Physics 195 **Fall 2009** **Problem Set 5**

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

Conceptual Questions: **Place the letter** corresponding to your answer in the box.

Limit your explanation to the space provided. Please write legibly.

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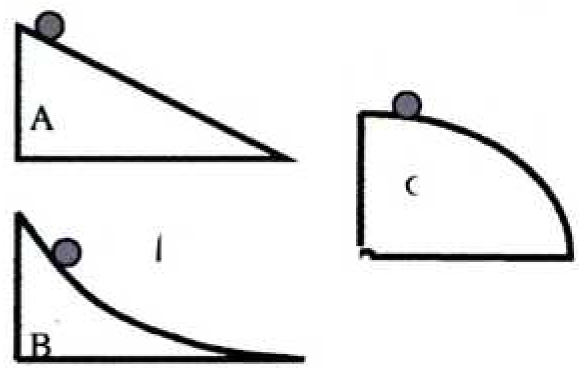
1. A ball starts from rest and rolls down three types of hill, A, B and C. For hill C, does the ball's speed...



$\boxed{A}$

a) increase
b) decrease
c) remain constant
d) Need more information

Explain

since $a > \emptyset$ the entire time v increases.

$\boxed{B}$

~~a)~~ For hill B, does the ball's acceleration... a) increase
b) decrease
c) remain constant
d) Unable to tell

Explain

since $\theta \to \emptyset$ then $g\sin\theta \to \emptyset$ as ball reaches bottom of hill...

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2. A ball dropped from rest accelerates at a rate of 9.81 m/s^2 if we ignore air resistance. If air resistance is not ignored, the ball reaches a terminal speed when the friction force of the air acting on the falling ball is equal to the gravitational force acting upon the ball. If, instead of being dropped, the ball is **hurled upwards** into the air at a **speed greater than the terminal speed** the acceleration of the ball is...

$\boxed{D}$

a) 9.81 m/s^2
b) less than 9.81 m/s^2
c) greater than 9.81 m/s^2 but less than 19.62 m/s^2
d) 19.62 m/s^2 or greater
e) More information is required.

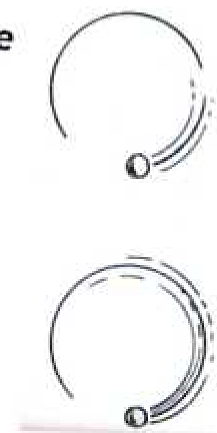
Explain:

since on the way up, there will be $F_{DRAG} + F_g$ acting on the ball in the same direction. since $F_D > F_g$ then $F_{net} > 2F_g$

$\therefore a_{net} > 2g > 19.6 \, m/s^2$

Show all calculations. Explain all assumptions. Answer in standard MKS units. Explicitly substitute units into your symbolic equations to verify solution. Express answers in 5 or fewer digits. Use scientific notation as appropriate.

3. Suppose that two identical objects travel in circular paths of equal diameter, but one object completes twice as many rotations per unit time. The centripetal force required to keep the faster object on the circular path is _____



E

a) The same as the force required to keep the slower object on the path
b) One-fourth of the force required to keep the slower object on the path
c) Half as much of the force required to keep the slower object on the path
d) Twice as much as the force required to keep the slower object on the path
e) Four times the force required to keep the slower object on the path

Explain

since $F = ma$ and $a = \frac{V^2}{R}$ for UCM

then $F_1 = m\frac{V_1^2}{R}$ $F_2 = m\frac{V_2^2}{R}$ with $\frac{m}{R}$ = constant

then $F_1 \propto V_1^2$ $F_2 \propto V_2^2$ and if $V_2 = 2V_1$

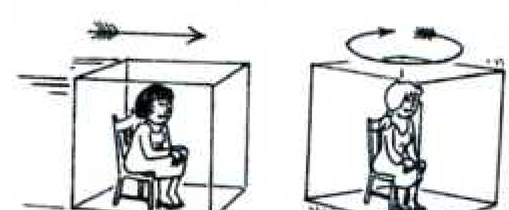
$F_2 \propto 4V_1^2$ $F_1 \propto V_1^2$ $F_2 = 4F_1$

4. A scientist is completely isolated inside a smoothly moving box that travels in a straight-line path through space. Another scientist is in a similar box, but this one is spinning smoothly (though not rapidly enough to affect the equilibrium of the scientist). Each scientist may have all the scientific goodies that she likes in her box for the purpose of detecting her motion through space, but they cannot see outside the box. Which of the following statements is true regarding the scientists?

