Please return SCANTRON ONLY to TA or instructor before you leave the room.

Your Name: Prof. Sarah TEST #2
Print clearly.

On the Scantron, fill out your student ID, leaving the first column empty and starting in the second column. Also write your name and “Test 2” at the bottom.

There are 20 equally-weighted questions on this test. There is only one correct answer per question. Mark your answer on the Scantron. Take off the last few pages: there is scrap paper and a formula sheet for you to keep.

The key will be posted online after all make-up tests are completed.

******************************************************************************

1. What has more kinetic energy: a 100 kg football player walking at 1 m/s to the right, or an apple with mass 100 grams that's been thrown and is now travelling at 10 m/s to the left?

   a. The football player has more kinetic energy.
   b. The apple has more kinetic energy.
   c. They both have the same kinetic energy.
   d. They both have zero kinetic energy.
   e. Their kinetic energies cancel out.

\[ KE = \frac{1}{2} m v^2 \]

\[
\text{Football player} \\
m = 100 \text{ kg} \\
v = 1 \text{ m/s} \\
KE = \frac{1}{2} \cdot 100 \cdot (1)^2 = 50 \text{ J} \quad \text{(bigger)}
\]

\[
\text{Apple} \\
m = 100 \text{ g} = 0.1 \text{ kg} \\
v = 10 \text{ m/s} \\
KE = \frac{1}{2} \cdot 0.1 \cdot (10)^2 = \frac{1}{2} \cdot 0.1 \cdot 100 = 5 \text{ J}
\]

2. A black cat is sitting on your front porch and senses a 40 N normal force acting on it from the floor. What is the mass of the cat?

a. 390 kg
b. 40 kg
c. 9.8 kg
d. 4.1 kg
e. 3.2 kg

\[ F_g = \text{weight} = mg \]

\[ 40N = m \cdot (9.8 \text{ m/s}^2) \]

\[ m = \frac{40}{9.8} = 4.08 \text{ kg} \]

\[ \Sigma F_y = m a_y \] (Given: \( a_y = 0 \))

\[ n - F_g = 0 \]

\[ n = F_g \]

\[ F_g = n = 40N \]
For the next three questions, use the information and figure below.
A steel block of mass 1.5 kg is sitting atop a table with a coefficient of static friction \( \mu_s = 0.35 \) and a coefficient of kinetic friction \( \mu_k = 0.25 \). Your physics professor is pushing on the block horizontally.

3. If the block is at rest, at least how hard do I need to push on the block to get it to move?

   a. 0.53 N
   b. 1.5 N
   c. 5.1 N
   d. 7.6 N
   e. 13 N

   Knowns:
   \[ m = 1.5 \text{ kg} \]
   \[ \mu_s = 0.35 \]
   \[ \mu_k = 0.25 \to \text{Not sliding, so kinetic friction is not relevant.} \]

   For block to move, \( F_{\text{push}} \) must overcome static friction force. The maximum static friction force is \( F_s = \mu_s N \), so we need: \( F_{\text{push}} \geq \mu_s N \).

   So what's \( n \)? \[ \sum F_y = ma_y \]
   \[ a_y = 0 \]
   \[ n - F_g = 0 \]
   \[ n = F_g = \text{weight} \]
   \[ n = mg = (1.5 \text{ kg})(9.8 \text{ m/s}^2) \]
   \[ n = 14.7 \text{ N} \]

   \[ F_{\text{push}} \geq \mu_s N \]
   \[ F_{\text{push}} \geq (0.35)(14.7 \text{ N}) \]
   \[ F_{\text{push}} \geq 5.145 \text{ N} \]

4. Of the following actions, what would make the block easier to start moving?

   a. Instead pushing the block on a table with properties \( \mu_s = 0.35 \) and \( \mu_k = 0.1 \).
   b. Instead pushing the block on a table with properties \( \mu_s = 0.35 \) and \( \mu_k = 0.25 \).
   c. Turning the block so that it rests on its small end, and sliding it that way.
   d. More than one of the above answers.
   e. None of the above answers would make it easier to start moving.

