= Mathematical answer
= Multiple choice answer

1. The density of lead is C, $\approx$ $\boxed{11.0 \times 10\ g\,cm^{-3}}$

2. $Time = \frac{Distance}{Speed}$, $\frac{600\,km}{60\,km/hr} = \frac{10}{1\,hr} = \boxed{10\,hr}$ = C

3. 25m/s $\Rightarrow$ km/hr

$\frac{25\,m}{1\,s} \cdot \frac{1\,km}{1000\,m} \cdot \frac{60\,s}{1\,min} \cdot \frac{60\,min}{1\,hr} = \frac{90{,}000\,km}{1000\,hr} \Rightarrow \frac{90\,km}{1\,hr} \Rightarrow \boxed{90\,km/hr}$, D

4. $Acceleration = \frac{\Delta V}{\Delta T}$, $V_i = 0\,km/hr$, $V_f = 10\,km/hr$, $T = 60\,s$

$= \frac{10-0}{60} = \frac{10}{60} = \boxed{\frac{1}{6}\ km/hr/second}$, C

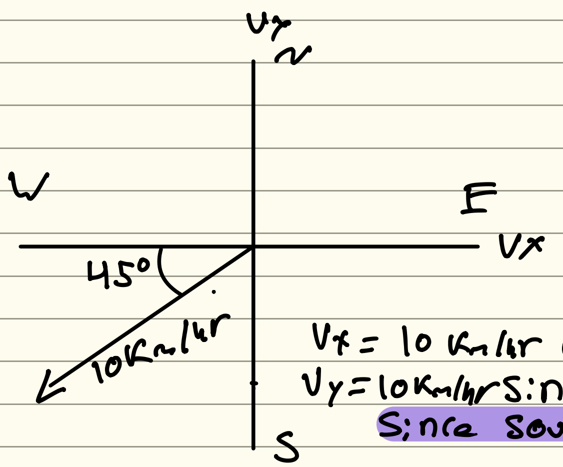
5. The North Quad is a wide space, but not that big. Probably around $\approx \boxed{500\,ft}$, C

6. 2 liters $\Rightarrow$ CC's, cm^3

$1L = 1000\,cm^3$, $\therefore 2L = 2000\,cm^3$, each bean is $\sim 0.5\,cm^3$

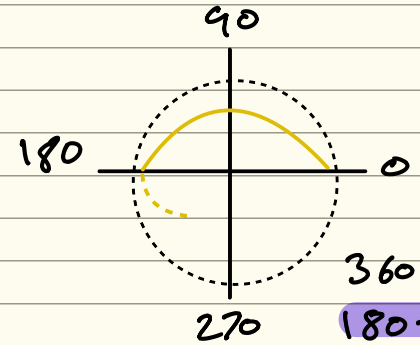
$\frac{2000\,cm^3}{0.5\,cm^3} = \boxed{4000\ beans}$, C

7. $\vec{v} = v_x\hat{i} + v_y\hat{j}$, V_x(east-west), V_y(North-South),



$V_x = 10\,km/hr\,\cos(45) = 5\sqrt{2} \approx 7.1$
$V_y = 10\,km/hr\,\sin(45) = 5\sqrt{2} \approx 7.1$
Since south = −, west = −, $\therefore$ −7.1, −7.1 D

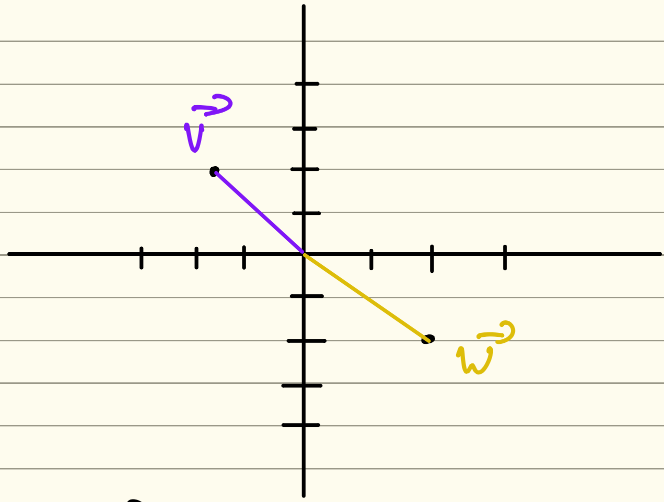
8.



