Momentum and Energy Mock Exam

10 MCQ 2 FRQ - 60 MINUTES

INSTRUCTIONS

DO NOT OPEN THIS TEST UNTIL YOU ARE TOLD TO BEGIN

- Use $g = 9.8$ N/kg throughout this contest.
- Test under standard conditions, meaning that you must complete the test in 60 minutes in one sitting.
- This test contains 10 Multiple Choice Questions, and 2 Free Response Questions.
- Correct answers will be awarded the points shown; Leaving an answer blank will be awarded zero points. The amount of partial credit is up to your discretion as the grader. Our recommendation is to be more strict than necessary.
- A hand-held calculator may be used. Its memory must be cleared of data and programs. You may use only the basic functions found on a graphing calculator. Calculators may not be shared. Cell phones may not be used during the exam. You may not use any tables, books, or collections of formulas.
- The number in **red** next to each question represents the amount of points the question is worth. There is a total of 40 points on this exam.
- While some problems may be solvable using Kinematics techniques, **it is generally advised to use theorems and equations pertaining to Momentum and Energy** to solve all problems. This is the sole focus of this unit and the AP Physics Teachers will likely omit credit unless this is done.
- If you have any questions, or clarifications, please contact us at tjhsstphysicsteam@gmail.com.

The creators of this exam are (in alphabetical order):

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Good luck, and have fun! Turn the page to start the mock.

10 MCQs

[2] **Problem 1.** Two astronauts, Alice and Bob, are initially next to each other and both at rest in space. They suddenly push each other apart and, after one second, Alice is 12 m away from her starting point and Bob is 10 m away. Find the ratio of Alice's kinetic energy to Bob's kinetic energy (K_A/K_B).

A) $\frac{25}{36}$

B) $\frac{5}{6}$

C) 1

D) $\frac{6}{5}$

E) $\frac{36}{25}$

[2] **Problem 2.** A collision occurs between two masses. In each inertial reference frame, one can compute the change in total momentum $\Delta\mathbf{P}$ and the change in total kinetic energy ΔK due to the collision. Which of the following is true?

(A) $\Delta\mathbf{P}$ and ΔK do not depend on the frame.

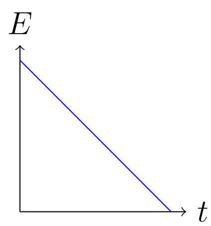
(B) $\Delta\mathbf{P}$ and ΔK do not depend on the frame for perfectly elastic collisions, but $\Delta\mathbf{P}$ may depend on the frame for inelastic collisions.

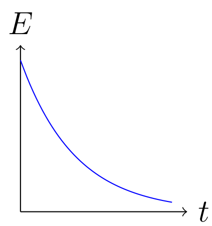
(C) $\Delta\mathbf{P}$ and ΔK do not depend on the frame for perfectly elastic collisions, but ΔK may depend on the frame for inelastic collisions.

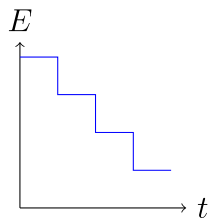
(D) $\Delta\mathbf{P}$ and ΔK do not depend on the frame for perfectly elastic collisions, but both may depend on the frame for inelastic collisions.

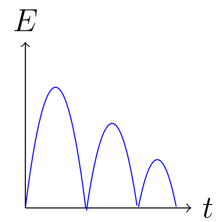
(E) $\Delta\mathbf{P}$ and ΔK do not depend on the frame for perfectly elastic collisions, but both may depend on the frame for inelastic collisions

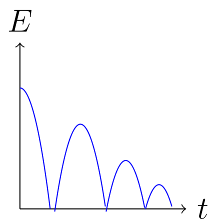
[2] **Problem 3.** A ball is dropped from a height h and bounces on the ground. The velocity of the ball after it bounces off the ground for the nth time is $v_n = \alpha v_{n-1}$, where $0 < \alpha \leq 1$. Take the system of the ball and the earth: which of the following graphs could show the mechanical energy of the system as a function of time?