   \[ F_s = \mu_s N \]
   \[ \text{less kinetic friction does not help.} \]
   \[ \text{Neither of these factors depends on the area of contact with the floor -- only the floor's roughness & normal force (ie mass of object).} \]
5. After pushing the same block for a while at a constant force of 5.00 N, the block is moving at 44.00 m/s when it reaches a rougher patch on the table. Here, the block decelerates at a constant value of -0.30 m/s² although your professor keeps pushing with the same force. Assume right and up represent positive axes in the figure shown. What is the force of kinetic friction that is felt by the block in this rough patch?

a. 1.20 N  

b. 5.45 N  

c. 6.32 N  

d. 7.73 N  

e. 20.0 N

\[ \text{WANT: } f_k = ? \]

Use Newton’s 2nd law in x-direction:

\[ \Sigma F_x = ma_x \]

\[ F_{\text{push}} - f_k = ma_x \]

\[ 5 \text{ N} - f_k = (1.5 \text{ kg})(-0.3 \text{ m/s}^2) \]

Solve for \( f_k \):

\[ f_k = (1.5)(0.3) + (5) = 0.45 + 5 = 5.45 \text{ N} \]

6. Two siblings are having an argument, and are pushing on opposing sides of a toy box of mass 20 kg. The smaller sibling is pushing horizontally on the box with a force of 30 N, while the larger sibling is pushing with a force of 35 N at an angle 40° below horizontal, as shown in the figure below. Assume negligible friction between the box and the floor. What will be the the net acceleration of the box?

a. 0.16 m/s² toward the smaller sibling

b. 0.16 m/s² toward the larger sibling

c. 0.38 m/s² toward the smaller sibling

d. 0.38 m/s² toward the larger sibling

e. None of the above

\[ \Sigma F_x = m_{\text{box}} a_x \]

\[ 30 \text{ N} - 26.8 \text{ N} = (20 \text{ kg}) a_x \]

\[ a_x = \frac{0.1595}{m/s^2} \]

*Positive: towards larger sibling*
7. An elevator is rising at a constant velocity. What is true about the net force acting on the elevator?

- It is equal to the weight of the elevator.
- It is zero.
- It is positive.
- It is negative.
- More than one of these answers is correct.

Also: "Constant velocity" means equilibrium condition; by definition \( \sum F = 0 \) N.

8. A 2 kg block is sitting on an incline (as shown), and the string has a tension of 4 N. If the string is suddenly cut, how long does it take the block to slide to the bottom of the incline?

- Starts @ 0 velocity.
- Kinematics!
- But have knowns:
  - \( m = 2 \text{ kg} \)
  - \( Ax = 3 \text{ m} \)
  - \( V_o = 0 \text{ m/s} \)

Not enough info; need \( r \) or \( a \) to calc. time.

Two options:
1) Use conservation of energy to determine \( r \) at bottom of incline.
2) Use Newton's laws to determine acceleration, I will use option #2.

\[
\sum F_x = m\alpha \quad \text{unknown}
\]

Note: after string is cut, the only x-direction force is \( F_{gx} \).

\[
\sum F_x = m\alpha
\]

\[
5.073 = (2)\alpha
\]

\[
\alpha = 2.54 \text{ m/s}^2
\]

\[
\Delta x = V_at + \frac{1}{2}at^2
\]

\[
3 = (0)\text{t} + \frac{1}{2}(2.54)(t)^2
\]

\[
t = 1.54 \text{ s}
\]
9. I push a large pumpkin across the ground with a horizontal force of 5 N, and I do 2 J of work during this push. How far did I push the pumpkin?

- a. 0.4 m
- b. 0.8 m
- c. 7 m
- d. 10 m
- e. 20 m

Unknown: $\Delta x = ?$

**Work:**

\[
W = F_x \Delta x
\]

\[
W = 5 \Delta x
\]

\[
2 = 5 \Delta x
\]

\[
\Delta x = \frac{2}{5} = 0.4 \text{ m}
\]

10. After pushing the pumpkin from the previous problem for a while, I get tired because there’s too much friction on the ground. I give the pumpkin a last shove, and after I push it, slides a distance of 1.0 meter, with friction dissipating the pumpkin’s energy and bringing it to rest. How fast was the pumpkin going when I first pushed it? Assume it has a mass of 12 kg.

