Name= **Studio Days/Time=**

Eng. Phys. I **Exam 2 - Chs. 2,4,5,6 - Vectors, 2D Motion, Newton's Laws** **Feb. 18, 2022**

Write **neat** & **clear** work. Show **formulas** used, essential steps, results with correct **units** and **significant figures**. Points shown in parenthesis. For TF and MC, choose the *best* answer. Use $g = 9.80$ m/s^2. Ignore air resistance unless it is mentioned in a question. You are allowed to use only a calculator and the attached equation sheet.

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1. (3) A displacement vector has components $\Delta x = -3.0$ m, $\Delta y = 4.0$ m, $\Delta z = 0$.
Its magnitude is

a. 1.0 m. b. 5.0 m. c. 7.0 m. d. 12.0 m. e. 25.0 m.

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2. (3) A velocity vector has a magnitude of 42 m/s and points at 32° west of south.
Its component along an axis pointing north is

a. (42 m/s)cos(32°). b. -(42 m/s)cos(32°), c. (42 m/s)sin(32°). d. -(42 m/s)sin(32°).

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3. (3) Two force vectors are $\vec{\mathbf{F}}_1 = 2.0\hat{\mathbf{i}} - 4.0\hat{\mathbf{j}}$ N and $\vec{\mathbf{F}}_1 = 6.0\hat{\mathbf{i}} + 3.0\hat{\mathbf{j}}$ N. Which of the following are true?

a. The forces are parallel. b. The forces are perpendicular. c. The angle between the forces is 30°.

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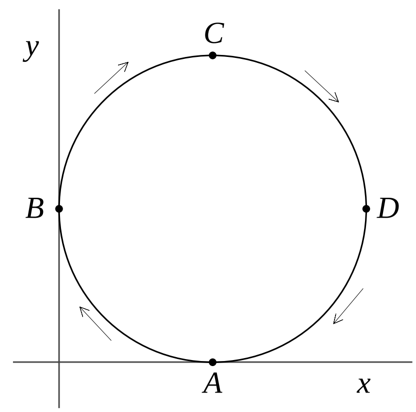
4. (14) A car moves at a constant speed of 26.0 m/s clockwise along a quarter circle of radius $R = 236$ m from A to B as shown. Use $\hat{\mathbf{i}}, \hat{\mathbf{j}}$ unit vector notation.



a) (8) Calculate its average velocity vector for the motion from A to B.

b) (6) Calculate its average acceleration vector for the motion from A to B.

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5. (2) **T F** Newton's First Law implies that an object at rest has no forces acting on it.

6. (2) **T F** The acceleration of a mass in uniform circular motion is unchanging.

7. (2) **T F** When a car makes a left turn, its acceleration is also to the left.

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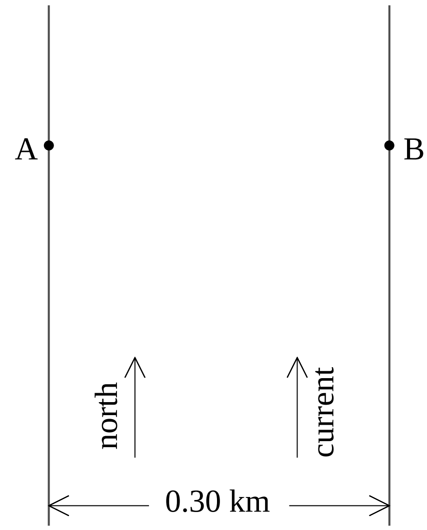
8. (12) Joe wants to paddle a canoe due east (from A to B in the diagram) across a 0.30-km-wide river that flows due north at 3.0 m/s. He can paddle at 5.0 m/s relative to the water.



a) (8) In what direction should Joe point the canoe as he paddles, so that he will arrive at a point on the opposite shore due east of where he starts? That is, find the direction of $\vec{v}_{BW}$. Give the result using map directions, like 27° west of north or similar.

b) (4) How long does it take for him to reach the opposite shore?

