

## Practice Test: Kinematics, Forces and Translational Dynamics

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Equations.**  $\vec{v} = \frac{\Delta \vec{x}}{\Delta t}$   $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$   $v_x = v_{x0} + a_x t$   $x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$   $v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$   $\vec{x}_{cm} = \frac{\sum m_i \vec{x}_i}{\sum m_i}$   $\vec{a} = \frac{\sum \vec{F}}{m}$

$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$   $F_g = G \frac{m_1 m_2}{r^2}$   $|\vec{g}| = \frac{F_g}{m}$   $|\vec{F}_{f,k}| = \mu_k |\vec{F}_n|$   $|\vec{F}_{f,s}| \leq \mu_s |\vec{F}_n|$   $\vec{F}_s = -k \Delta \vec{x}$   $a_c = \frac{v^2}{r}$   $T = \frac{2\pi r}{v}$

**Given.**  $\vec{a}_g = -9.80665 \hat{j} \text{ m/s}^2$ , which may be taken as  $10 \text{ N/kg}$   $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$  Air resistance is negligible throughout.

## Section I. Multiple choice.

Only 15 multiple choice questions will be required on the real test next week. Suggested time: 30 minutes.

1. A jogger runs 300 m due east along a straight path, turns around, and runs 400 m due west along the same path. For the whole run, [3 pts]
  - (A) the distance is 100 m and the displacement is 100 m west.
  - (B) the distance is 700 m and the displacement is 100 m west.
  - (C) the distance is 700 m and the displacement is 700 m west.
  - (D) the distance is 100 m and the displacement is 700 m west.
2. The velocity of an object moving along a straight line changes from +8.0 m/s to -2.0 m/s over 4.0 s. Its average acceleration is [3 pts]
  - (A) +2.5 m/s<sup>2</sup>.
  - (B) -1.5 m/s<sup>2</sup>.
  - (C) +1.5 m/s<sup>2</sup>.
  - (D) -2.5 m/s<sup>2</sup>.
3. The position of an object against time is a parabola that opens upward, with its lowest point at  $t = 3.0 \text{ s}$ . Which statement must be true? [3 pts]
  - (A) The velocity is zero at  $t = 3.0 \text{ s}$  and the acceleration is positive throughout.
  - (B) The object is at rest for the whole motion.
  - (C) The acceleration is zero at  $t = 3.0 \text{ s}$ .
  - (D) The object reverses direction twice.
4. Over an interval in which an object's velocity is negative, the area between the velocity against time graph and the time axis represents [3 pts]
  - (A) a negative acceleration.
  - (B) a negative distance.
  - (C) a negative displacement.
  - (D) zero, because an area cannot be negative.
5. A train travels due east at 22 m/s relative to the ground. A passenger walks toward the back of the train at 1.2 m/s relative to the train. The velocity of the passenger relative to the ground is [3 pts]
  - (A) 23.2 m/s east.
  - (B) 20.8 m/s east.
  - (C) 1.2 m/s west.
  - (D) 22 m/s east.
6. From the edge of a table, one ball is launched horizontally at the same instant an identical ball is released from rest. Both land on level floor. [3 pts]
  - (A) They land at the same instant.
  - (B) The released ball lands first.
  - (C) The launched ball lands first.
  - (D) Which lands first depends on the launch speed.
7. A projectile is launched from level ground at 20 m/s, 60° above the horizontal. At the highest point of its path its speed is [3 pts]
  - (A) zero.
  - (B) 17 m/s.
  - (C) 20 m/s.
  - (D) 10 m/s.