- a. 0.2 m/s
- b. 0.3 m/s
- c. 0.5 m/s
- d. 0.7 m/s
- e. 1.5 m/s

Unknown: $v_i = ?$

Friction does work:

\[
W_{fr} = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2
\]

\[
W_{fr} = \frac{1}{2} (12)(0) - \frac{1}{2} (12) v_i^2
\]

\[
-3 = -6 v_i^2
\]

So:

\[
v = \sqrt{0.5} = 0.71 \text{ m/s}
\]
11. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy’s hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are)

a. A downward force of gravity, along with a steadily decreasing upward force.
b. A steadily decreasing upward force from the moment it leaves the boy’s hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the ball gets closer to Earth.
c. A constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.

d. A constant downward force of gravity only.
e. None of the above. The ball falls back down to the ground because of its natural tendency to rest on the surface of the Earth.

The ball is in free-fall. FBD:

\[ \text{The whole time!} \]

\[ \text{v} \_{\text{Fg}} \]

12. A logging truck with a truckbed full of unsecured logs is driving down the highway and suddenly rapidly accelerates. As it accelerates, its logs slide off the back of the truck onto the road. What is the physical principle that most accurately describes the reason that the logs slid off the truck bed?

a. Friction between the logs and the truck.
b. Centripetal force from the accelerating truck.
c. A backwards (not centripetal) force on the logs in reaction to the accelerating truck.

d. Inertia of the logs.
e. None of the above.

They wanted to continue @ the same velocity but the truck accelerated away from them.

[Norton's 1st Law]
13. I lift a 50 N weight from the floor to a height of 2m above the floor. What is the work done by gravity on the weight over this motion?

a. 0 J  

\[ W = F \Delta x \]

\[ W = F_g \Delta y \]

\[ W = (50 \text{ N}) (2 \text{ m}) = 100 \text{ J} \]

Vertical work

b. \(-25 \text{ J}\)

c. \(-50 \text{ J}\)

d. \(-100 \text{ J}\)

e. \(-980 \text{ J}\)

14. There are two pies cooling in the windows of a high-rise apartment building. One, of mass \(m\), is in a window at a height of \(h\). The other has \(1/3\) the mass of the first pie and is in a window twice as high. What is true about the gravitational potential energies of the pies?

a. The higher pie's gravitational potential energy is 0.67 times that of the lower pie.

b. The higher pie's gravitational potential energy is 1.5 times that of the lower pie.

c. The higher pie has twice the gravitational potential energy of the lower pie.

d. The higher pie has six times the gravitational potential energy of the lower pie.

e. Both pies have the same gravitational potential energy.

Gravitational PE: \(PE_g = mgh\) ; \(g = 9.8 \text{ m/s}^2\)

**Low pie**

- \(m_{\text{pie}} = m\)
- \(h_{\text{pie}} = h\)

Symbolically: \(GPE = mgh\)

Or with numbers:

- \(m_{\text{low}} = 1 \text{ kg}\)
- \(h_{\text{low}} = 10 \text{ m}\)

\[ PE_{\text{low}} = (1)(9.8)(10) = 98 \text{ J} \]

**High pie**

- \(m_{\text{pie}} = \frac{1}{3} m\)
- \(h_{\text{pie}} = 2h\)

\[ PE_{\text{high}} = \left(\frac{1}{3}m\right)(9.8)(2h) = \frac{2}{3} mgh = 0.67 mgh \]

\[ PE_{\text{high}} = (\frac{1}{3})(9.8)(20) = 65.33 \text{ J} \]

\[ \frac{65.33}{98} \approx 0.67 \]
15. Two balls collide, as shown in the figure below. The white ball has a mass 1.0 kg, and the grey ball has a mass 5.0 kg. Before the collision (shown below left), the white ball is travelling with a velocity 5.0 m/s. After the collision (shown below right), the white ball is travelling at a velocity of -5.0 m/s, and the grey ball is travelling at a velocity of -1.0 m/s. What is the velocity of the grey ball before the collision?

\[
m_1 = 1 \text{ kg} \quad v_{i1} = +5 \text{ m/s} \quad v_{f1} = -5 \text{ m/s} \\
m_2 = 5 \text{ kg} \quad v_{i2} = ? \quad v_{f2} = -1 \text{ m/s}
\]

\[
m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}
\]

\[
(1) (5) + (5)(v_{i2}) = (1)(-5) + (5)(-1)
\]

\[
5 + 5v_{i2} = -5 - 5
\]

\[
\frac{5v_{i2}}{5} = -\frac{10}{5}
\]

\[
v_{i2} = -2 \text{ m/s}
\]

16. Now assume a car crash involving the two “cars” shown below, where the car masses are unknown. The velocities of the cars before and after the collision are as indicated in the figure. Is this collision elastic, inelastic, or perfectly inelastic?