(A) 

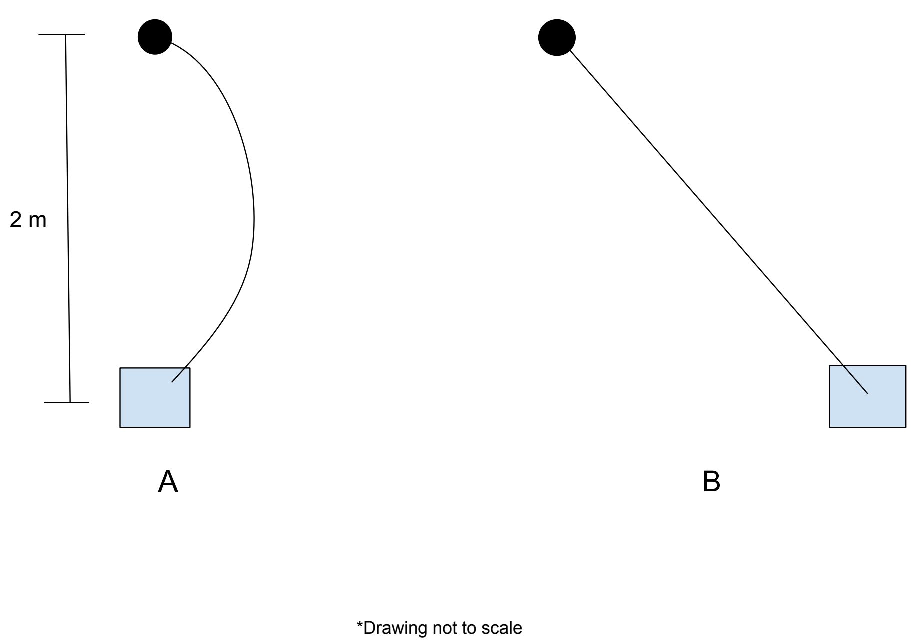
(B) 

(C) 

(D) 

(E) 

[2] **Problem 4.** A small block of mass 1 kg slides on an icy surface with a velocity of 10 m/s to the east. It is attached by a rope of length 4 meters (there is initially some slack in the rope) to a small pole as shown. At time A, the center of the block is 2 meters directly south of the pole. At time B, the rope suddenly becomes taut and does not stretch. Find the magnitude (to the nearest hundredth) and direction of the impulse the block experiences.



A) 5 Newton-seconds towards the pole

B) 5 Newton-seconds west

C) 5 Newton-seconds north-east (perpendicular to the line from block to pole)

D) 8.66 Newton-seconds towards the pole

E) 8.66 Newton-seconds west

F) 10 Newton-seconds towards the pole

G) 10 Newton-seconds west

[2] **Problem 5.** A balloon is filled with helium at the bottom of a room and floats to the ceiling. In other words, the gravitational potential energy of the balloon increased. Since mechanical energy is conserved, something else must have decreased during this process. Which of the following is the main contribution to this decrease?

A) The kinetic energy of the balloon decreased.

B) The elastic potential energy of the balloon decreased.

C) The thermal energy of the air in the balloon decreased.

D) The thermal energy of the air in the room decreased.

E) The gravitational potential energy of the air in the room decreased.

[2] **Problem 6.** A train of mass M is driving horizaontally at a velocity v. Snow falls vertically on the train at a rate of ρ kg/s. What is the power required to keep the train traveling at a constant speed v?

A) 0

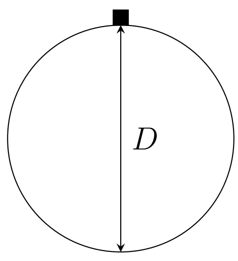
B) Mgv

C) $\frac{1}{2}Mv^2$

D) $\frac{1}{2}\rho v^2$

E) ρv^2

[2] **Problem 7.** A small bead is placed on the top of a frictionless glass sphere of diameter D. The bead is given a slight push and starts sliding down along the sphere. Find the speed v of the bead at the point at which the bead leaves the sphere.