A

a) The one in the spinning box can detect her motion
b) Both can detect their motions
c) Neither can detect their motions
d) The one in the traveling box can detect her motion

Explain



accelerations can be detected

$\therefore$ the spinning FOR can be detected

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in belt FOR it is at rest and everything that was at rest wrt earth is now moving in the opposite direction as the belt with speed of 2.5 m/s

EARTH FOR	BELT FOR
BAG $V_{xB0} = 0$	← BAG $V'_{xB0} = 2.5\,\text{m/s}\,(-\hat{x})$
BELT → $V_{xC0} = 2.5\,\text{m/s}\,(+\hat{x})$	BELT $V'_{xB0} = 0$
EARTH $V_{xE0} = 0$	EARTH $V'_{xE0} = 2.5\,\text{m/s}\,(-\hat{x})$

WRT BELT. time for bag to stop moving...

$$V_f = 0 \quad V_0 = 2.5\,\text{m/s}\,(-\hat{x}) \quad a = \frac{\mu m g}{m} = \frac{F_f}{m}$$

$a = 3.92\,\text{m/s}^2\,(+\hat{x})$ ← friction acting opposite bag's motion.

$$0 = 2.5\,\text{m/s}\,(-\hat{x}) + 3.92\,\text{m/s}^2\,(+\hat{x})\,t_{stop}$$

$$\boxed{t_{stop} = 0.64\,\text{s}}$$

WRT BELT. distance <u>bag</u> (B) moves by time it stops wrt <u>belt</u> (C)

$$\Delta X_{BC} = 2.5\,\text{m/s}\,(-\hat{x})\,t + \tfrac{1}{2}(3.92\,\text{m/s}^2)(+\hat{x})\,t^2$$

$$\boxed{\Delta X_{BC} = 0.8\,\text{m}\,(-\hat{x})}$$

WRT EARTH: belt moves to right @ constant speed, distance <u>belt</u> (C) moves wrt <u>earth</u> (E)... $\Delta X_{CE} = (2.5\,\text{m/s})(0.64\,\text{s})(+\hat{x})$

$\Delta X_{CE} = 1.6\,\text{m}\,(+\hat{x})$. however, belt moves right wrt earth, but bag moves left wrt belt... therefore

$$\Delta X_{BE} = \Delta X_{BC} + \Delta X_{CE} = (0.8\,\text{m}(-\hat{x})) + (1.6\,\text{m}(+\hat{x}))$$

$$\boxed{\Delta X_{BE} = 0.8\,\text{m}\,(+\hat{x})}$$

$$\left.\frac{mv^2}{R}\right)_{required} = \mu mg\Big)_{provided} \qquad V = 2\pi R \frac{m}{rot} \times \frac{N_{rot}}{s}$$

$$\frac{V^2}{R} = \mu g \Rightarrow \quad V = \sqrt{R\mu g} \quad ; \quad 2\pi R \frac{N_o}{t} = \sqrt{R\mu g}$$

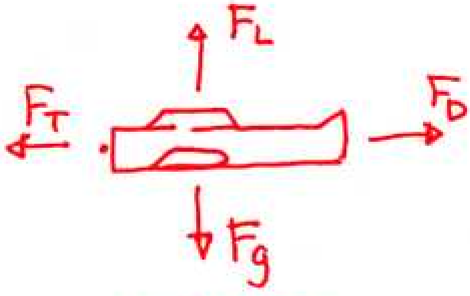
$$\frac{rot}{sec} \quad \frac{N_o}{t} = \frac{1}{2\pi R}\sqrt{R\mu g} \qquad \frac{60 N_o}{t} \frac{rot}{min} = \frac{60}{2\pi R}\sqrt{R\mu g}$$

$$\boxed{N_{1}\frac{rot}{min} = \frac{30}{\pi}\sqrt{\frac{\mu g}{R}}} \qquad \text{with } R_1 = R/3 \quad R_2 = R/4$$