360° total
180 + 45 = 225
A

9.

a) $\vec{v} = -2\hat{i} + 2\hat{j}$ and $\vec{w} = 2\hat{i} - 2\hat{j}$. Draw



b) what is $\vec{v} + \vec{w}$?

$$\left.\begin{aligned}\vec{v} &= 2\hat{i} + 2\hat{j} \\ \vec{w} &= 2\hat{i} - 2\hat{j}\end{aligned}\right] -2\hat{i} + 2\hat{i} + 2\hat{j} - 2\hat{j} = \boxed{0}$$

c) $\vec{v} \cdot \vec{w} = (-2)(2) + (2)(-2) = -4 - 4 = \boxed{-8}$

Unit 2

1. Cyclist velocity $= 15 m/s$ @ $t = 0s$, $a = 3 m/s^2$

a) velocity @ $t = 4s$?

$V_f = V_i + at$, $15 + (3)(4) = 15 + 12 = \boxed{27 m/s}$

b) Displacement @ $t = 4s$?

$S = V_i t + \frac{1}{2}(a)(t)^2$, $(15)(4) + \frac{1}{2}(3)(4)^2$, $60 + 24 = \boxed{84 \text{ meters}}$

c) Avg. and inst. v @ $t = 0, 4$?

@ $t = 0$, the instantaneous velocity is $\boxed{15 m/s}$

no displacement before $t = 0$, $\therefore$ $\boxed{V_{avg} = \text{undefined}}$

@ $t = 4$, the instantaneous velocity is $\boxed{27 m/s}$

$V_{avg} = \dfrac{\text{total displacement}}{\text{total time}}$, $\dfrac{84 m}{4s} = \boxed{21 m/s}$

@ $t = 0$ and $t = 4$, both velocities are different

2.

a) $P = (10, 600)$
$Q = (25, 2138)$

Speed of $P = \frac{\text{change in pos.}}{\text{change in time}} = \frac{600-200}{10-0} = \frac{400}{10} = \boxed{40\,m/s}$

speed of $Q = \frac{\text{change in pos.}}{\text{change in time}} = \frac{2138-200}{25-0} = \frac{1938}{25} \approx \boxed{77.52\,m/s}$

b) Slope is increasing from P to Q, ∴ acceleration is (+)

$A = \frac{VQ - VP}{TQ - TP} = \frac{77.52 - 40}{25 - 10} \approx \boxed{2.50\,m/s^2}$

3.

a) Distance before take off

Given:

$V_i = 0\,m/s$

$V_f = 6.0\,m/s$

$A = 0.8\,m/s$

$V_f^2 = v_i^2 + 2(A)(S)$

$6.0^2 = 0^2 + 2(0.8)(S)$

$\frac{36}{2(0.8)} = \frac{2(0.8)S}{2(0.8)}$, $S = \frac{36}{1.6} \approx \boxed{22.5\text{ meters}}$

b) Time before take off

$V_f = V_i + At$

$\frac{6.0}{0.8} = 0 + \frac{(0.8)t}{0.8}$, $t = \frac{6.0}{0.8} = \boxed{7.5\text{ seconds}}$

4.

Baseball experiment

Given: Desired range = 60 m

Assume no air resistance, on flat ground, $g = 9.81\,m/s^2$, mass of ball = 0.15kg

Design:

For optimal range, the launch angle will be 45°

V_i calculated as:

$\text{Range} = \frac{V_\theta^2 \sin 2\theta}{g}$, where: $V_\theta = V_i$, θ = launch angle (45°), $g = 9.81\,m/s^2$

$60 = \frac{V_\theta^2 \sin 90}{9.81} \rightarrow 60 = \frac{V_\theta^2}{9.81}$ ~~9.81~~ $\rightarrow \sqrt{588.6} = \sqrt{V_\theta^2}$, $V_\theta \approx \boxed{24.26\,m/s}$

∴ V_i @ 45° should = 24.26 m/s

Time of flight:

Time = $\frac{(2 V_0 \sin\theta)}{g}$, $\frac{(2)(24.26)(\sin 45)}{9.81} \approx \frac{34.31}{9.81} \approx \boxed{3.5 \text{ Seconds}}$

Once tested on PhET with the given calculations, T = 3.46 seconds
Range = 58.72 meters

5. Trial 1:

Length: 58 cm
Period: 1.26

$1.26 = 2\pi\sqrt{\frac{0.58}{9.81}}$

$1.26 = 2\pi(0.243)$

$1.26 \neq 1.53$

Trial 2:

Length: 48 cm
Period: 1.23

$1.23 = 2\pi\sqrt{\frac{0.48}{9.81}}$

$1.23 \neq 1.46$

Trial	Observed	Theoretical
1	1.26	1.53
2	1.23	1.46
3	0.85	0.90
4	1.63	1.67
5	1.18	1.17

