This exam consists of 12 problems on 8 pages. Please check that you have them all.

All of the formulas that you will need are given below. You may also use a calculator.

\[ \sin \theta = \frac{y}{r} \quad \cos \theta = \frac{x}{r} \quad \tan \theta = \frac{y}{x} \]

average speed = \frac{\text{distance traveled}}{\text{time}} \quad g = 9.8 \text{ m/s}^2

1 mile = 1.6 km

average velocity = \vec{v} = \frac{\text{displacement}}{\text{time}}

instantaneous velocity = slope of position versus time

instantaneous acceleration = slope of velocity versus time

For constant acceleration:
\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]
\[ v = v_0 + at \]
\[ v^2 = v_0^2 + 2a(x - x_0) \]

\[ \vec{F} = m\vec{a} \]
\[ F_{friction}^{max} = \mu_S N \text{ (static friction)} \]
\[ F_{friction} = \mu_K N \text{ (sliding friction)} \]

\[ F_{gravity} = \frac{Gm_1m_2}{r^2} \]
1. A rock is dropped from a tall bridge into the water below. If the rock begins with a speed of zero, and has a speed of 12 m/s just before it hits the water, find the height of the bridge. Ignore air resistance.

(a) 15 m
(b) 2.4 m
(c) 37 m
(d) 7.3 m
(e) 29 m

\[ h = \frac{v_0^2}{2a} = \frac{12^2}{2(9.8)} = 7.3 \text{ m} \]

2. A car starts from the origin and drives 1.2 km south, then 3.1 km in a direction 53° north of east. Relative to the origin, what is the car’s final location?

(a) 1.9 km east
(b) 3.1 km east and 1.2 km south
(c) 1.9 km east and 1.3 km north
(d) 1.9 km east and 2.5 km north
(e) 1.9 km east and 3.7 km north
3. A watermelon falls from rest from the roof of a building. An observer from across the street notices that it takes 0.43 s for the time to pass between two window sills. The windows are 2.5 m apart. How far is the sill of the upper window from the roof of the building?

(a) 3.9 m  
(b) 1.7 m  
(c) 5.8 m  
(d) 0.70 m  
(e) 2.3 m

\[ h = \frac{1}{2}gt^2 = 0.70 \text{ m} \]

4. A block slides down an inclined plane as shown below. There is friction between the block and the plane. If the acceleration of the block is 2.4 m/s², find the coefficient of kinetic friction between the block and the plane.

(a) 0.44  
(b) 0.25  
(c) 0.60  
(d) 0.20  
(e) zero

\[ F = ma \]
\[ mgs \sin \theta - \mu N = ma \]
\[ \mu N = mgs \sin \theta - ma \]
\[ \mu = \frac{mgs \sin \theta - ma}{mg \cos \theta} \]
\[ \mu = \frac{9.8 \times 5.3 \times \sin 37\degree - 2.4 \times 5.3}{9.8 \times 5.3 \cos 37\degree} = 0.44 \]
5. A baseball is thrown up into the air at an angle of $30^\circ$ above the horizontal from the top of a tall building. Which of the graphs below could be a plot of the vertical component of the velocity of the ball, $v_y$, as a function of time?

(a) A
(b) B
(c) C
(d) D
(e) E
6. A baseball is hit with an initial speed of 45 m/s at an angle of 53° with respect to the horizontal. How long does it stay in the air? For simplicity, assume that the ball starts at ground level. Ignore air resistance.

- (a) 9.2 s
- (b) 7.3 s
- (c) 1.8 s
- (d) 5.5 s
- (e) 3.7 s

\[
\begin{align*}
\nu_{y0} &= 45 \text{ m/s} \sin 53° = 36 \text{ m/s} \\
0 &= \nu_{y0}t - \frac{1}{2} gt^2 \\
\frac{1}{2} gt &= \nu_{y0} \\
t &= \frac{2\nu_{y0}}{g} = \frac{2(36)}{9.8} = 7.35 \text{ s}
\end{align*}
\]

7. Two blocks and a pulley are arranged as shown. Block #2 sits at rest on a table. The pulley is frictionless and massless, and the cable is massless. Find the force of the table on block #2.