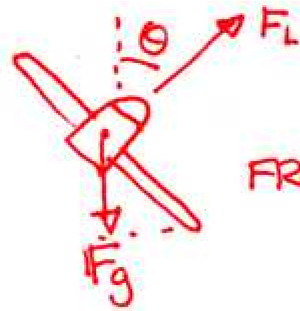
$$N \frac{rot}{min} \text{ @ which slip occurs} = \frac{30}{\pi}\sqrt{\frac{3\mu g}{R}} \quad \text{for } m_1$$

$$= \frac{30}{\pi}\sqrt{\frac{4\mu g}{R}} \quad \text{for } m_2$$

$$\boxed{m_1 \text{ slips first}}$$



SIDE VIEW



FRONT VIEW...

b) for constant speed V_1, level flight

$$F_T(+\hat{x}) + F_D(-\hat{x}) = \emptyset \quad \therefore \; F_T = F_D = C_1 V_1^2$$

$$F_L(+\hat{y}) + F_g(-\hat{y}) = \emptyset \quad \therefore \; F_L = F_g \; ; \; C_2 V_1^2 = Mg$$

$$\therefore \boxed{F_T = \frac{C_1}{C_2} Mg}$$

during banked turn @ speed V_2, still level

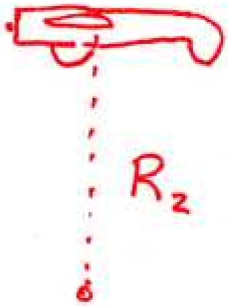
$$F_T(+\hat{x}) + F_D(-\hat{x}) = \emptyset \quad \therefore \; F_T = F_D = C_1 V_2^2$$

$$F_L \overset{\cos}{\cancel{\sin}}\theta(+\hat{y}) + F_g(-\hat{y}) = \emptyset \quad \therefore \; F_L = \frac{Mg}{\cos\theta} = C_2 V_2^2$$

also $F_L \sin\theta(-\hat{r}) = \frac{M V_2^2}{R}(-\hat{r})$ for circular motion...

but since variables requested do not include R..

$$V_2^2 = \frac{Mg}{C_2 \cos\theta} \qquad \boxed{F_T = \frac{C_1}{C_2}\frac{Mg}{\cos\theta}}$$



for circular motion

$$\Sigma F(\hat{r}) = \frac{m v_3^2}{R_2}$$

if "weightless" then $mg = \frac{m v_3^2}{R_2}$

$\therefore v_3^2 = R_2 g$ since $F_T = F_D$ for constant speed

then $F_T = C_1 v_3^2 = \boxed{C_1 R_2 g}$

$$V_{cmx} = \frac{N_1(8.2\cdot10^3) - N_2(766) + \emptyset + 2.54\cdot10^3 D_1}{3N+D}$$

$$\simeq \quad 2.5\cdot10^3 \text{ m/s } (+\hat{x})$$

$$V_{cmy} = \frac{N_1(5.7\cdot10^3) - N_2(643) - N_3(5\cdot10^4) + D_1(5.44\cdot10^3)}{3N+D}$$

$$\simeq \quad 6.8\cdot10^3 \text{ m/s } (-\hat{y})$$

$$V_{COM} = \left\langle 2.5\cdot10^3 \text{ m/s } (+\hat{x})\ ;\ 6.8\cdot10^3 \text{ m/s } (-\hat{y}) \right\rangle$$

in polar coordinate form then

$V_{com} = 7.3\cdot10^3 \frac{m}{s}$ $\theta = 69.8°$ below $(+\hat{x})$

or $\theta = 290.2°$ wrt $(+\hat{x})$

or $\theta = -69.8°$ wrt $(+\hat{x})$