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PHYS 121 **EXAM I** **February 27, 2009**

SOLN **Prof. S. M. Bhagat**

Name:

(Sign in ink, print in pencil)

Notes

1) There are four (4) problems in this exam. Please make sure that your copy has all of them.

2) Please show your work indicating clearly what formula you used and what the symbols mean. Just writing the answer will not get you full credit. In stating vectors give both magnitude and direction.

3) Write your answers on the sheets provided.

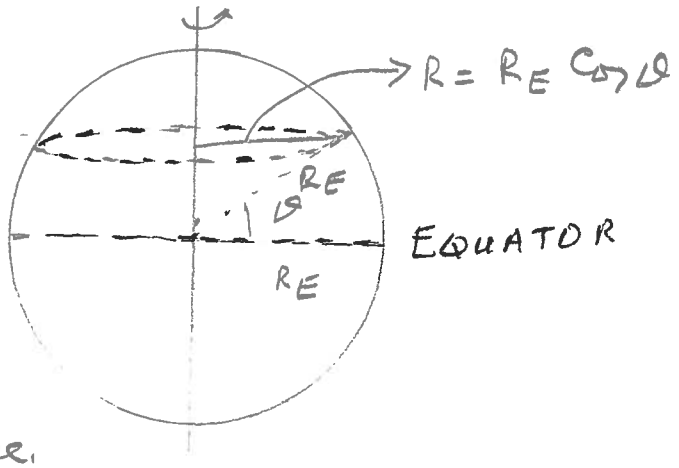
4) Do not forget to write the units.

5) Do not hesitate to ask for clarification at any time during the exam. You may buy a formula at the cost of one point.

Best of Luck! God Bless You!

Problem 1a The Earth can be thought of as a sphere of radius 6400 km which rotates about its axis (passing through the poles) once every 24 hours. If a person is located near New York where the latitude is close to 45°N what is her/his speed in meters/ sec due to the rotation? Why? (10)

As the Earth rotates every point on its surface will travel on a circle of radius



$R = R_E \cos\theta$

where θ is the latitude.

& $R_E = 6400$ km

So for a person located near NY

$$S = \frac{2\pi \times 6400 \times 10^3 \times \cos 45}{24 \times 3600} \text{ m/sec} \qquad \cos 45 = \frac{1}{\sqrt{2}}$$

$$= 329 \text{ m/sec.}$$

Problem 1b The motion of an object is described by the equation

$$\underset{\rightarrow}{x} = (15 - 20t - 5t^2)\hat{x}$$

Write down its position, velocity and acceleration vectors at $t = 0$

(5, 5, 5)

The motion is given by the equation

$$\underset{\rightarrow}{x} = (x_i + v_i t + \tfrac{1}{2} a t^2)\hat{x}$$

where x_i, v_i, a are magnitudes of position, vel. & acc. at $t = 0$.

If we choose to measure distances in meters and times in seconds

$$\underset{\rightarrow}{x_i} = 15\text{m}\,\hat{x}$$

$$\underset{\rightarrow}{v_i} = -20\text{m/sec}\,\hat{x}$$

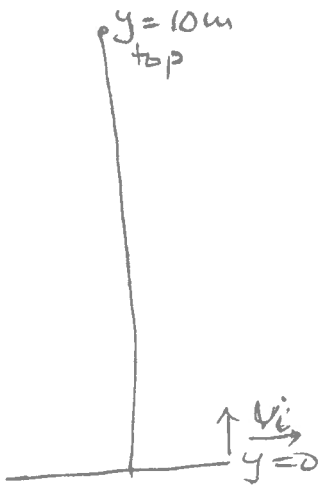
$$\underset{\rightarrow}{a} = -10\text{m/sec}^2\,\hat{x}$$

Problem 2 Starting from y=0, a ball is thrown vertically upward $(+\hat{y})$ and reaches a height of 10 meters before returning to ground. (i) Why does it stop rising? (ii) What is its acceleration at y= 10m. (iii) What was its initial velocity? (iv) If you want it to reach a height of 20m by what factor would you change its initial velocity? (3, 5, 10, 7)

i) It stops rising because its velocity goes to zero.

ii) It is unsupported so its acceleration is

$$\vec{a} = -9.8\,m/s^2\,\hat{y}$$



(iii) because $\vec{a}$ is constant the magnitude of its velocity obeys

$$v^2 = v_i^2 - 19.6(y - y_i)$$

Since $y_i = 0$, and at y_{top}, $v = 0$.

$$0 = v_i^2 - 19.6\,y_{top} \quad \text{— (1)}$$

$$v_i = \sqrt{196}\ m/s$$

$$\vec{v_i} = +14\,m/s\,\hat{y}$$

(iv) From Eq (1)

$$y_{top} = \frac{v_i^2}{19.6}$$

To increase y_{top} from 10 m to 20 m we must double v_i^2, and that requires v_i to increase by a factor of $\sqrt{2}$.

