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Department of Engineering Sciences
Phy101 Physics I
Midterm Examination
November 03, 2025 10:20 – 11:50
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 90 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
◇ **Calculator is allowed.**
◇ **You are not allowed to use any other electronic equipment in the exam.**

Question	Grade	Out of
1A		15
1B		15
2		15
3		20
4		15
5		20
TOTAL		100

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1. A) A rectangular piece of copper is 6.43±0.02 cm long and 1.50±0.01 cm wide.

   i Find the area of the rectangle and the uncertainty in the area.

   ii Find the perimeter of the rectangle with the uncertainty?

   Express the answers with the correct number of significant figures.

$L = 6.43 \pm 0.02$ cm

$W = 1.50 \pm 0.01$ cm

Area: $A = L * W$

Perimeter: $P = 2L + 2W$

i) Area; find $A \pm \Delta A$

$A = L * W = 6.43 * 1.50 = 9.65\ cm^2$ 2

$\Delta A = |A| \sqrt{\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta W}{W}\right)^2} = |9.65\ cm^2| \sqrt{\left(\frac{0.02}{6.43}\right)^2 + \left(\frac{0.01}{1.50}\right)^2} = 0.07\ cm^2$ 2 2

$\Rightarrow$ Area: $\boxed{9.65 \pm 0.07\ cm^2}$ 2

ii) Perimeter; find $P \pm \Delta P$

$P = 2L + 2W \Rightarrow$ $2L = 2 * (6.43 \pm 0.02\ cm) = 12.9 \pm 0.04\ cm$ 1

$2W = 2 * (1.50 \pm 0.01\ cm) = 3.00 \pm 0.02\ cm$ 1

$P = 15.9$ cm 1

2 $\Delta P = \sqrt{\Delta L^2 + \Delta W^2} = \sqrt{(0.04\ cm)^2 + (0.02\ cm)^2} = 0.05$ cm

$\Rightarrow$ Perimeter: $\boxed{15.9 \pm 0.1\ cm}$ 2

B) Three vectors are given by $\vec{a} = 3.0\hat{i} + 3.0\hat{j} - 2.0\hat{k}$, $\vec{b} = -1.0\hat{i} - 4.0\hat{j} + 2.0\hat{k}$, and $\vec{c} = 2.0\hat{i} + 2.0\hat{j} + 1.0\hat{k}$. Find (a) $\vec{a}.(\vec{b} \times \vec{c})$, (b) $\vec{a}.(\vec{b} + \vec{c})$, and (c) $\vec{a} \times (\vec{b} + \vec{c})$.

Three vectors:

$\vec{a} = 3.0\hat{i} + 3.0\hat{j} - 2.0\hat{k}$

$\vec{b} = -1.0\hat{i} - 4.0\hat{j} + 2.0\hat{k}$

$c = 2.0\hat{i} + 2.0\hat{j} + 1.0\hat{k}$

i) $\vec{a}.(\vec{b}\times\vec{c}) = ?$ (scalar)

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -1 & -4 & 2 \\ 2 & 2 & 1 \end{vmatrix} \Rightarrow \vec{b}\times\vec{c} = (b_y c_z - b_z c_y)\hat{i} + (b_z c_x - b_x c_z)\hat{j} + (b_x c_y - b_y c_x)\hat{k}$$ 3

$$\vec{b}\times\vec{c} = ((-4)(1) - (2)(2))\hat{i} + ((2)(2) - (-1)(1))\hat{j} + ((-1)(2) - (-4)(2))\hat{k} = \underline{-8\hat{i} + 5\hat{j} + 6\hat{k}}$$ 2

$$\vec{a}.(\vec{b}\times\vec{c}) = (3\hat{i} + 3\hat{j} - 2\hat{k}).(-8\hat{i} + 5\hat{j} + 6\hat{k}) = -24 + 15 - 12 = \boxed{-21}$$ 3

ii) $\vec{a}.(\vec{b}+\vec{c}) = ?$ (scalar)

$\vec{b} + \vec{c} = 1\hat{i} - 2\hat{j} + 3\hat{k}$ 1

$$\vec{a}.(\vec{b}+\vec{c}) = (3\hat{i} + 3\hat{j} - 2\hat{k}).(1\hat{i} - 2\hat{j} + 3\hat{k}) = 3 - 6 - 6 = \boxed{-9}$$ 3

iii) $\vec{a}\times(\vec{b}+\vec{c}) = ?$ (vector)

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 3 & -2 \\ 1 & -2 & 3 \end{vmatrix} \rightsquigarrow ((3)(3) - (-2)(-2))\hat{i} + ((-2)(1) - (3)(3))\hat{j} + ((3)(-2) - (3)(1))\hat{k}$$

$$= \boxed{5\hat{i} - 11\hat{j} - 9\hat{k}}$$ 3

2. The position $\vec{r}$ of a particle moving in an xy-plane is given by $\vec{r} = (2.00t^3 - 5.00t)\hat{\imath} + (6.00 - 7.00t^4)\hat{\jmath}$, with $\vec{r}$ in meters and t in seconds. In unit-vector notation, calculate (a) $\vec{r}$, (b) $\vec{v}$, and (c) $\vec{a}$ for t=2.00 s. (d) What is the angle between the positive direction of the x axis and a line tangent to the particle's path at t=2.00 s?

