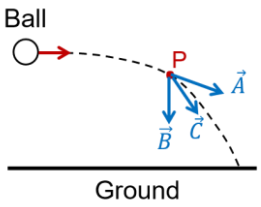
**PHYS 204 – Mechanics**
**Sections 01, EC1, EC2, EC3**
**Midterm Examination – Fall 2021**

## Multiple choice

1. **(5 marks)** Two stones are dropped from the same height, an interval of 1.0 s apart. During the time that both stones continue to fall, their separation:
   a) increases at first, but then stays constant
   b) Increases
   c) Stays constant
   d) Decreases
   e) Decreases at first, but then stays constant

2. **(5 marks)** The figure shows the path of a ball which was thrown horizontally. What is the direction of the acceleration of the ball at point P?




   a) Along vector $\vec{A}$ (tangent to the curve)
   b) Along vector $\vec{B}$ (straight down)
   c) Along vector $\vec{C}$ (vector sum of vectors $\vec{A}$ and $\vec{B}$)
   d) The acceleration is zero

3. **(5 marks)** A force of $\vec{F} = (6\hat{\imath} + 4\hat{\jmath})\ N$ is applied on a 2-kg box that is originally resting at $\vec{r}_1 = (3\hat{\imath} - 2\hat{\jmath})\ m$. If this is the only force acting on the box, what is the magnitude of the displacement of the box after 2 seconds?
   a) 16.16 m
   b) 6.5 m
   c) 7.2 m
   d) 9.4 m
   e) 14.42 m

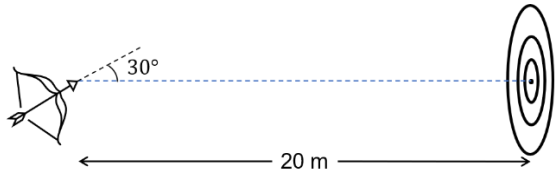
4. **(5 marks)** An object moving at a constant speed requires 6 seconds to go once around a circle with a diameter of 4 meters. What is the magnitude of the instantaneous acceleration of the particle during this time?
   a) 2.2 m/s$^2$
   b) 2.7 m/s$^2$
   c) 3.3 m/s$^2$
   d) 3.8 m/s$^2$

e) 4.4 m/s$^2$

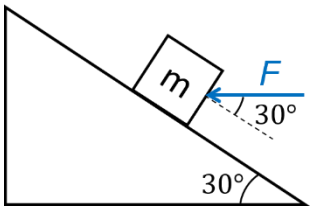
5. **(5 marks)** The frictional force of the floor on a large suitcase is least when the suitcase is:
   a) pushed by a force parallel to the floor.
   b) dragged by a force parallel to the floor.
   c) pulled by a force directed at an angle $\theta$ above the floor.
   d) pushed by a force directed at an angle $\theta$ into the floor.
   e) turned on its side and pushed by a force parallel to the floor.

## Long Answer

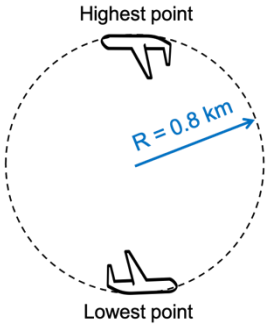
1. **(15 marks)** An arrow, held at the same level as the center of a target that is 20 m away, is shot with speed 15 m/s at 30° above horizon.
   a) **(5 marks)** After how long will the arrow hit the target?
   b) **(5 marks)** How far from the center will the arrow hit the target? Above or below?
   c) **(5 marks)** With what velocity will the arrow hit the target?
   Show your detailed work. Take $g = 10\frac{m}{s^2}$.




2. **(15 marks)** A block of mass 3-kg is pushed up an surface with force F = 25 N, as shown in the figure. If the coefficient of kinetic friction of is $\mu_k = 0.1$,
   a) **(5 marks)** Draw the free-body diagram
   b) **(10 marks)** Determine the magnitude of the acceleration of the block.
   Show your detailed work. Take $g = 10\frac{m}{s^2}$.

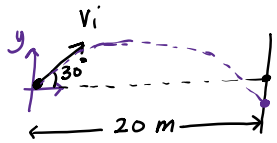



3. **(15 marks)** A stunt pilot weighing 700 N performs a vertical circular dive of radius 0.80 km with constant speed of 0.2 km/s.
   a) **(5 marks)** Draw the free-body diagrams at the highest and lowest points of the dive
   b) **(10 marks)** Determine the forces the pilot's seat exerts on the pilot at the highest and lowest point of the dive.
   Show your detailed work. Take $g = 10\frac{m}{s^2}$.