9. (3) If you can throw a projectile straight up to a height $h = 28.0$ m, then the maximum range it can have on level ground when thrown at the same initial speed $v_0 = \sqrt{2gh}$ is

a. 7.0 m. b. 14.0 m. c. 28.0 m. d. 56.0 m. e. something else.

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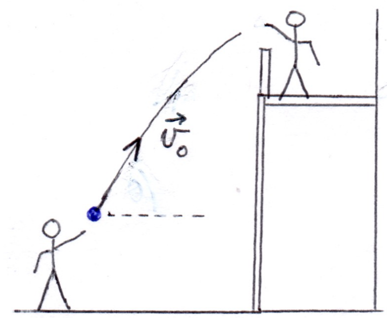
10. (12) Jimmy throws a baseball to Nathan, who catches it 1.34 s later at the peak of its trajectory, up on his deck above Jimmy. The two are separated by a horizontal distance of 8.20 m.



a) (8) Find the horizontal and vertical components (v_{0x}, v_{0y}) of the ball's initial velocity $\vec{\mathbf{v}}_0$.

b) (4) How high above its release point does Nathan catch the ball?

11. (2) **T F** A 100-kg object on Earth will have the same mass on the moon.

12. (2) **T F** A 250-N object on Earth will have the same weight on the moon.

13. (2) When you jump upward from a trampoline, it exerts a force on your feet. Which force is the reaction force to that "action" force?

a. the normal force on your feet.
b. gravitational force on your body.
c. the force of your feet on the trampoline.
d. air resistance pushing down on you.

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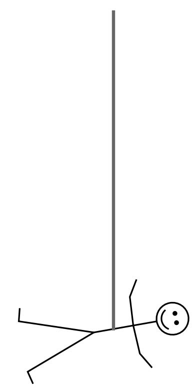
14. (12) Cheryl, whose mass is 65 kg, trys bungee jumping. She leaps from a bridge and after free falling, the bungee cord tightens and she decelerates from moving down at 24 m/s to 0 m/s over a time interval of 4.0 s. There is an air resistance force of average magnitude 95 N also slowing her fall. After that initial deceleration she bounces up and down until coming to rest.



a) (6) Draw and label the forces on Cheryl during the initial deceleration (free body diagram), and indicate the direction of her acceleration.

b) (6) During the initial deceleration, what was the magnitude of the average tension in the bungee cord?

15. (2) **T F** Static friction acting on a mass can never accelerate that mass.

16. (2) **T F** In the washer spin cycle water leaves the clothes because of centripetal force.

17. (2) **T F** Negotiating a level curve, a car's tires require friction to hold the curve.

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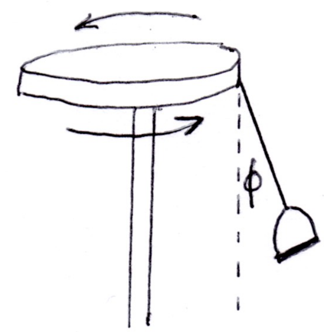
18. (12) During a snowstorm you are driving a 1240-kg car wth 4-wheel drive. On a level road, the maximum forward acceleration you can get before the tires start slipping is $0.16g$. When you brake suddenly on the level road, the wheels lock and the car skids at a deceleration of $-0.080g$.

a) (6) Calculate the coefficient of static friction for the tires on the road in this situation.

b) (6) Find the angle (above horizontal) of the steepest incline that the car will be able to climb at constant speed without sliding backwards.

19. (16) In a carnival ride the occupants sit in swings suspended from a horizontal circular wheel that rotates with a period of 8.0 s around a vertical axis. Suppose the mass of the swing and its occupant is 75 kg, and they move in a circle of 4.0 m radius.



a) (4) What force (or forces or force component) provides the "centripetal force" on the swing with occupant? Be specific.

b) (6) What is the magnitude of the centripetal force?

c) (6) Estimate the angle ϕ that the swing cable makes with the vertical.

Prefixes

z=10^{-21},	a=10^{-18},	f=10^{-15},	p=10^{-12},	n=10^{-9},	$\mu = 10^{-6}$,	m=10^{-3},	c=10^{-2},	k=10^{3},	M=10^{6},	G=10^{9},	T=10^{12},	P=10^{15},	E=10^{18},	Z=10^{21}
zepto,	atto,	femto,	pico,	nano,	micro,	milli,	centi,	kilo,	mega,	giga,	tera,	peta,	exa,	zeta.

