Test 3

Name: Solutions - NJS

Place an X next to your Problems Lab section:

_____ Frank (TR 11:20 – 1:50)   _____ Youngkins (WF 8:00 – 10:30)
_____ Weller (TR 2:40 – 5:10)   _____ Smith (WF 8:00 – 10:30)
_____ Kavich (TR 6:00 – 8:30)   _____ Youngkins (WF 11:30 – 2:00)
_____ Ford (MW 1:15 – 3:45)     _____ Kavich (WF 6:00 – 8:30)

⇒ The following test consists of two parts. Part I contains 10 multiple choice questions worth 3 points each. Part II contains 3 problems worth a total of 70 points.
⇒ Multiple Choice: There is no partial credit for the multiple choice questions. Choose the best answer from the choices provided. Write the letter of the best answer in the boxes provided on page 3.
⇒ The Problems: To receive full credit on the problems, all reasoning must be shown and any numerical answer must have the appropriate units. Box in your final answer.
⇒ Rounding: Round final answers to two decimal places, if necessary.
⇒ Ask if you don’t understand the statement of a given problem.
⇒ Cell phones must be put in silent or vibrate mode and put away. Anybody caught using a cell phone during the test will receive a zero grade.
⇒ You may not leave the room during the exam unless you have permission from one of the proctors.
⇒ CHEATING: Cheating in any form will not be tolerated, and will result in a zero grade for this test. A formal complaint may also be submitted to the Office of Judicial Affairs. Refer to the course syllabus for further details.
⇒ You should have only a pencil, eraser, calculator, and the test papers out – all other material should be put away.

You have 1 hour and 25 minutes to complete this exam.
GOOD LUCK!

Instructor use only:

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Part I – Multiple Choice (3 points each)

Choose the best answer to each of the following questions.

Write your answers in the spaces provided at the bottom of page 3.

1. A cannon ball is shot at an angle of 75° above the horizontal from a height of 10 m with an initial speed of 88 m/s. Which of the following statements is true? (Assume no air resistance.)
   A. Before the cannon ball hits the ground, it has a constant speed.
   B. Before the cannon ball hits the ground, it has a constant velocity.
   C. Before the cannon ball hits the ground, it has a constant momentum.
   D. Before the cannon ball hits the ground, it has constant total energy (KE + PE).
   E. None of these is true.

2. A rope is used to pull a 55 kg box along a rough, horizontal surface. The rope makes an angle of 30° above the horizontal. If the box moves a distance of 15 m, and the tension in the rope is 102 N, how much work is done by the tension force?
   A. 998 J
   B. 1530 J
   C. 565 J
   D. 1325 J
   E. 3230 J

3. The work done by friction
   A. is always positive.
   B. is always negative.
   C. can be positive or negative, depending on the specific situation
   D. always points in the direction opposite to that of the motion of the object.
   E. always points in the same direction as the motion of the object.

4. A compact disc rotates through an angular distance of 143 radians. How many revolutions has it made?
   A. 22.8 rev
   B. 41.3 rev
   C. 143 rev
   D. 84.3 rev
   E. 101 rev

5. Convert 1590 cm/h to m/s.
   A. 4.42×10⁻⁴ m/s
   B. 0.027 m/s
   C. 5.72×10⁴ m/s
   D. 4.42×10⁻³ m/s
   E. 44.2 m/s
6. What would the length of the minute hand on an analogue clock have to be for its tip to be moving at 2.0 m/s?

\[
V = 2 \text{ m/s} \\
V = \omega R \\
\omega = \frac{1 \text{ rev}}{60 \text{ s}} = \frac{2\pi \text{ rad}}{60 \text{ s}} = \frac{0.10 \text{ rad}}{s} \\
\therefore R = \frac{V}{\omega} = \frac{2}{0.10} = 20 \text{ m}
\]

A. 20 m  
B. 0.55 m  
C. 14 m  
D. 130 m  
E. 6.0 m

7. A force of magnitude \( F = 90 \text{ N} \) is applied to a wrench, as shown in the diagram. The angle \( \theta \) is 65°. What is the torque about the axis of rotation? (The axis of rotation is at the “x” in the diagram.)

\[
\tau = \frac{F \cdot \ell}{\sin \theta} \\
= \frac{90 \times 0.136}{15 \sin 65^\circ} \\
= 12.2 \text{ Nm}
\]

A. 24.5 Nm  
B. 12.2 Nm  
C. 36.7 Nm  
D. 5.4 Nm  
E. 90.0 Nm

8. A box of mass 35 kg is pushed with a force of 100 N at constant speed across a horizontal floor for a distance of 5.5 m. The push force is horizontal to the floor, and the coefficient of friction between the box and the floor is 0.12. How much work is done by the normal force?