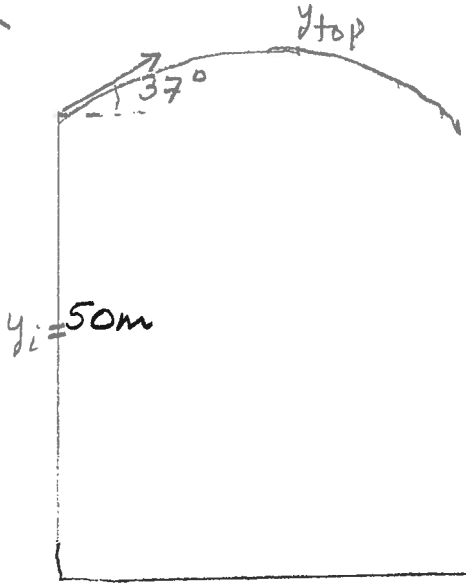
Problem 3 A ball is launched from a 50m high tower with a velocity of 20m/s at an angle of 37° above the horizontal. (i) How high will the ball go? (ii) When will it be at y= 50m again? (iii) What will be the values of $\underset{\sim}{x}$, $\underset{\sim}{v}$ and $\underset{\sim}{a}$ when ball is again at y= 50m. (25)

Initial position $x_i = 0$, $y_i = 50m$

Initial velocity

$\underset{\sim}{V_i} = 20\cos 37\,\hat{x} + 20\sin 37\,\hat{y}$

$= 16\,m/s\,\hat{x} + 12\,m/s\,\hat{y}$



i) At its highest point $V_y = 0$.

$V_y^2 = (V_i \sin\theta_i)^2 - 19.6(y - y_i)$.

$0 = (V_i \sin\theta_i)^2 - 19.6(y - y_i)$

$y_{top} = \frac{(V_i \sin\theta_i)^2}{19.6} + y_i = \frac{144}{19.6} + 50 = 57.3m$

(ii) For a projectile y varies as

$y = y_i + (V_i \sin\theta_i)t - 4.9t^2$

To beat 50m again

$50 = 50 + 12t - 4.9t^2$

$t = \frac{12}{4.9} = 2.45\,sec.$

(iii) Along x, v is const.

So $\underset{\sim}{x} = (16 \times 2.45)\hat{x} = 39.2\,m\,\hat{x}$

$V_x = 16m/s$ $V_y = 12 - 2.4 \times 9.8 = -12\,m/s$

So $\underset{\sim}{V} = 16m/s\,\hat{x} - 12m/s\,\hat{y}$

acceleration

$\underset{\sim}{a} = -9.8\,m/s^2\,\hat{y}$

b/c Ball is unsupported.

Problem 4a If your mass on Earth is 50~~N~~ kg what is your mass on the moon. (5)

Mass is an intrinsic property.
It does not change.
On moon Mass = 50 kg

Problem 4b The acceleration due to gravity on the moon is $\frac{1}{6}$th of that on Earth. By what factor would your weight change if you went from Earth to the moon? Why? (5)

$\vec{W} = -Mg\hat{y}$

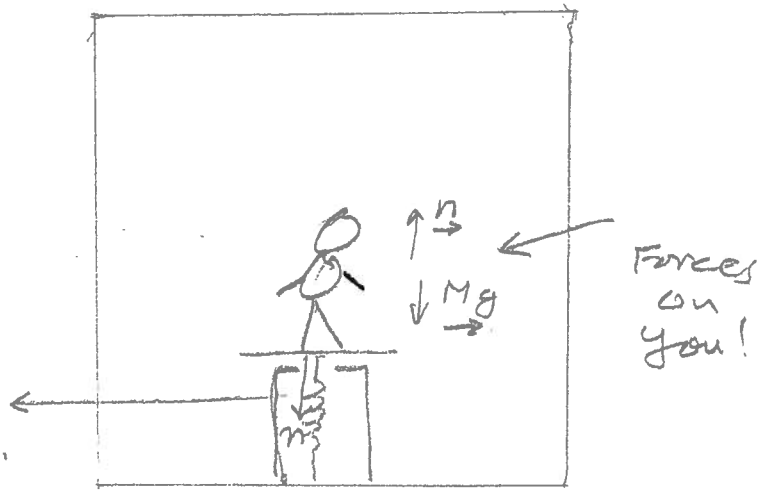
On Earth $\vec{W}_E = -9.8M\hat{y} = -490N\hat{y}$

On Moon $\vec{W}_M = -\frac{9.8}{6}M\hat{y} = -\frac{490}{6}N\hat{y}$

So your weight reduces to $\frac{1}{6}$th of its value on Earth. It reduces by $\frac{5}{6}$th of its value on Earth

Problem 4c You are in an elevator standing on a weighing machine. Your mass is 50kg. What will be the readings on the machine if (i) elevator is at rest (ii) moving up at a constant velocity of $3m/s\ \hat{y}$ (iii) moving down at a constant acceleration $\underset{\rightarrow}{a} = -g\hat{y}$? Why? (2, 3, 10)

When you stand on a weighing machine, there are two forces on you $-Mg\hat{y}$ and $n\hat{y}$ (machine). Earth pulls by Newton's Third law force on machine is $-n\hat{y}$ and that is what the machine records.



i) If elevator at rest, Eqm prevails on you!

$$\therefore (n - Mg)\hat{y} = 0$$

$$n = Mg = 50 \times 9.8 = \underline{\underline{490N}}$$

ii) If elevator moves at constant velocity, it is still an inertial system so you are still in Eqm

$$(n - Mg)\hat{y} = 0$$

$$n = Mg = 490N$$

[Recall, in an inertial system no experiment can reveal your own velocity].

iii) If elevator accelerates, you acquire the acceleration and Newton says $M\underset{\rightarrow}{a} = \Sigma \underset{\rightarrow}{F}$ At that pt. of that time. ONLY FORCES ON YOU ARE $n\hat{y}$ & $-Mg\hat{y}$ SO

$$M\underset{\rightarrow}{a} = (n - Mg)\hat{y}$$

$$\underset{\rightarrow}{n} = M(g + a)\hat{y} = M(9.8 - 9.8)\hat{y} = 0$$

Weighing machine records <u>Zero</u>