8. Three objects lie along the  $x$ -axis: 1.0 kg at  $x = 0$ , 2.0 kg at  $x = 3.0$  m, and 3.0 kg at  $x = 5.0$  m. The center of mass of the three is at [3 pts]  
(A)  $x = 2.5$  m. (B)  $x = 2.7$  m.  
(C)  $x = 3.5$  m. (D)  $x = 4.0$  m.
9. A crate is pulled at constant velocity across a rough level floor by a rope held at an angle above the horizontal. Its free-body diagram should show [3 pts]  
(A) the gravitational force, the normal force, the tension and the friction force.  
(B) the gravitational force, the normal force and the tension only.  
(C) the tension and the friction force only.  
(D) five forces, including a forward force of motion.
10. A horse pulls a cart forward, and the cart pulls back on the horse with a force of equal magnitude. The horse and cart still accelerate forward because [3 pts]  
(A) the horse's pull on the cart is slightly larger than the cart's pull on the horse.  
(B) the two forces act on different objects, and the net external force on the horse and cart together comes from the ground.  
(C) Newton's third law does not apply while an object is accelerating.  
(D) the cart's pull on the horse begins a moment later.
11. Two boxes start from rest on a level frictionless floor. The same constant horizontal force is exerted on each of them, for the same length of time. Box X has twice the mass of box Y. At the end of that time, [3 pts]  
(A) the two boxes are moving at the same speed.  
(B) box X is moving twice as fast as box Y.  
(C) box X has traveled twice the distance that box Y has traveled.  
(D) box Y is moving twice as fast as box X.
12. Two satellites of equal mass orbit the same planet. Satellite B is three times as far from the planet's center as satellite A. The magnitude of the gravitational force exerted on B, compared with that on A, is [3 pts]  
(A) one third. (B) three times.  
(C) one ninth. (D) nine times.
13. A block rests on a rough level surface. A horizontal force of 12 N is exerted on it and the block does not move. The magnitude of the static friction force exerted on the block is [3 pts]  
(A) 12 N.  
(B) the coefficient of static friction times the normal force.  
(C) zero, because the block is not moving.  
(D) greater than 12 N, because the block does not move.
14. An ideal spring of force constant 200 N/m hangs vertically from a ceiling. A 2.0 kg object is attached to its lower end and hangs at rest. The spring stretches by [3 pts]  
(A) 0.010 m. (B) 1.0 m.  
(C) 10 m. (D) 0.10 m.
15. A car travels around a flat, level circular curve at constant speed. The inward net force that produces its centripetal acceleration is [3 pts]  
(A) the normal force exerted by the road on the tires.  
(B) the static friction force exerted by the road on the tires.  
(C) the kinetic friction force exerted by the road on the tires.  
(D) a centripetal force that appears because the car is turning.
16. A car travels 60 km at a steady 30 km/h, then a further 60 km at a steady 60 km/h. Its average speed for the whole journey is [3 pts]  
(A) 45 km/h. (B) 50 km/h.  
(C) 40 km/h. (D) 30 km/h.

- 17.** A ball is thrown straight up and later returns to the hand that threw it. Air resistance is negligible. Which statement about the acceleration of the ball during the flight is correct? [3 pts]
- (A) It is the same at every instant of the flight.  
(B) It is zero at the highest point of the flight.  
(C) It is negative on the way up and positive on the way down.  
(D) It reverses at the instant the ball reverses its direction.
- 18.** Two identical balls are launched from level ground at the same speed, one at  $30^\circ$  above the horizontal and one at  $60^\circ$ . Compared with the ball launched at  $60^\circ$ , the ball launched at  $30^\circ$  has [3 pts]
- (A) a longer time of flight.  
(B) a greater maximum height.  
(C) a shorter horizontal range.  
(D) the same horizontal range.
- 19.** A boat is steered due north and moves at 4.0 m/s relative to the water. The water flows due east at 3.0 m/s relative to the bank. The speed of the boat relative to the bank is [3 pts]
- (A) 1.0 m/s. (B) 5.0 m/s.  
(C) 7.0 m/s. (D) 4.0 m/s.
- 20.** A vector of magnitude 3 is added to a vector of magnitude 5. Which of the following could be the magnitude of the resultant? [3 pts]
- (A) 1 (B) 9  
(C) 10 (D) 2
- 21.** Two carts, of mass 2.0 kg and 3.0 kg, are held 5.0 m apart on a frictionless track, joined by a stretched spring, and released from rest. They meet at a distance from the starting point of the 2.0 kg cart of [3 pts]
- (A) 3.0 m. (B) 2.0 m.  
(C) 2.5 m. (D) 5.0 m.
- 22.** A block rests on an inclined surface. On the free-body diagram for the block, the normal force is drawn [3 pts]
- (A) straight up, opposite the gravitational force.  
(B) down the slope.  
(C) perpendicular to the inclined surface.  
(D) along the inclined surface, in the direction of any motion.
- 23.** Two students stand facing each other on skateboards and push off. Student A has twice the mass of student B. Immediately after the push, [3 pts]
- (A) student A moves twice as fast as student B.  
(B) student B moves twice as fast as student A.  
(C) they move at the same speed.  
(D) student A does not move at all.
- 24.** An elevator is moving downward and slowing at a steady rate as it comes to a stop. A passenger stands on a bathroom scale inside the elevator. While the elevator slows, the reading on the scale is [3 pts]
- (A) greater than the weight of the passenger.  
(B) less than the weight of the passenger.  
(C) equal to the weight of the passenger.  
(D) zero, because the elevator is coming to rest.
- 25.** An object weighs 100 N at the surface of the Earth. At an altitude of one Earth radius above the surface, its weight is [3 pts]
- (A) 100 N. (B) 50 N.  
(C) zero. (D) 25 N.

