficient of kinetic friction between m_1 and the table is 0.50. The pulley has a mass of 6.0 kg, and a radius of 0.25 m. Find the acceleration of the blocks. The moment of inertia of the pulley is given by $(1/2)MR^2$, where M is the mass of the pulley, and R is its radius.



A. $\frac{1}{3}$ m/s^2

B. $\frac{2}{3}$ m/s^2

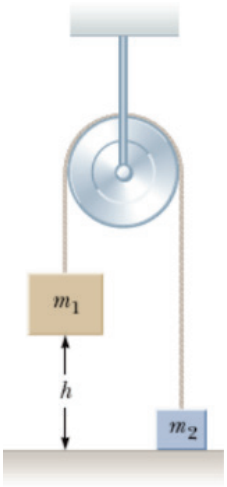
C. $\frac{5}{3}$ m/s^2

D. $\frac{8}{3}$ m/s^2

E. $\frac{10}{3}$ m/s^2

F. None of the above

Q-31) Two blocks are connected by a light string that passes over a pulley, as shown in the figure. The masses of the blocks are m_1 = 3.0 kg, m_2 = 2.0 kg, and the pulley has a mass of 6.0 kg with a radius of 0.25 m. The blocks are released from rest, with m_1 is starting at a height h = 2.0 m above the ground, while m_2 starts on the ground. The system accelerates as block m_1 falls. What is the speed of the blocks just before m_1 hits the floor? The inertia of the pulley is given by $(1/2)MR^2$, where M is the mass of the pulley, and R is its radius.



A. 1.0 m/s

B. $\sqrt{2.0}$ m/s

C. $\sqrt{3.0}$ m/s

D. 2.0 m/s

E. $\sqrt{5.0}$ m/s

F. None of the above

Q-32) A rider on a motorcycle travels at a constant speed around a circular track with a radius of 150 m. Each lap takes 20 s to complete. What is the angular momentum of the rider and motorcycle if their combined mass is 300 kg? Consider the system as a point mass.

A. 450,000 π m/s

B. 675,000 π m/s

C. 900,000 π m/s

D. 1,125,000 π m/s

E. 1,350,000 π m/s

F. None of the above

Q-33) A Ferris wheel starts at rest and acquires a rotational velocity of 10 rad/s after turning 5 rad. Find the magnitude of the angular acceleration of the wheel, assuming it is constant.

A. 10 rad/s^2

B. 50 rad/s^2

C. 100 rad/s^2

D. 500 rad/s^2

E. 1000 rad/s^2

F. None of the above

Q-34) Which of the following statements is true about torque, rotational kinetic energy, and/or angular momentum (choose only one)?

A. If the angular momentum of a system is conserved, then its rotational kinetic energy must also be conserved.

B. Two objects of equal mass and equal angular velocities can have different angular momenta.

C. An applied force can only create a torque on a system if the force is applied at the axis of rotation.

D. The torque due to an applied force will always be the same regardless of where the axis of rotation is defined.

E. Only extended rigid objects can have angular momentum, whereas point masses cannot.

F. None of the above

Q-35) A 500 g ball is thrown perpendicular to the solid door at rest at a speed of 20.0 m/s and hits 80.0 cm from the hinged side. The ball rebounds with a speed of 10.0 m/s along the same direction. What is the angular speed of the door just after the collision with the ball? The door mass is 35.0 kg, it is 3.00 m tall, 2.00 m wide, and has a moment of inertia of 20 kg rad/s^2.

A. 0.20 rad/s

B. 0.40 rad/s

C. 0.60 rad/s

D. 0.80 rad/s

E. 10.0 rad/s

F. None of the above

Q-36) A ballet dancer is spinning in the middle of a horizontal frictionless stage. Which of the following things could he change by moving parts of his body or his whole body?

A. His linear momentum

B. His mass

C. His angular momentum

D. His rotational kinetic energy

E. His translational kinetic energy

F. None of the above

Q-37) A mass of 3.0 kg is attached to a vertical spring and allowed to hang. The spring stretches 0.25 m to reach its new equilibrium position. The mass is then displaced from its new equilibrium position and undergoes simple harmonic motion when released. What is the period of the oscillations?

A. $\sqrt{\frac{\pi^2}{10}}$ s

B. $\sqrt{\frac{\pi^2}{5}}$ s

C. $\sqrt{\frac{2\pi^2}{5}}$ s

D. $\sqrt{\frac{\pi^2}{30}}$ s

E. $\sqrt{\frac{\pi^2}{15}}$ s

F. None of the above

Q-38) An oscillator consists of a 2.0 kg mass and a spring with a force constant of 400 N/m. The amplitude of the oscillator is 0.50 m. What is the maximum speed of the oscillator?

A. $\sqrt{10}$ m/s

B. 5.0 m/s

C. $\sqrt{50}$ m/s

D. $\sqrt{75}$ m/s

E. 10 m/s

F. None of the above

Q-39) A pendulum of length L oscillates on a Planet with a period of 2.5 T_E, where T_E is the period of pendulum on Earth. What is the gravitational acceleration on this planet?

A. 1/5 m/s^2

B. 2/5 m/s^2

C. 4/5 m/s^2

D. 8/5 m/s^2

E. 16/5 m/s^2

F. None of the above