$\vec{r} = (2t^3 - 5t)\hat{\imath} + (6 - 7t^4)\hat{\jmath} \sim \vec{r}(t)$

2 1

i) $\vec{r}(t=2\,s) \overset{1}{=} (2\cdot 8 - 5\cdot 2)\hat{\imath} + (6 - 7\times 16)\hat{\jmath} = \boxed{(6\hat{\imath} - 106\hat{\jmath})\,m}$

2 1

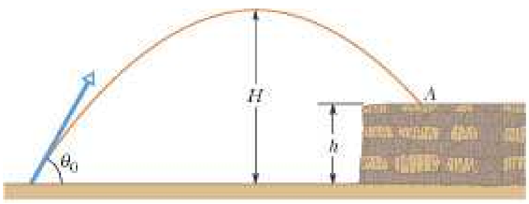
ii) $\vec{v} = \frac{d\vec{r}}{dt} \underset{1}{=} (6t^2 - 5)\hat{\imath} - 28t^3\hat{\jmath} \rightsquigarrow \vec{v}(t=2s) = (6\cdot 4 - 5)\hat{\imath} - 28\times 8\hat{\jmath} = \boxed{(19\hat{\imath} - 224\hat{\jmath})\,m/s}$

iii) $\vec{a} = \frac{d\vec{v}}{dt} \underset{1}{=} 12t\hat{\imath} - 84t^2\hat{\jmath} \rightsquigarrow \vec{a}(t=2s) = 12\cdot 2\hat{\imath} - 84\cdot 4\hat{\jmath} = \boxed{(24\hat{\imath} - 336\hat{\jmath})\,m/s^2}$

2 1

iv) Direction of the velocity computed in part (ii), since that represents the asked-for tangent line. $\rightsquigarrow \theta = \tan^{-1}\frac{-224\,m/s}{19\,m/s} = \boxed{-85.2^\circ \text{ OR } 94.8^\circ}$ 3

3. In figure given below, a stone is projected at a cliff of height h with an initial speed of $42.0\ m/s$ directed at angle $\theta_0 = 60°$ above the horizontal. The stone strikes point A in $5.50\ s$ after launching.



Find

i the height h of the cliff,

ii the speed of the stone hit at point A,

iii the maximum height H reached above the ground.

$v_0 = 42.0\ m/s$
$\theta_0 = 60°$
$t_A = 5.50\ s$

i) $y - y_0 = v_0 \sin\theta\, t - \frac{1}{2} g t^2$ (2)

$h - 0 = (42 m/s) \sin 60°(5.5s) - \frac{1}{2}(9.8 m/s^2)(5.5s)^2$ (2)

$\rightarrow h = 51.8\ m$ (1) (1)

ii) 

v at 5.5 s ?

$v = \sqrt{v_x^2 + v_y^2}$ (2)

$v_x = v_{0x} = v_0 \cos\theta_0$

$v_y = v_0 \sin\theta_0 - gt$

$\rightarrow \vec{v} = v_x \hat{i} + v_y \hat{j} = v_0 \cos\theta_0 \hat{i} + (v_0 \sin\theta_0 - gt)\hat{j}$ (2)

$v(t = 5.5s) = \sqrt{v_0^2 \cos^2\theta_0 + (v_0 \sin\theta_0 - gt)^2}$ (2)

$= \sqrt{(42 m/s \cos 60)^2 + [42 m/s \sin 60 - (9.8 m/s^2)(5.5s)]^2} = 27.35\ m/s$ (1) (1)

iii) H ? at maximum height $v_y = 0$

$v_y = v_0 \sin\theta_0 - gt = 0$ (1) (1) $\rightarrow t_H = \frac{v_0 \sin\theta_0}{g} = \frac{(42 m/s)(\sin 60°)}{9.8 m/s^2} = 3.71\ s$

$\Rightarrow y - y_0 = H = v_0 \sin\theta_0\, t_H - \frac{1}{2} g t_H^2$ (2)

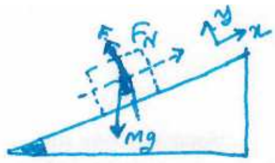
$= 42 m/s \sin 60°\ 3.71s - \frac{1}{2}\ 9.8 m/s^2\ 3.71s^2$

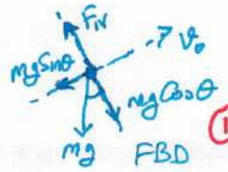
$= 67.5\ m$ (1) (1)

4. A block is projected up a frictionless inclined plane with initial speed $v_0 = 3.50\ m/s$. The angle of incline is $\theta = 32.0°$. (a) How far up the plane does the block go? (b) How long does it take to get there? (c) What is its speed when it gets back to the bottom? Prove your answer.