(A) $v = \sqrt{gD}$ (B) $v = \sqrt{4gD/5}$ (C) $v = \sqrt{2gD/3}$

(D) $v = \sqrt{gD/2}$ (E) $v = \sqrt{gD/3}$

[2] **Problem 8.** A block of mass 5 kg with a horizontal velocity of 8 m/s and no vertical velocity explodes into two pieces that initially fly apart at right angles to each other. One piece has a mass of 1.5 kg and a velocity of 11 m/s. Which of the options is closest to the change in kinetic energy of the system?

(A) −85 J

(B) 0 J

(C) 60 J

(D) 120 J

(E) 310 J

[2] **Problem 9.** An object of mass m_1 initially moving at speed v_0 collides with an originally stationary object of mass $m_2 = \alpha m_1$, where $\alpha < 1$. The collision could be completely elastic, completely inelastic, or partially inelastic. After the collision, the two objects move at speeds v_1 and v_2. Assume that the collision is one dimensional, and that object one cannot pass through object two. After the collision, the speed ratio $r_2 = v_2/v_0$ of object 2 is bounded by:

A) $1/(1+\alpha) \le r_2 \le 2/(1+\alpha)$

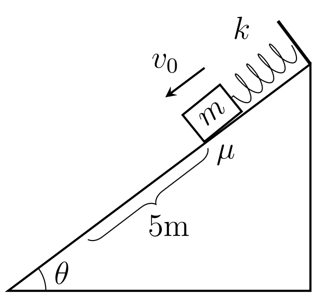
B) $(1-\alpha)/(1+\alpha) \le r_2 \le 1$

C) $(1-\alpha)/(1+\alpha) \le r_2 \le 1/(1+\alpha)$

D) $\alpha/(1+\alpha) \le r_2 \le 1$

E) $0 \le r_2 \le 2\alpha/(1+\alpha)$

[2] **Problem 10.** A block of mass 1 kg initially has a velocity 4.9 m/s down an inclined plane of angle 50°. The block is attached to a spring of spring constant 9kg/s^2, which is initially at it's relaxed length. The coefficient of kinetic and static friction between the block and the plane are μ. Given that the lowest position on the plane the block will reach is 5m along the plane, which of the following is the closest to the value of μ?



(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

2 Free Responses

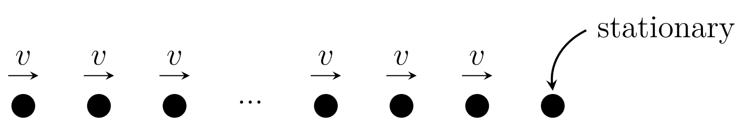
[10] **Problem 1.** A stream of N clay balls of mass m move with a speed v in a line across a frictionless table. The spacing between them in ℓ. An additional ball of mass m sits in front of them. The front ball collides with the stationary ball and forms a blob of mass $2m$. Then the second ball collides with the blob and forms a blob of mass $3m$, and so on. How much time elapses between the instant shown below (when all balls are separated by a distance ℓ) and the last collision?

Solve this by working in:

A) The lab frame

B) The frame in which the N balls are initially at rest.

C) If instead of having equally distributed mass, imagine each ball has more mass than the previous ball. Will the collisions then take more, less, or the same amount of time? In this case, the stationary ball has mass m, and the first ball to collide has mass am where $a > 1$, and each succeeding ball has a greater mass than the previous ball. Give a formulaic explanation for full credit.



[10] **Problem 2.** A hose shoots a stream of water vertically upward. The water leaves the hose at a velocity v_0 and at a mass rate R (kg/s).

A) A horizontal board with mass m is placed a very small distance above the hose and then released. What should m be so that the board hovers at this height? Assume that when the water crashes into the board, it bounces off essentially sideways. Solve in terms of given variables and fundamental constants.

B) If you break the board in half, so that its mass is now $m/2$, how high above the hose will it be located such that it will hover in place? Solve in terms of given variables and fundamental constants.

C) In part (A), what should m be if the stream of water is replaced by a stream of marbles that bounce off the board elastically (that is, they bounce off downward with the same speed v_0)? Solve in terms of given variables and fundamental constants.

(Even though the marbles are discrete objects, assume that they have an essentially continuous mass rate equal to R. Also, assume that the downward-moving marbles that have bounced off the board somehow magically pass through the upward-moving ones without colliding.)