Your name sticker with exam code. SIGN HERE:

1. The exam will last from 4:00 p.m. to 7:00 p.m. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.

2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.

3. Under STUDENT # enter your 9-digit RUID Number.

4. Enter 123 under COURSE, and your section number (see label above) under SEC.

5. Under CODE enter the exam code given above.

6. During the exam, you may use pencils, a calculator, and two 8.5 x 11 inch sheets with formulas and notes.

7. There are 30 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. At the end of the exam, hand in the answer sheet and the cover page. Retain this question paper for future reference and study.

8. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.

9. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

10. If needed, the acceleration due to gravity on earth may be take as $g = 9.81 \text{ m/s}^2$.

Circle your choice to the question starting with “Two stars and two rectangles ...”: (a) (b) (c) (d) (e)
Explain your reasoning below.

Circle your choice to the question starting with “The velocity vs. time ...”: (a) (b) (c) (d) (e)
Explain your reasoning below.
1. Which of the following quantities has the same dimensions as kinetic energy, $\frac{1}{2}mv^2$? Note: x and h are lengths, a is acceleration, g is acceleration due to gravity and t is time. 

\[ \text{Energy} = \frac{1}{2} \text{mv}^2 \]

\[ \text{a) } ma \quad \text{b) } m(v \cdot t) \quad \text{c) } \frac{\text{d) } mgh \quad \text{e) } mgt}{g^2} \]

2. At $t = 0$, a particle leaves the origin with a velocity of 12 m/s in the positive x direction and moves in the xy plane with a constant acceleration of $(-2.0\,\text{i} + 4.0\,\text{j})$ m/s². At the instant the y coordinate of the particle is 18 m, what is the x coordinate of the particle?

\[ x = x_0 + v_x \cdot t + \frac{1}{2} a_x t^2 \]

\[ y = y_0 + v_y \cdot t + \frac{1}{2} a_y t^2 \]

Given:
- $x_0 = 0$
- $v_x = 12$ m/s
- $a_x = -2.0$ m/s²
- $y_0 = 0$
- $v_y = 4.0$ m/s
- $a_y = 4.0$ m/s²

\[ x = 0 + 12 \times 3 + \frac{1}{2} (-2.0) \times 3^2 = 27 \text{ m} \]

3. Taking the acceleration due to gravity to be 9.8 m/s², which of the following statements is true for a body falling freely from rest near the surface of the earth? (Ignore air resistance.)

\[ \text{a) } \text{after 1 second, the body has fallen 9.8 meters.} \]
\[ \text{b) } \text{after 3 seconds, its speed is 29.4 meters per second.} \]
\[ \text{c) } \text{during each time interval of 1 second, its speed changes by 9.8 meters per second.} \]
\[ \text{d) } \text{after 2 seconds, the body has fallen 19.6 meters.} \]
\[ \text{e) } \text{The force on the body remains constant.} \]

4. An automobile moving along a straight track changes its velocity from 40 m/s to 80 m/s in a distance of 200 m. What is the (constant) acceleration of the vehicle during this time?

\[ a = \frac{v_f^2 - v_i^2}{2 \cdot \Delta \chi} \]

\[ a = \frac{80^2 - 40^2}{2 \times 200} \]

\[ a = 12 \text{ m/s}^2 \]

5. At $t = 0$ a particle leaves the origin with a velocity of 5.0 m/s in the positive y direction. Its acceleration is given by $a = (3.0i - 2.0j)$ m/s². At the instant the particle reaches its maximum y coordinate how far is the particle from the origin?

\[ y = y_0 + v_{y0}t + \frac{1}{2} a_{y0} t^2 \]

\[ s = \sqrt{x^2 + y^2} \]

\[ \text{a) } 11 \text{ m} \quad \text{b) } 16 \text{ m} \quad \text{c) } 22 \text{ m} \quad \text{d) } 29 \text{ m} \quad \text{e) } 19 \text{ m} \]

6. The velocity vs. time graph describes the motion of a snowboarder. The snowboarder's acceleration (in m/s²) at the time of $t = 2$ s is (explain your reasoning on the front cover sheet.):

\[ \alpha = \frac{\Delta v}{\Delta t} = \text{constant here} \]

\[ \alpha \text{ for } \Delta t = 6 \text{ s} \]

\[ \alpha = 6 \text{ m/s}^2 \]

7. A 0.14-km wide river flows with a uniform speed of 4.0 m/s toward the east. It takes 20 s for a boat to cross the river to a point directly north of its departure point on the south bank. What is the speed of the boat relative to the water?

\[ R = \text{River, } B = \text{Boat, } E = \text{Earth} \]

\[ \text{a) } 5.7 \text{ m/s} \quad \text{b) } 8.5 \text{ m/s} \quad \text{c) } 8.1 \text{ m/s} \quad \text{d) } 7.0 \text{ m/s} \quad \text{e) } 6.4 \text{ m/s} \]

\[ \frac{140}{v_{BE}} = 20 \Rightarrow v_{BE} = 7 \text{ m/s} \]

\[ v_{BR} = \sqrt{40^2 + 7^2} = 8.1 \text{ m/s} \]
8. You hold a tennis racket vertically in your hand. On the top edge of the racket you have balanced a ball. Which statement is true?
   a) The force of your hand on the racket and the force of the ball on the racket are equal in magnitude and opposite in direction.
   b) The force of the racket on your hand and the force of the ball on the racket are equal in magnitude and opposite in direction.
   c) The force of your hand on the racket and the force of the racket on the ball are equal in magnitude and opposite in direction.
   d) The force of your hand on the racket and the force of the racket on the ball are equal in magnitude and opposite in direction.
   e) The force of your hand on the racket and the force of the racket on your hand are equal in magnitude and opposite in direction.