- 26.** A puck is given an initial speed along a level floor and slides to a stop. The same puck is then given the same initial speed along a second level floor, whose coefficient of kinetic friction is half as large. On the second floor the puck slides [3 pts]
- (A) half as far. (B) twice as far.  
(C) the same distance. (D) four times as far.
- 27.** Two ideal springs hang side by side from a ceiling. One has force constant  $k$  and the other has force constant  $2k$ . Identical objects are hung at rest from the lower end of each. Compared with the stretch of the stiffer spring, the stretch of the softer spring is [3 pts]
- (A) half as large. (B) the same.  
(C) twice as large. (D) four times as large.
- 28.** A 0.50 kg ball moves in a horizontal circle of radius 1.2 m at a constant speed of 3.0 m/s. Its centripetal acceleration is [3 pts]
- (A)  $7.5 \text{ m/s}^2$ . (B)  $2.5 \text{ m/s}^2$ .  
(C)  $3.75 \text{ m/s}^2$ . (D)  $1.2 \text{ m/s}^2$ .
- 29.** A satellite moves in a circular orbit about a planet. Its orbital radius is then doubled. Its orbital period [3 pts]
- (A) doubles.  
(B) is halved.  
(C) is unchanged, since the period does not depend on the radius.  
(D) increases by a factor of about 2.8.
- 30.** A hockey puck slides across level, frictionless ice at constant velocity. The net force exerted on the puck is [3 pts]
- (A) in the direction of its motion.  
(B) opposite to its motion.  
(C) zero.  
(D) directed downward, since gravity still acts on it.

## Section II. Free response.

Two free-response questions will be required on the real test next week. Show all your work. Include all units when applicable.

### Question 1. Mathematical Routines

25 pts, suggested time 18 minutes

A block of mass  $M$  rests on a ramp inclined at an angle  $\theta$  to the horizontal. The coefficient of kinetic friction between the block and the ramp surface is  $\mu_k$ . A light string runs from the block, up along the ramp surface and over an ideal pulley at the top of the ramp, to a second block of mass  $m$  that hangs freely, as shown in Figure 1. The system is released from rest and the hanging block descends.