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration) — $G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (gravitational constant)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth) — $R_E = 6380$ km (mean radius of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass) — $m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$c = 299,792,458$ m/s (speed of light) — 1 amu = 1 u = $1.6605402 \times 10^{-27}$ kg (atomic mass unit)

Units & Conversions

1 inch = 1 in = 2.54 cm — 1 foot = 1 ft = 12 in = 0.3048 m
1 mile = 5280 ft =1760 yards — 1 mile = 1609.344 m = 1.609344 km
1 m/s = 3.6 km/hour — 88 ft/s = 60 mile/hour
1 acre = (1 mile)^2/640 = 43 560 ft^2 — 1 hectare = (100 m)^2 = 10^4 m^2
1 lb = 4.45 N — 1 N = 0.225 lb

Algebra

Quadratic equations: $ax^2 + bx + c = 0$, solved by $x = \left(-b \pm \sqrt{b^2 - 4ac}\right)/(2a)$.

Geometry

Triangles: $A = \frac{1}{2}bh$, Circles; $C = 2\pi r$, $A = \pi r^2$, arc $= s = r\theta$. Spheres: $A = 4\pi r^2$, $V = \frac{4\pi}{3}r^3$

Trigonometry

$\sin\theta = (\text{opp})/(\text{hyp})$, $\cos\theta = (\text{adj})/(\text{hyp})$, $\tan\theta = (\text{opp})/(\text{adj})$, $(\text{opp})^2 + (\text{adj})^2 = (\text{hyp})^2$.
$\sin^2\theta + \cos^2\theta = 1$, $a^2 + b^2 - 2ab\cos\gamma = c^2$, $\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$, $\alpha + \beta + \gamma = 180° = \pi$ rad.

Chapter 1 - Units, measurements, errors or uncertainties

Unit conversions:	value = # (old units),	(old units) × $\left(\frac{\text{new units}}{\text{old units}}\right)$ = (new units).
Significant figures:	÷ or ×, use the least no. of sig. figs.,	+ or −, drop the insignificant *digits*.
Sig. figs. "1" rule:	if 1st digit=1, keep 1 extra digit,	⟵ for division or multiplication only.
Measurements:	measurement = $x \pm \delta x$,	x = observed value, δx = error or uncertainty.
Percent error:	measurement = value ± error,	percent error = (error / value)×100%.
Combining errors:	÷ or ×, add the % errors,	+ or −, $\delta x = \sqrt{(\delta x_1)^2 + (\delta x_2)^2 + ...}$.

Chapter 2 - Vectors - Magnitude & Direction

2D Vectors:	$\vec{\mathbf{a}} = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}}$	magnitude = $a = \sqrt{a_x^2 + a_y^2}$	direction → $\tan\theta = a_y/a_x$
Components:	$a_x = a\cos\theta$	$a_y = a\sin\theta$	θ=angle to $+x$-axis.
Addition:	$\vec{\mathbf{a}} + \vec{\mathbf{b}}$, head to tail.	Subtraction: $\vec{\mathbf{a}} - \vec{\mathbf{b}}$ is $\vec{\mathbf{a}} + (-\vec{\mathbf{b}})$	$-\vec{\mathbf{b}}$ is $\vec{\mathbf{b}}$ reversed.
Scalar product:	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = ab\cos\phi$	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = a_xb_x + a_yb_y + a_zb_z$	$\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = 1$, $\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = 0$, etc.
Cross product:	$\lvert\vec{\mathbf{a}} \times \vec{\mathbf{b}}\rvert = ab\sin\phi$	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	$\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0$