\[
W_N = \text{ Net work done by the force} \\
= \text{ Work done by the push force} \\
= \text{work done by frictional force}
\]

A. 3500 J  
B. 1887 J  
C. -3500 J  
D. -226.4 J  
E. 0 J

9. A 5.6-kg box is at the top of a frictionless incline of height 0.72 m. The box starts sliding from rest at the top of the incline. What is the speed of the box at the bottom of the incline?

\[
\text{KE}_i + \text{PE}_i = \text{KE}_f + \text{PE}_f - W_f \\
\frac{1}{2} \text{mv}_i^2 + mgh = \frac{1}{2} \text{mv}_f^2 \\
\therefore \text{v}_f = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.72} \approx 3.8 \text{ m/s}
\]

A. 3.8 m/s  
B. 9.8 m/s  
C. 15 m/s  
D. 0.72 m/s  
E. 1.44 m/s  
F. 19.6 m/s
10. In an experiment about momentum, the momentum of a toy car is determined to be 56.18573 kg m/s, with a fractional uncertainty of 0.07. How should you write the momentum of the toy car, together with its uncertainty, in your lab notebook?

A. 56.18573 kg m/s
B. 56.19 ± 0.07 kg m/s
C. 56 ± 4 kg m/s
D. 56.19 kg m/s ± 0.07
E. 56.2 ± 0.1 kg m/s

\[ \delta(p) = F_U(p) \times p \]

\[ = 0.07 \times 56.18573 \]

\[ = 4 \text{ kg m/s (to 1 s.f.)} \]

\[ \Rightarrow p = 56 ± 4 \text{ kg m/s} \]

Write your multiple choice answers here. This is the ONLY place your answers will be graded!

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Part II – Long Answer Questions

1. (25 pts) A block of mass \( m_1 = 5.6 \text{ kg} \) is sliding to the right on a frictionless surface with speed \( v_1 = 7.5 \text{ m/s} \), as shown in the diagram. Block 1 then collides in a completely inelastic collision with block 2, which is initially motionless and which has a mass \( m_2 = 3.8 \text{ kg} \). After the collision the two blocks (now stuck together) continue sliding to the right and up a hill of height \( h \). From position B onwards the surface is rough and has a coefficient of friction of 0.3. The combined blocks come to a rest at position C on the rough surface. 

   Make additions to the diagram as necessary as you work through the problems.

(a) (6 pts) What is the speed of the combined blocks immediately after the collision, at position A?

\[
\begin{align*}
\text{Before} & \quad \begin{array}{c}
m_1 \quad v_1 \\
m_2 \quad v_2
\end{array} & \quad \text{After} & \quad \begin{array}{c}
m_3 \quad v_3 \\
m_3 \quad v_A
\end{array} & \quad \text{Work Energy} & \quad \text{Conservation of Linear Momentum} \\
\text{\( \sum P_{ix} = \sum P_{fx} \)} & \quad \text{\( m_1 v_1 = m_3 v_A \)} & \quad \text{\( V_A = \frac{5.6 \times 7.5}{\frac{9.4}{0.4}} \)} & \quad \text{\( V_A = 4.47 \text{ m/s} \)}
\end{align*}
\]

\[
r_3 = m_1 + m_2 = 9.4 \text{ kg}
\]

(b) (6 pts) The speed of the combined blocks at the top of the hill is 2.0 m/s. What is the height \( h \) of the hill?

\[
\begin{align*}
\frac{1}{2} m_3 v_A^2 & = \frac{1}{2} m_3 v_B^2 + m_3 g h \\
j h & = \frac{1}{2} v_A^2 - \frac{1}{2} v_B^2 \\
h & = \frac{\frac{1}{2} v_A^2 - \frac{1}{2} v_B^2}{g} \\
& = \frac{\frac{1}{2} \times 4.47^2 - \frac{1}{2} \times 2^2}{9.8} \\
& = 0.82 \text{ m}
\end{align*}
\]

(c) (6 pts) How much work is done by the friction force as the combined blocks move from B to C?

\[
\begin{align*}
KE_B + PE_B = KE_C + PE_C - W_f & \quad \text{Note: \( PE_B = PE_C \)} \\
\Rightarrow KE_B = -W_f
\end{align*}
\]

\[
\begin{align*}
\text{W}_f & = -KE_B \\
& = -\frac{1}{2} m_3 v_B^2 \\
& = -\frac{1}{2} \times 9.4 \times 2^2 \\
& = -18.8 \text{ J}
\end{align*}
\]

(d) (7 pts) What is the distance from B to C?