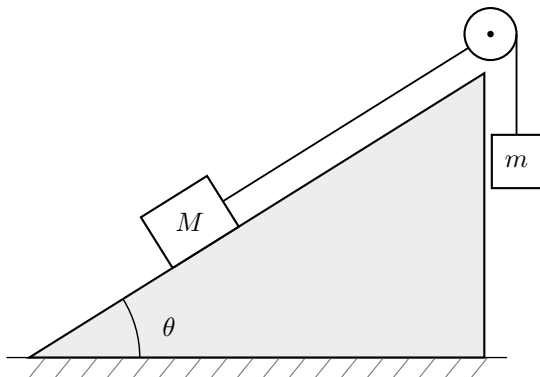


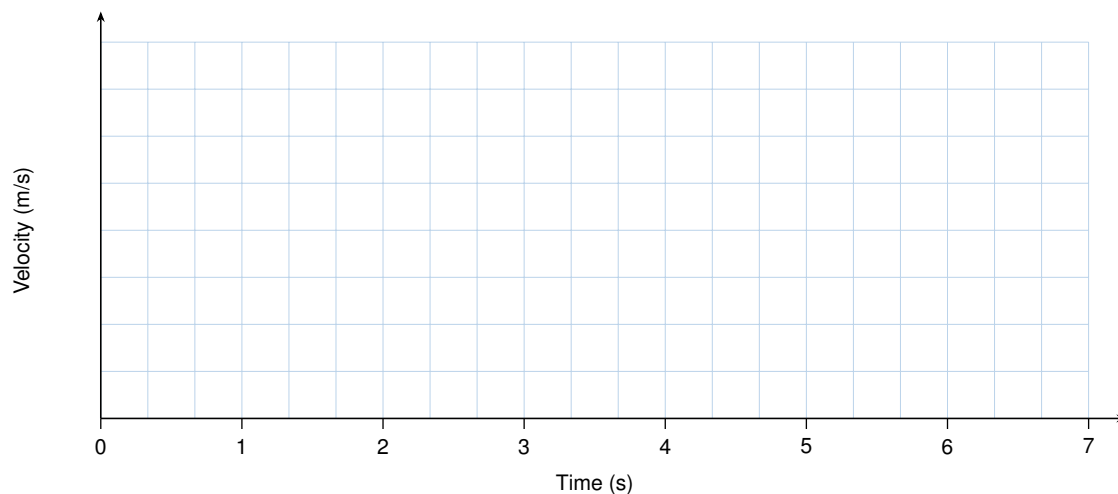
Figure 1

- (a) Derive an expression for the magnitude of the acceleration of the blocks in terms of  $M$ ,  $m$ ,  $\theta$ ,  $\mu_k$  and physical constants. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.
- (b) Derive an expression for the magnitude of the tension in the string in terms of  $M$ ,  $m$ ,  $\theta$ ,  $\mu_k$  and physical constants.
- (c) A student sets up the apparatus with  $M = 2.0$  kg,  $m = 3.0$  kg,  $\theta = 30^\circ$  and  $\mu_k = 0.25$ .
  - (i) Calculate the magnitude of the acceleration of the blocks.
  - (ii) Calculate the magnitude of the tension in the string.
- (d) Consider the case in which the mass  $m$  of the hanging block is made very much larger than  $M$ , with everything else held fixed. Show that your expression from part (a) approaches a physically reasonable value, and state what that value represents.

**Question 2. Translation Between Representations****30 pts, suggested time 22 minutes**

A student pushes a 5.0 kg box across a level floor with a constant horizontal force. The box starts from rest, and its speed increases steadily to 6.0 m/s in 3.0 s. At  $t = 3.0$  s the student stops pushing. The box then slides and comes to rest at  $t = 7.0$  s. The floor is uniform, so the coefficient of kinetic friction is the same throughout.

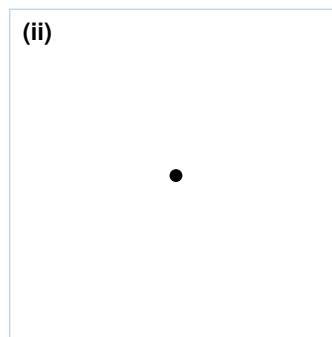
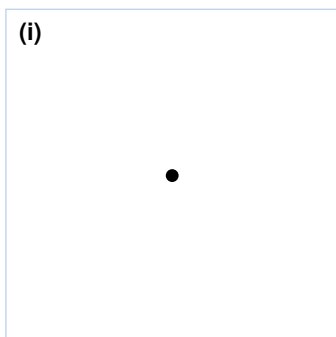
(a) On the axes below, sketch a graph of the velocity of the box as a function of time from  $t = 0$  to  $t = 7.0$  s. Label the vertical axis with a numerical scale.



(b) On each dot below, draw a free-body diagram showing the forces exerted on the box. Draw each force as a single straight arrow that starts on the dot and points in the direction of that force. Do not draw components, and draw forces in the same direction side by side rather than on top of one another.

(i) At a time between  $t = 0$  and  $t = 3.0$  s.

(ii) At a time between  $t = 3.0$  s and  $t = 7.0$  s.



(c) Starting from Newton's second law, derive an expression for the coefficient of kinetic friction  $\mu_k$  in terms of quantities that can be read from your graph in part (a), and physical constants. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

(d) Calculate the magnitude of the constant horizontal force the student exerts on the box during the first 3.0 s.

(e) Indicate whether the magnitude of the force the student exerts during the first 3.0 s is greater than, less than, or equal to the magnitude of the friction force exerted on the box during that interval. Justify your answer. In your justification, include qualitative reasoning beyond mathematical derivations or expressions.