Trial 3:

Length: 20 cm
Period: 0.85

$0.85 = 2\pi\sqrt{\frac{0.2}{9.8}}$

$0.85 \neq 0.90$

Trial 4:

Length: 69 cm
Period: 1.63

$1.63 = 2\pi\sqrt{\frac{0.69}{9.8}}$

$1.63 \neq 1.67$

Trial 5:

Length: 34
Period: 1.18

$1.18 = 2\pi\sqrt{\frac{0.34}{9.8}}$

$1.18 \neq 1.17$

Unit 2

a) Tension in the Rope

$F\perp$: The perpendicular force applied to the rope (1000 N)
θ: The angle between the rope and the line between the vehicle and the tree (7 degrees)
T: The tension in the rope

Using trigonometry:

The horizontal component of the tension (T_x) is what pulls the vehicle
$T_x = T\cos\theta$
$F\perp = T_x \therefore F\perp = T\cos\theta$

Solving for T

$T = F\perp / \cos\theta$
$T = 1000N / \cos 3$
$T \approx 1002.1N$ ∴ $\boxed{1002.1N = \text{the tension in the rope}}$

b) Acceleration of the Vehicle
Understanding the Forces:
T_x: The horizontal component of the tension ($\approx 1002.1N$)
F_friction: The force Of kinetic friction opposing the motion
m: Mass of vehicle (900kg)
a: Acceleration of the vehicle

Calculating Friction:
F_friction: μmg
Where:
μ is the coefficient of kinetic friction (0.05)
m is the mass of the vehicle (900 kg)
g is the accelation due to gravity ($9.8\ m/s^2$)
F_friction = (0.05)(900)(9.81)
F_friction $\approx$ 441.45 N

Net force = mass • Acceleration
T_x − F_friction = m • A

a = (T_x − F_friction)/m
a = (1002.1 − 441.45)/900
$\boxed{a \approx 0.623\ m/s^2}$

2.
a) Average Acceleration

Step 1: Convert units

$\frac{120\ km}{1\ hr} \cdot \frac{1000\ m}{1\ km} \cdot \frac{1\ hr}{60\ min} \cdot \frac{1\ min}{60\ s} \approx \boxed{33.3\ m/s}$

$V_f^2 = V_i^2 + 2as$, $0 = 33.3^2 + 2(a)(100)$
$a = \frac{(V_f^2 - V_i^2)}{2s}, \frac{0 - 33.3^2}{2(100)} = \boxed{-5.56\ m/s^2}$ ∴ deceleration

b) $F = ma$,
$m = 20{,}000\ kg$
$a = (-5.56\ m/s^2)$

$\boxed{F \approx -111{,}200\ N}$ The tow cable exerts a force of approx. 111,200N to Stop the jet

3.

Given:
$F_1 = 40N @ 20°$
$F_2 = 30N @ 40°$

$F_1x = F_1 \cos 20 \approx 37.59 N$
$F_1y = F_1 \sin 20 \approx 13.68 N$
$F_2x = F_2 \cos 40 \approx 22.98 N$
$F_2y = F_2 \sin 40 \approx 19.28 N$

$Fx = F_1x + F_2x \approx 37.59 N + 22.98 N \approx 60.57 N$
$Fy = F_1y + F_2y \approx 13.68 N + 19.28 N \approx 32.96 N$

$F_{net} = \sqrt{(Fx^2 + Fy^2)} \approx \sqrt{(60.57^2 + 32.96^2)} \approx 68.93 N$
$\theta = \tan^{-1}(Fy/Fx) \approx \tan^{-1}(32.96/60.57) \approx 28.31°$

$F_{net} = ma$
$m = 50 kg$
$a = F_{net}/m$
$a \approx 68.93/50 kg$
$\approx 1.38 m/s^2$

The acceleration of the sled is $1.38 m/s^2$ in the direction of the net force

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Unit 3

1) $F_{net} = mg \sin\theta - \mu mg \cos\theta$
and
$F_{net} = ma$

$\therefore \quad mg \sin\theta - \mu mg \cos\theta = ma$

$$\boxed{a = g(\sin\theta - \mu \cos\theta)}$$

b) When $\mu \to 0$

$a = g \sin\theta - 0 \cos\theta$
$\boxed{= g \sin\theta}$

2) a)
Given:
$\theta = 10°$
$g = 9.81 m/s^2$
$\mu \approx 0.05$

$a = g(\sin\theta - \mu \cos\theta)$
$a = 9.81 \sin 10 - 0.05 \cos 10$
$\boxed{a \approx 1.53 m/s^2}$

b) Distance and Speed after 30 s

$S = V_i t + \left(\frac{1}{2}\right) a t^2$

$S = \left(\frac{1}{2}\right)(1.53)(30^2)$

$S \approx 688.5$ meters

$V_f = V_i + at$

$V_f = 0 + (1.53)(30)$

$\boxed{V_f = 45.9 \text{ m/s}}$ after 30 seconds

3.