9. An 80-kg person slides on a patch of ice, pulled by a horizontal rope. The coefficient of friction of the person with the ice is 0.05. If the person sliding is not accelerating, the tension in the rope is
   a) 800 N
   b) 4 N
   c) 8 N
   d) 20 N
   e) 39 N

10. A mass \( M = 5.6 \) kg on a horizontal table is pulled by a horizontal string that passes over a frictionless massless pulley to a free-hanging mass \( m = 3.4 \) kg. The coefficient of friction between \( M \) and the table is 0.28. The acceleration of \( M \) is
   a) \( 3.7 \text{ m/s}^2 \)
   b) \( 2.0 \text{ m/s}^2 \)
   c) \( 2.2 \text{ m/s}^2 \)
   d) \( 0.20 \text{ m/s}^2 \)
   e) \( 0.49 \text{ m/s}^2 \)

11. A conical pendulum consists of a 2.0-kg bob suspended by a massless string of length 3.0 m. The bob moves in a circle in the horizontal plane such that the angle of the string to the vertical is constant at 20°. The tension in the string is
   a) 19 N
   b) 21 N
   c) 23 N
   d) 25 N
   e) 27 N

12. A mass \( m \) slides down a loop-the-loop track shown. The track is frictionless and the mass \( m \), which is released from rest a height \( h \) above point A, just makes it around the track without losing contact at point C. What is the value of \( h \) in terms of \( r \)? Neglect air resistance.
   a) \( 2r \)
   b) \( 1.5r \)
   c) \( 2.2r \)
   d) \( 2.4r \)
   e) \( 2.5r \)

13. A train engine pulls a freight train with mass \( 10^7 \) kg with a force of 500 kN, starting from rest. After one minute the speed of the train is
   a) \( 0.05 \text{ m/s} \)
   b) \( 0.3 \text{ m/s} \)
   c) \( 3 \text{ m/s} \)
   d) \( 0.003 \text{ m/s} \)
   e) \( 5 \text{ m/s} \)

14. Two balls, projected at different times so they don’t collide, have trajectories A and B, as shown below. Which statement is correct?
   a) Ball B’s initial speed must be greater than that of ball A.
   b) Ball A is in the air for a longer time than ball B.
   c) Ball B is in the air for a longer time than ball A.
   d) Ball B has a greater acceleration than ball A.
   e) Ball A has a greater acceleration than ball B.
15. A mass of 2.0 kg is placed at rest on an inclined plane making an angle of 40° with the horizontal and slides down a distance of 15 m, as shown. Its speed at the bottom is 12 m/s. How much of its mechanical energy is lost due to friction? (in J)

\[
\begin{align*}
\mathbf{K}_i + \mathbf{U}_i &= \mathbf{K}_f + \mathbf{U}_f + \mathbf{W}_{\text{other}} \\
&= \frac{1}{2}m(v_f^2 - v_i^2) + \mathbf{W}_{\text{other}} \\
&= \frac{1}{2}m(12)^2 + 45 J
\end{align*}
\]

\[\mathbf{W}_{\text{other}} = 189 J - 144 J = 45 J\]

17. A bumper on a car can be thought of as a spring with constant \(k = 900 \text{ kN/m} \). If a 1000-kg car with such a bumper is coasting at 3 m/s and hits a wall, what will the maximum compression of the bumper be? Assume the collision is elastic, and that the bumper has negligible mass compared with the car.

a) 1 cm
b) 10 cm
c) 1 m
d) 1 mm
e) 0.1 mm

\[
\begin{align*}
\mathbf{x}^2 &= \frac{9 \times 10^3}{2 \times 10^4} \\
&= 0.02 \Rightarrow \mathbf{x} = 0.1 m = 10 cm
\end{align*}
\]

18. A boy launches a rock straight up with an elastic slingshot by pulling it a certain distance \(x\) from the unstretched position. The rock reaches a maximum height \(h\) above the point of launch, where \(h\) is much greater than \(x\). If the boy then launches the same rock by stretching the slingshot by \(2x\), the maximum height will be nearest

a) \(\frac{h}{2}\)
b) \(\frac{3h}{2}\)
c) \(2h\)
d) \(\frac{5h}{2}\)
e) \(4h\)