# Solutions

(1)




$\begin{cases} x_i = 0 \\ x_f = 20\ m \end{cases}$ $\begin{cases} y_i = 0 \\ y_f = ? \end{cases}$ $\begin{cases} V_i = 15\ m/s \\ \theta = 30^\circ \end{cases}$ $\begin{cases} V_{ix} = V_i \cos\theta \\ V_{iy} = V_i \sin\theta \end{cases}$ (1/5)

a) Time of flight:

(3/5) $\Delta x = V_{ix}\Delta t \rightarrow \Delta t = \dfrac{\Delta x}{V_i \cos\theta} = \dfrac{20}{15\,(\sqrt{3}/2)} = 1.54\,s$ (1/5)

b) (4/5) $\Delta y = V_{iy}\Delta t - \frac{1}{2} g \Delta t^2 = V_i \sin\theta\,\Delta t - \frac{1}{2} g \Delta t^2 = -0.31\ m$

$\Delta y = y_f - y_i \rightarrow y_f = -0.31\ m$ (1/5)

31 cm below target

c) $\vec{V_f} = V_{fx}\,\hat{i} + V_{fy}\,\hat{j}$

$V_{fx} = V_{ix} = 15\,\frac{\sqrt{3}}{2} = 13\ \frac{m}{s}$ $(a_x = 0)$ (2/5)

$V_{fy} = V_{iy} - g\Delta t = V_i \sin\theta - g\Delta t = 15(\tfrac{1}{2}) - (10)(1.54) = -7.9\ \frac{m}{s}$ (2/5)

$\vec{V_f} = (13\,\hat{i} - 7.9\,\hat{j})\ \frac{m}{s}$ (1/5)

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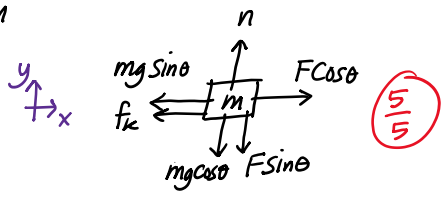
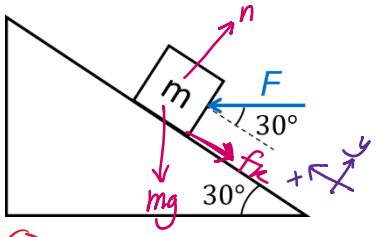
(2) a) Free-body diagram




(5/5)




b) $\sum F_x = ma_x$ $\qquad \sum F_y = ma_y = 0$

(6/10) $F\cos\theta - mg\sin\theta - f_k = ma$ $\qquad \rightarrow n = mg\cos\theta + F\sin\theta$ (3/10)

($f_k = \mu_k n$)

$\rightarrow F\cos\theta - mg\sin\theta - \mu_k(mg\cos\theta + F\sin\theta) = ma$

$\rightarrow a = \dfrac{F\cos\theta - mg\sin\theta - \mu_k(mg\cos\theta + F\sin\theta)}{m} = \dfrac{21.65 - 15 - 3.85}{3}$

$\rightarrow a = 0.93\ \frac{m}{s}$ (1/10)

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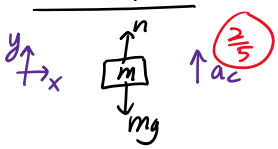
③ a) Free-body diagrams:

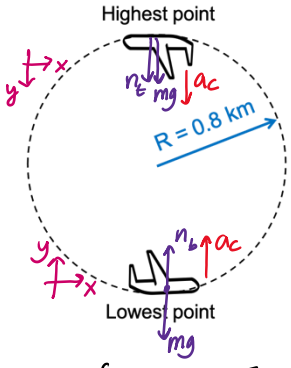
Highest point


3/5

Lowest point




2/5




$$\begin{cases} W = mg = 700\ N \\ m = \frac{700}{10} = 70\ kg \\ V = 0.2\ km/s = 200\ \frac{m}{s} \end{cases}$$

b) Highest point

$$\sum F = ma_c$$

$$n_t + mg = m\frac{v^2}{R}$$ 4/10

$$n_t = m\left(\frac{v^2}{R} - g\right)$$

$$n_t = 70\left(\frac{200^2}{800} - 10\right)$$

$$\boxed{n_t = 2800\ N}$$ 1/10

Lowest point

$$\sum F = ma_c$$

$$n_b - mg = m\frac{v^2}{R}$$ 4/10

$$n_b = m\left(\frac{v^2}{R} + g\right)$$

$$n_b = 70\left(\frac{200^2}{800} + 10\right)$$

1/10 $$\boxed{n_b = 4200\ N}$$