$v_0 = 3.50\ m/s$

$\theta = 32°$





1

(1) $x - x_0 = v_0 t + \frac{1}{2}at^2$

(2) $v = v_0 + at$

(3) $v^2 = v_0^2 + 2a(x - x_0)$

(4) $a = -g\sin\theta$ 2

i) block stops: $v = 0$, find Δx

(3) & (4) $0 = v_0^2 + 2a\Delta x$ 2 $\rightsquigarrow \Delta x = -\dfrac{v_0^2}{2(-g\sin\theta)} = -\dfrac{1}{2}\left(\dfrac{3.50\ m/s}{-(9.8\ m/s^2)\sin 32°}\right) = \boxed{1.18\ m}$ 1 1

ii) required time when block stops

(2) & (4) $0 = v_0 + at$ 2 $\Rightarrow t = \dfrac{-v_0}{a} = \dfrac{-3.50\ m/s}{(-9.8\ m/s^2)\sin 32} = \boxed{0.674\ s}$ 1 1

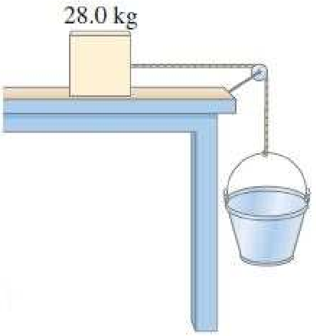
iii) return speed is identical to the initial speed (no dissipative forces)

2 total time (up & back down) : $2 \times 0.674\ s = \underline{1.35\ s}$ 2

then, the velocity it returns: $v = v_0 + at = v_0 - g\sin\theta t$

$\Rightarrow v = 3.50\ m/s - (9.8\ m/s^2)\sin 32\ (1.35\ s) = \boxed{-3.50\ m/s}$ negative sign indicates as downward 2

5. A 28.0 kg block is connected to an empty 2.00 kg bucket by a cord running over a frictionless pulley as shown in the figure.

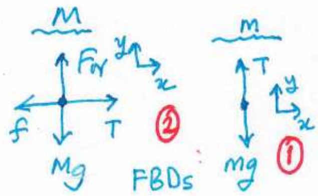


The coefficient of static friction between the table and the block is 0.45 and the coefficient of kinetic friction between the table and the block is 0.32. Sand is gradually added to the bucket until the system just begins to move.

i Calculate the mass of sand added to the bucket.

ii Calculate the acceleration of the system.

$M = 28\,kg$, $m = 2\,kg$, $\mu_s = 0.45$, $\mu_k = 0.32$



initially stationary.
T will increase by adding sand.
f_s will increase up to $f_{s,max} (= \mu_s F_N)$
Then the system will start to move.

i) Equations of motion (Newton's 2nd law)

M:

$x: \ \Sigma F_x = T - f_s = M a_{x,M}$ ①

$y: \ \Sigma F_y = F_N - Mg = M a_{y,M}$ ②

m:

$y: \ \Sigma F_y = -mg + T = -m a_{y,m}$ ③

no motion & $f_{s,max}$:

① $T - f_{s,max} = 0 \rightarrow T = \mu_s F_N$

② $F_N - Mg = 0 \rightarrow F_N = Mg$

③ $T - mg = 0 \rightarrow T = mg$

④ $f_{s,max} = \mu_s F_N$

$\rightarrow \mu_s (Mg) = mg \rightarrow m = \mu_s M = (0.45)(28\,kg) = 12.6\,kg$

$\rightsquigarrow$ which is $m_{bucket} + m_{sand} = 12.6\,kg \rightsquigarrow m_{sand} = 12.6\,kg - 2\,kg = \boxed{10.6\,kg}$

ii) now, we have motion as: $a_{x,M} = a_{y,m} = a$ & $f_k = \mu_k F_N$

① $T - f_k = Ma$

③ $-T + mg = ma$

④ $f_k = \mu_k F_N$

$m(g-a) - \mu_k F_N = Ma \rightsquigarrow \dfrac{mg - \mu_k Mg}{(M+m)} = a$

$\rightarrow a = \dfrac{(12.6\,kg - 0.32(28\,kg))\,9.8\,m/s^2}{(28\,kg + 12.6\,kg)} = \boxed{0.88\,m/s^2}$