**Question 3. Experimental Design and Analysis****25 pts, suggested time 18 minutes**

A group of students is asked to determine the coefficient of kinetic friction  $\mu_k$  between a wooden block and a level wooden board. They have the block, the board, a spring scale that reads force in newtons, a set of known masses that can be placed on top of the block, a meterstick and a stopwatch.

**(a)**

- (i) Indicate the quantities that could be measured, and describe a procedure that would allow the students to determine  $\mu_k$  using a linear graph.
- (ii) Briefly describe a method for reducing the experimental uncertainty in the measured quantities.

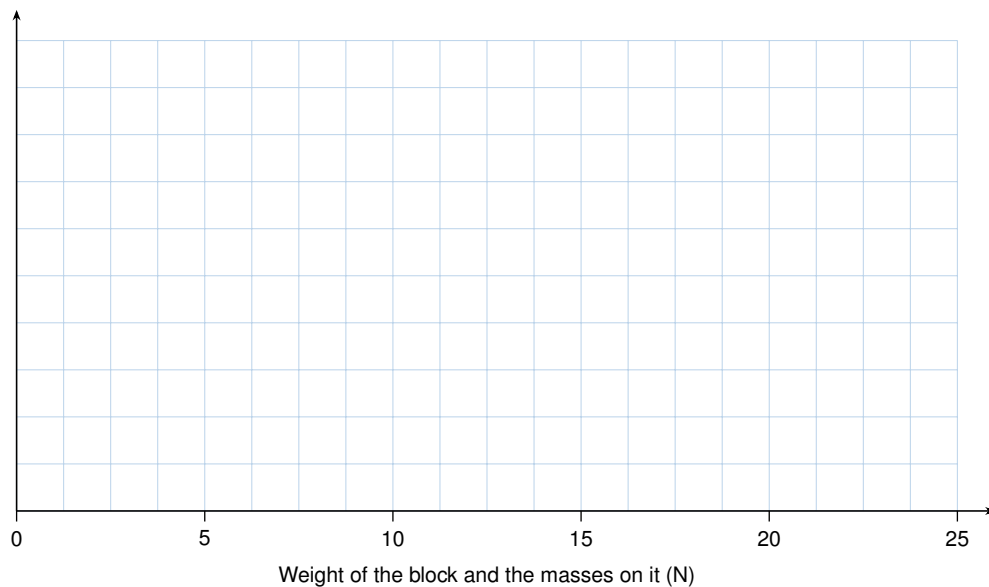
**(b)**

- (i) Indicate what quantities should be graphed on the horizontal and on the vertical axes so that the graph is linear. Clearly state which quantity goes on each axis.
- (ii) Describe how  $\mu_k$  could be found from a feature of that graph.

**(c)** The students obtain the data below.

|                                        |     |      |      |      |      |
|----------------------------------------|-----|------|------|------|------|
| Total weight of block and masses (N)   | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| Applied force at constant velocity (N) | 1.8 | 3.4  | 5.4  | 6.9  | 8.8  |

- (i) Label the vertical axis of the graph below with a quantity and a numerical scale.
- (ii) Plot the data points.
- (iii) Draw a straight best-fit line through the plotted points.

**(d)** Using the best-fit line you drew in part (c)(iii), calculate an experimental value for  $\mu_k$ .

**Question 4. Qualitative/Quantitative Translation****20 pts, suggested time 14 minutes**

Two blocks are released from rest at the top of two identical frictionless ramps of height  $h$  and angle  $\theta$ . Block P has mass  $m$  and block Q has mass  $3m$ .

- (a) Indicate whether the speed of block Q at the bottom of its ramp is greater than, less than, or equal to the speed of block P at the bottom of its ramp. Justify your answer using qualitative reasoning beyond referencing equations.
- (b) Starting with Newton's second law, derive an expression for the speed of a block of mass  $M$  at the bottom of such a ramp, in terms of  $h$ ,  $\theta$ ,  $M$  and physical constants. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.
- (c) Justify how your expression in part (b) is or is not consistent with your reasoning in part (a).
- (d) The two ramps are now given a surface with the same nonzero coefficient of kinetic friction. Indicate whether your answer to part (a) changes, and briefly justify your response by referencing a fundamental physics principle.