19. A mass of 2.0 kg is moving south with a speed of 4.0 m/s while a mass of 5.0 kg is moving east at 3.0 m/s. They collide at the origin and stick together as shown. In what direction does the combined mass of 7.0 kg move? (A line pointing horizontally towards the right of the figure is defined as 0° and the angle is measured in the clockwise direction from this reference direction.)

\[
\begin{align*}
\mathbf{P}_f &= \mathbf{P}_i \\
\mathbf{i} &= \mathbf{P}_i = 15 \mathbf{i} - 9 \mathbf{j} = 15 \mathbf{i} + 9 \mathbf{j} \\
\mathbf{j} &= \mathbf{P}_i = 5 \mathbf{k} \mathbf{j} = 3 m/s \\
\theta &= \tan^{-1}(\frac{g}{15}) = 26°
\end{align*}
\]
20. A 2.0 kg object, initially traveling in the +x direction with a speed of 4.0 m/s, explodes in flight into two pieces, each of mass 1.0 kg. One piece travels at 12.0 m/s in the same direction as the 2.0 kg object was moving initially. What is the velocity (speed in m/s, and direction) of the center of mass of the two pieces after the explosion?
   a) 8, in the -x-direction.
   b) 4, in the +x-direction.
   c) 6, in the +x-direction.
   d) 6, in the -x-direction.
   e) 12, in the +x-direction.

21. An 80-g particle moving with an initial speed of 50 m/s in the positive x direction strikes and sticks to a 60-g particle moving 50 m/s in the positive y direction. How much kinetic energy is lost in this collision?
   a) 96 J
   b) 89 J
   c) 175 J
   d) 86 J
   e) 110 J

22. An empty rail car coasts along a track at constant velocity v and couples to a full rail car initially at rest. If the velocity of the two cars coupled together is v/5, the ratio of the mass of the empty car to that of the full car is
   a) 1/4
   b) 4
   c) 1/5
   d) 5
   e) need more information

23. A 1.2-kg ball falling vertically hits the floor with a speed of 2.5 m/s and rebounds with a speed of 1.5 m/s. What is the magnitude of the impulse exerted on the ball by the floor?
   a) 9.6 N-s
   b) 4.8 N-s
   c) 6.4 N-s
   d) 1.6 N-s
   e) 1.0 N-s

24. A flywheel, initially at rest, has a constant angular acceleration. After 9 seconds the flywheel has rotated 450 rad. Its angular acceleration in rad/s² is:
   \[ \Theta = \Theta_0 + \dot{\Theta}_0 t + \frac{1}{2} \alpha t^2 = \frac{1}{2} \alpha t^2 \]
   a) 100 b) 1.77 c) 50 d) (1.1) e) 15.9

25. The turntable of a record player has an angular velocity of 8.0 rad/s at the moment when it is turned off. The turntable comes to rest 2.5 s after being turned off. Through how many radians does the turntable rotate after being turned off? Assume constant angular acceleration.
   a) 12 rad
   b) 8.0 rad
   c) (10 rad)
   d) 16 rad
   e) 6.8 rad

26. Two stars and two rectangles are hung from a uniform rod of mass \( m_{rod} \). The rod is suspended from the ceiling such that the mobile balances in a perfectly horizontal orientation, as shown. How does the total mass of the stars, \( M_S \), compare to the total mass of the rectangles, \( M_R \)? (Explain your reason in the front cover sheet.)
27. A hoop of mass $M$ and radius $R$ rotates about its axis of circular symmetry with angular velocity $\omega$. A solid disk of mass $M$ and radius $R$ rotates about its axis of circular symmetry with angular velocity $2\omega$. The ratio of the kinetic energy of rotation of the hoop to that of the disk is

$$K = \frac{1}{2} I \omega^2$$

a) $\frac{1}{4}$

b) $\frac{1}{2}$

c) $\frac{1}{4}$

d) 2

e) $\frac{1}{2}$

28. You are hired by a lumber company to design a machine that will make cylindrical logs (with radius $R = 0.30$ m) roll about their axis on a horizontal surface (without slipping) at just the right angular velocity so that they can go up an 11.5° ramp that is 10 m long and just drop into a waiting truck. At what angular velocity $\omega$ (in rad/s) should your machine make the logs roll?

a) 17

b) 5

c) 1.5

d) 40

e) 21

29. A torque of 42 Nm gives a large wheel an angular acceleration of 0.78 rad/s$^2$. What is the moment of inertia in units of (kg m$^2$) of the wheel?

a) 32

b) 12

c) 5.1

d) 54

e) 0.98

$$\tau = I \alpha \Rightarrow I = \frac{\tau}{\alpha} = 54 \text{ kg m}^2$$

30. A block of mass $M$ is hanging from a horizontal bar of length $L$ as shown in the figure. One end of the bar is held on the edge of a desk and the other end is held up by a rope vertically. What is the magnitude of the torque exerted by the rope about the edge of the desk? Assume that the mass of the bar is negligible.

a) $MgL$

b) $\frac{2MgL}{3}$

c) $\frac{MgL}{3}$

d) $MgL/4$

e) The answer depends on the length of the rope.

[Diagram showing a block $M$ hanging from a bar with a rope attached to one end of the bar.]