- a. Elastic
- b. Inelastic
- c. Perfectly inelastic → no, they don’t stick together.

Could also have inferred this because we have discussed car crashes involve much friction & deformation; lots of dissipative energy loss, so by definition inelastic.

Can test elastic collision with equation:

\[
v_{i1} - v_{i2} = -(v_{f1} - v_{f2})
\]

\[
5 - (-5) \overset{?}{=} -(-(5 - (-1))
\]

\[
5 + 5 \overset{?}{=} -(4)
\]

\[
10 \overset{?}{=} 4
\]

No, not equal, so not elastic!
17. You’re on a frictionless surface (say, a frozen pond), holding a 30kg weight. You push the weight away from you so that it’s travelling at 10 m/s. You experience recoil as you push the weight away, and after the push you’re moving at 4.1 m/s in the opposite direction of the weight. You remember physics class and realize this experiment can allow you to calculate your mass. What is your mass based on this experiment?

a. 59 kg
b. 63 kg
c. 71 kg
d. 73 kg
e. 100 kg

Recoil: use cons. of momentum.

\[ m_1 = 30 \text{ kg} \]
\[ m_2 = ? \]
\[ V_{1i} = V_{2i} = 0 \text{ m/s} \]
\[ V_{1f} = -10 \text{ m/s} \]
\[ V_{2f} = 4.1 \text{ m/s} \]

\[ 0 = m_1 V_{1f} + m_2 V_{2f} \]

\[ (30)(-10) = -m_2(4.1) \]

\[ m_2 = \frac{300}{4.1} = 73 \text{ kg} \]

18. A penny is sliding across a frictionless surface at 1 m/s in the x direction. If I apply a 3N force acting only in the y direction for 5 seconds, which of the following statements is true?

a. While I am pushing it, my finger feels a force from the penny in the x direction.
b. After about 3 seconds, the penny no longer has any motion in the x direction.
c. After 5 seconds, the penny no longer has any motion in the x direction.
d. All of the above statements are true.
e. None of the above statements are true.
19. As a 65 kg baseball player slides to rest at home plate on a level playing field, -1170 J of his energy is dissipated into the ground via friction. What was the player's initial speed when he began sliding?

a. 1.8 m/s  
b. 5.0 m/s  
c. 6.0 m/s  
d. 7.3 m/s  
e. 12 m/s

\[ W_{nc} = -1170 \text{ J (dissipated energy via friction)} \]

Note: no change in height; \( PE_f = PE_i = 0 \)

\[ W_{nc} = (KE_f + PE_f) - (KE_i + PE_i) \]

\[ W_{nc} = 0 - \frac{1}{2} m v_i^2 \]

\[-1170 = -\frac{1}{2} (65) v_i^2 \]

\[ v_i = \sqrt{36} = 6 \text{ m/s} \]

20. Cart #1 is pulled with a 1.0-N force for 1 second, while cart #2, also 0.50 kg, is pulled with a 2.0 N-force for 0.50 seconds. Which cart has the greatest change in its momentum before and after the pull?

a. Cart #1  
b. Cart #2  
c. Both carts have the same change in momentum  
d. Neither cart changes its momentum because momentum is always conserved.

\[ I = \Delta p = F \Delta t \]

\[ \begin{align*}
\text{Cart #1} & \quad F = 1 \text{ N} \\
& \quad \Delta t = 1 \text{s} \\
& \quad \Delta p = (1)(1) = 1 \text{ N.s} \\
\text{Cart #2} & \quad F = 2 \text{ N} \\
& \quad \Delta t = 0.5 \text{s} \\
& \quad \Delta p = (2)(0.5) = 1 \text{ N.s}
\end{align*} \]

SAME