\[
\begin{align*}
\sum F = ma & \quad \text{W}_f = \sum F_{fx} \\
F_N - m_3 g = 0 & \quad \Rightarrow F_{N} = m_3 g \\
F_N - m_3 g & = -d F_{f} \\
& = -d \mu m_3 g \\
\Rightarrow d & = \frac{-W_f}{\mu m_3 g} \\
& = \frac{-(-18.8)}{0.3 \times 9.4 \times 9.8} \\
& = 0.68 \text{ m}
\end{align*}
\]
2. (20 pts) The Phoenix Centrifuge at the NASTAR training center is used for high-g training of pilots and astronauts. Basically, it swings them around in a circle really fast, so that they experience the kinds of forces that are present when a rocket launches or very fast, tight turns in a plane are performed. The pilot sits in a pod at the end of a 7.62 m arm which can be swung around at various angular speeds. In one training session the pilot starts from rest and increases in speed at a constant rate, reaching a final angular speed of 2.5 rad/s, taking 15 s to do so.

\[ R = 7.62 \text{ m} \]

\[ \Theta_i = 0, \quad \Theta_f = ? \]
\[ \omega_i = 0 \text{ rad/s} \]
\[ \omega_f = 2.5 \text{ rad/s} \]
\[ \alpha = ? \]
\[ t = 15 \text{ s} \]

(a) (6 pts) What is the angular acceleration of the pilot?

\[ \omega_f = \omega_i + \alpha t \]
\[ \therefore \alpha = \frac{\omega_f}{t} = \frac{2.5}{15} \Rightarrow \alpha = 0.17 \frac{\text{rad}}{\text{s}^2} \]

(b) (6 pts) What angular distance did the pilot cover during “spin-up”?

\[ \Theta_f = \Theta_i + \frac{1}{2} \left( \omega_i + \omega_f \right) t \]
\[ = \frac{1}{2} \omega_f t \]
\[ = \frac{1}{2} \times 2.5 \times 15 \Rightarrow 18.75 \text{ rad} \]

(c) (3 pts) What is the linear (or tangential) speed of the pilot when he’s spinning at the final angular speed?

\[ v = R \omega \]
\[ = 7.62 \times 2.5 \]
\[ = 19.05 \text{ m/s} \]

(d) (5 pts) If the pilot remains rotating at 2.5 rad/s for a time of 25 s, what linear distance would be covered in the 25 s interval? 

Note: There are many ways to do this.

\[ x = R \theta \]
\[ \theta = 2.5 \frac{\text{rad}}{s} \times 25 \text{ s} = 62.5 \text{ rad} \]
\[ \therefore x = 7.62 \times 62.5 \]
\[ = 476 \text{ m} \]
3. (25 pts) Two masses are placed on a 2-m long beam so that the beam is perfectly balanced on a support located at the 150 cm mark, as shown in the diagram. Denote the mass of the beam by \( m_b \).

\[
\begin{array}{c}
\text{0 cm} \hspace{2cm} \text{m}_1 \hspace{2cm} 20 \text{ cm} \hspace{2cm} \text{150 cm} \hspace{2cm} \text{m}_2 \hspace{2cm} 200 \text{ cm}
\end{array}
\]

Data: \( m_1 = 0.5 \text{ kg} \), \( m_2 = 2.7 \text{ kg} \), \( m_b = 0.3 \text{ kg} \)

(a) (8 pts) Draw a good extended FBD for the beam (Draw a new diagram—do not make additions to the diagram given above).

(b) (7 pts) What is the distance \( d_2 \) of the second mass from the support?

\[
\sum \tau = 0 \implies m_1 g d_1 + m_b g d_b - m_2 g d_2 = 0
\]

\[
 d_2 = \frac{m_1 d_1 + m_b d_b}{m_2} = \frac{(0.5 \times 1.3) + (0.3 \times 0.5)}{2.7} = 0.30 \text{ m}
\]

(c) (6 pts) What is the magnitude of the normal force exerted by the support on the beam?

\[
\sum F_y = 0 \implies F_N = m_1 g - m_b g - m_2 g = 0
\]

\[
F_N = (m_1 + m_2 + m_b)g = (0.5 + 2.7 + 0.3) \times 9.8 = 34.3 \text{ N}
\]

(d) (4 pts) If mass \( m_1 \) was moved toward the left end of the beam (i.e. closer to the 0-cm end of the beam) while keeping mass \( m_2 \) in the same position, how would you have to change the mass of \( m_2 \) (increase, decrease or keep the same) in order to keep the beam perfectly balanced? Give reasons for your answer.

Moving \( m_1 \) towards the left increases the torque in the CCW direction. Therefore the torque in the CW direction must be increased to compensate. This means \( m_2 \) would have to be increased, if \( d_2 \) is held constant, since \( \tau_2 = m_2 g d_2 \).