Chapter 3 - 1D Kinematics - Straight-line motion

Velocity:	$v_{\text{avg}} = \Delta x/\Delta t$	$\Delta x = x - x_0$	$v(t) = \frac{dx}{dt}$= slope of $x(t)$
Acceleration:	$a_{\text{avg}} = \Delta v/\Delta t$	$\Delta v = v - v_0$	$a(t) = \frac{dv}{dt}$= slope of $v(t)$
Integrals = areas:	$x(t) = x_0 + \int_0^t v(t')dt'$,	$v(t) = v_0 + \int_0^t a(t')dt'$.	
Constant acceleration:	$v = v_0 + at$,	$v_{\text{avg}} = \frac{1}{2}(v_0 + v)$,	$\Delta x = v_{\text{avg}}\Delta t$.
	$x = x_0 + v_0t + \frac{1}{2}at^2$,	$x = x_0 + v_{\text{avg}}t$,	$v^2 = v_0^2 + 2a\Delta x$.
	(position from acceleration)	(using average velocity)	(timeless equation)
Free fall ($+y$-axis is up):	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

Chapter 4 - 2D and 3D Motion - Vector displacement, velocity, acceleration

Position:	$\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$	$\vec{\mathbf{r}} = (x, y, z)$	$\Delta\vec{\mathbf{r}} = (\Delta x, \Delta y, \Delta z)$
Velocity:	$\vec{\mathbf{v}}_{\text{avg}} = \Delta\vec{\mathbf{r}}/\Delta t$	$\vec{\mathbf{v}} = d\vec{\mathbf{r}}/dt$	$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0$
Acceleration:	$\vec{\mathbf{a}}_{\text{avg}} = \Delta\vec{\mathbf{v}}/\Delta t$	$\vec{\mathbf{a}} = d\vec{\mathbf{v}}/dt$	$\Delta\vec{\mathbf{v}} = \vec{\mathbf{v}} - \vec{\mathbf{v}}_0$
Projectiles:	$a_x = 0$	$v_x = v_{0x}$	$x = x_0 + v_{0x}t$
(+y-axis is up)	$a_y = -g$	$v_y = v_{0y} - gt$	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$
Range:	$R = (v_0^2/g)\sin(2\theta_0)$	$\leftarrow$ (range on level ground only)	
Relative Motion:	$\vec{\mathbf{v}}_{\text{BS}} = \vec{\mathbf{v}}_{\text{BW}} + \vec{\mathbf{v}}_{\text{WS}}$	B=Boat, S=Shore, W=Water.	BS is "boat relative to shore", etc.
Circular motion:	$a_c = v^2/r = \omega^2 r$	$v = 2\pi r/T = \omega r$	$\omega = 2\pi/T$, T=period of 1 rev.

Chapter 5 - Newton's laws and forces

Newton's 1$^{\text{st}}$ Law:	$\vec{a} = d\vec{v}/dt = 0$ unless $\vec{F}_{\text{net}} \neq 0$	$\vec{F}_{\text{net}} = \sum \vec{F}_i$ = sum of all forces on a mass.
Newton's 2$^{\text{nd}}$ Law:	$\vec{F}_{\text{net}} = m\vec{a}$	$F_{\text{net},x} = ma_x,\ F_{\text{net},y} = ma_y,\ F_{\text{net},z} = ma_z$
Newton's 3$^{\text{rd}}$ Law:	$\vec{F}_{AB} = -\vec{F}_{BA}$	Forces exist in action-reaction pairs.
Gravitational force near Earth:	$F_G = mg$, downward.	Apparent weight is force measured by a scales.
Gravity components on inclines:	$F_\parallel = mg\sin\theta,\ F_\perp = mg\cos\theta$	$\leftarrow$ for incline at angle θ to horizontal.
Spring force:	$F_s = -kx$	x is the displacement from equilibrium.

Chapter 6 - Friction, circular motion

Static friction (object is stuck):	$f_s \leq \mu_s N$	Can balance other forces in any direction.
Kinetic friction (object sliding):	$f_k = \mu_k N$	Acts **against** the relative motion of surfaces.
Centripetal acceleration:	$a_c = v^2/r$	Points towards the center of the circle.
Centripetal force:	$F_{\text{net,inward}} = ma_c$	"Centripetal force" is the **sum** of forces inward.
Rates of circular motion:	$v = 2\pi r/T = 2\pi rf$	frequency $f = 1/T$, T=period of one revolution.