a) Centripetal Force

$F_c = L \sin \theta$

$F_c = 80000N \sin 30$

$= 40000N$

$\therefore$ centripital force $= \boxed{40,000 \text{ N}}$

b) Turn Radius

$F_c = \frac{mv^2}{r}, \quad r = \frac{mv^2}{F_c}$

$\frac{600 \text{ km}}{\text{hr}} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{1 \text{ hr}}{60 \text{ min}} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 166.6 \text{ m/s}$

$r = \frac{(6000)(166.6)^2}{40,000} = 4163.334$ meters

$\therefore$ the turn radius $\approx \boxed{4163 \text{ meters}}$

c) Time to complete $\frac{1}{2}$ turn

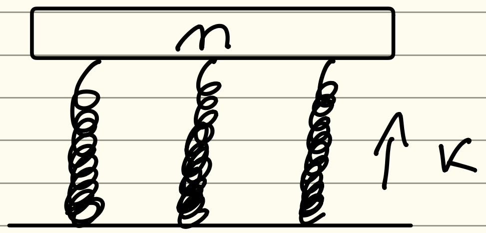
$\text{Distance} = \frac{1}{2} 2 \pi r$

$\text{Time} = \frac{\text{distance}}{\text{speed}}, \quad \text{Time} = \frac{(\pi r)}{v} \Rightarrow \frac{(\pi\, 4163)}{166.6} \approx 785.64$

$\therefore$ it will take $\approx$ 786 seconds or 13.1 minutes for the plane to go halfway

4. Analyzing the Spring System

a)



b) Expression

$F_1 + F_2 + F_3 = mg, \quad F = kx$

$kx + kx + kx = mg \rightarrow 3kx = mg$

$$\boxed{x = \frac{mg}{3k}}$$

c) Limit as $k \rightarrow \infty$

As $k \rightarrow \infty$, the denominator $(3k)$ becomes infinitely large
This means displacement (x) approaches 0

$\therefore$, in the limit that $k \rightarrow \infty$, the displacement goes to zero

5)

a) w/o parachute

$F_{gravity} = mg, \quad F_{drag} = \frac{1}{2} \rho v^2 CA$

$mg = \frac{1}{2} \rho v^2 CA, \quad v = \sqrt{\frac{2mg}{\rho CA}} \rightarrow \sqrt{\frac{(2)(60)(9.81)}{(1.2)(0.5)(0.25)}} \approx 56.7\,m/s$

56.7 m/s in km/hr $\approx$ 204 km/hr

$\therefore$ terminal velocity w/o parachute is 204 km/hr

b) w/ parachute

$v = \sqrt{\frac{(2)(60)(9.81)}{(1.2)(0.5)(25)}} \approx 5.67\,m/s$ in km/hr $= \boxed{20.4\ km/hr}$

$\therefore$ terminal velocity w/ parachute $= \boxed{20.4\ km/hr}$

6)

a) Δ in length

$$\frac{\Delta L}{L_0} = \frac{F}{(A)(Y)}$$

Given:

$Y = 45 \times 10^8 \ N/m^2$

$F = 10{,}000 \ N$

$L_0 = 10 \ m$

Diameter $= 20cm \therefore r = 10 \ cm$ or $0.1 \ m$

$A = \pi r^2 = \pi (0.1m)^2$

$$\frac{\Delta L}{10m} = \frac{10{,}000 \ N}{((\pi)(0.1m))^2 (45 \times 10^8)}$$

$\Delta L \approx 7.07 \times 10^{-7}$, $\therefore$ change in length $\approx$ 7.07×10^{-7} meters

b) Different material

$$\frac{\Delta L}{10m} = \frac{10{,}000 \ N}{((\pi)(0.1m))^2 (22.5 \times 10^8 \ N/m^2)}$$

$\Delta L \approx 1.41 \times 10^{-8} m$

$\therefore$ with a material w/ half the Young's modulus the $\Delta L = 1.41 \times 10^{-8}$ meters