\[
\begin{align*}
m_1 &= 2.4 \text{ kg} \\
m_2 &= 8.6 \text{ kg} \\
m_1g - T &= 0 \\
T &= m_1g \\
N + m_1g - T &= m_2a = 0 \\
N &= m_2g - T = m_2g - m_1g \\
&= 61 \text{ N}
\end{align*}
\]
8. A crate of mass 6.8 kg is suspended from a system of 3 cables as shown. If the crate is at rest, find the tension in the cable on the upper left.

\[ +T_R \sin 30 - T_L \sin 45 = 0 \]
\[ T_R = \frac{T_L \sin 45}{\sin 30} = 1.41 \cdot T_L \]
\[ T_L \cos 45 + T_L \cos 30 - mg = 0 \]
\[ mg = T_L (\cos 45 + 1.41 \cos 30) \]
\[ T_L = \frac{mg}{(\cos 45 + 1.41 \cos 30)} = 35 \text{ N} \]

(a) 35 N  
(b) 55 N  
(c) 67 N  
(d) 87 N  
(e) 11 N

9. The sun has a radius that is 110 times larger than the earth's, and the mass of the sun is 2.0 \times 10^6 times larger. Find the acceleration due to gravity on the surface of the sun. The radius of the earth is 6.4 \times 10^6 m, and its mass is 6.0 \times 10^{24} kg.

\[ g = \frac{Gm}{R^2} \]
\[ g_{\text{sun}} = \frac{m_s}{m_e} \cdot \frac{R_e^2}{R_s^2} = \frac{2 \times 10^5}{(110)^2} = 16.5 \]
\[ g_{\text{earth}} = 16.5 \times 9.8 = 160 \text{ m/s}^2 \]
10. A rocket is fired at a speed of 90 m/s from ground level at an angle of 37° above the horizontal. It is fired towards a wall that is 15 m tall and 32 m away. By how much does the rocket clear the top of the wall?

(a) 9.0 m  
(b) 23 m  
(c) It does not clear the wall.  
(d) 3.5 m  
(e) 8.0 m

\[ x = x_0 + v_{x0}t = \frac{32}{72} = 0.444 \]

\[ y = y_0 + v_{y0}t - \frac{1}{2}gt^2 = 0 + 54t - \frac{1}{2} \times 9.8t^2 \]

\[ = 23.0 \text{ m} \]

\[ \Rightarrow \text{clear by } 23.0 - 15 = 8 \text{ m} \]

11. A ball is thrown straight up and rises to a maximum height of 24 m. At what height is its speed half of its initial value?

(a) 18 m  
(b) 12 m  
(c) 6.0 m  
(d) 22 m  
(e) 9.0 m

\[ \sqrt{v^2} = v_0 + 2ay \]

\[ 0 = v_0^2 + 2(-9)h \]

\[ 2s = 23 \text{ m} \]

\[ h = \frac{v_0^2}{2a} \]

When \( v = \frac{v_0}{2} \)

\[ \left( \frac{v_0^2}{2a} \right) = v_0^2 + 2(-9)y \]

\[ \frac{1}{4}v_0^2 = v_0^2 - 2gy \]

\[ 2gy = \frac{3}{4}v_0^2 \]

\[ y = \frac{3}{4} \left( \frac{v_0^2}{2g} \right) = \frac{3}{4} \left( \frac{24}{2g} \right) = 18 \text{ m} \]
12. The figure shows 3 blocks sitting on the floor of an elevator. The elevator is accelerating downwards at 2.4 m/s². Find the force of block #1 on block #2.

\[ \text{m}_1 = 3.0 \text{ kg} \]
\[ \text{m}_2 = 7.0 \text{ kg} \]
\[ \text{m}_3 = 12.0 \text{ kg} \]

\[ \text{Force of \#1 on \#2 = - Force of \#2 on \#1} \]
\[ \text{(action/reaction pair)} \]

- (a) 74 N directed down
- (b) 17 N directed down
- (c) 22 N directed down
- (d) 52 N directed down
- (e) 7.2 N directed down

For #1: \[ +N - m_1g = m_1a \]

\[ N = m_1(g+a) = 3.0(9.8+2.4) = 22N \]

The End
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(c) 22 N directed down
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For #1: \[ N - m_1g = m_1a \]

\[ N = m_1(g + a) \]
\[ = 3.0(9.8 + 2.4) \]
\[ = 22 N \]

The End