**Name=** **Studio Day/Time=**

**Eng. Phys. I** **Exam 2 - Chs. 5,6,7 - Forces, Circular Motion, Energy** **Oct. 1, 2021**

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$^2$.

1. (3) A block of mass 1.5 kg is acted on by two forces: one of magnitude 3.0 N directed east and another of magnitude 3.0 N directed north. What can you say about the block's instantaneous motion?

a. It is moving to the east.
b. It is moving to the north.
c. It is moving towards northeast.
d. It must be at rest.
e. It could be moving in any direction.

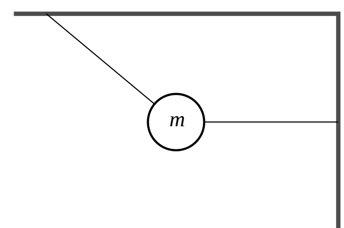
2. (3) A 1.5 kg block is moving at constant speed towards due north. What can you conclude?

a. There is just one force towards the north acting on it.
b. There is no net force acting on the block.
c. The net force on the block is directed towards the north.
d. There are no forces acting on the block.

3. (3) A block slides to the right on a level table. One force that acts on it is the "normal force" $\vec{N}$. The 3rd law pair force associated with $\vec{N}$ is the

a. force opposite to $\vec{N}$ that acts on the table.
b. frictional force on the block.
c. force of gravity on the block due to the Earth.
d. force of gravity on the Earth due to the block.

4. (9) A spherical light fixture of mass $m$ is suspended using two cables as shown, one connected to the wall with tension $T_1$ and one connected to the ceiling with tension $T_2$ at an angle $\theta$ from horizontal.




a) (3) Draw and label all forces (as arrows) acting on mass $m$ on the diagram.

b) (6) Determine the magnitude of $T_1$ in terms of $m$, $g$, and $\theta$.

5. (2) **T F** The normal force of the road on the tires can give your car forward acceleration.

6. (2) **T F** A body in "free fall" has no net force acting on it.

7. (2) **T F** While you are seated, your mass exerts a gravitational force on the Earth.

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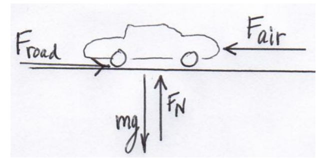
8. (4) The diagram shows the forces acting on a car accelerating to the right on level pavement. $F_{\text{road}}$ is the friction force of the road on the tires, and $F_{\text{air}}$ is the air resistance. Select the correct relationship between the force magnitudes.




a) a. $F_{\text{road}} > F_{\text{air}}$ b. $F_{\text{road}} = F_{\text{air}}$ c. $F_{\text{road}} < F_{\text{air}}$

b) a. $F_N > mg$ b. $F_N = mg$ c. $F_N < mg$

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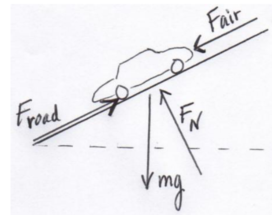
9. (4) A car is moving at constant speed up a $\theta = 30°$ incline; the forces are shown on the diagram. Choose the correct relationships between the force magnitudes.




a) a. $F_{\text{road}} = F_{\text{air}}$ b. $F_{\text{road}} = F_{\text{air}} - mg\sin\theta$ c. $F_{\text{road}} = F_{\text{air}} + mg\sin\theta$

b) a. $F_N = mg$ b. $F_N = mg\cos\theta$ c. $F_N = mg\sin\theta$

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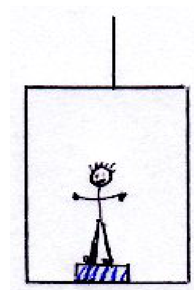
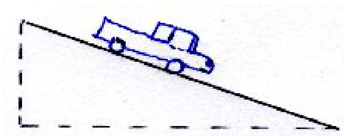
10. (9) At home a bath scales reads "88.4 kg" when Michael stands on it. Then he stands on the scales in an elevator that starts from the ground floor, going up to the 5th floor, and sees that its reading changes to "145 kg" as the elevator starts moving.



a) (3) Draw a free body diagram just for Michael when the elevator starts moving. You can add vector arrows on the diagram here and label them.

b) (6) Determine Michael's acceleration in $g$'s as the elevator starts moving.

11. (8) Meredith is driving her truck down a 12.0° slope at 60.0 mph (26.8 m/s) and has to brake suddenly for a deer. If the coefficients of static and kinetic friction between tires and road are $\mu_s = 0.85$ and $\mu_k = 0.55$, what is the maximum deceleration that the truck can experience with proper braking? Show the forces needed on the diagram, and your calculation.



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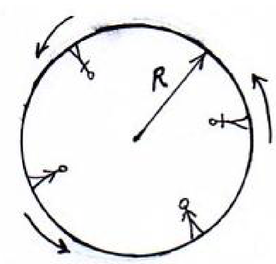
12. (12) A space station is a hollow cylinder of radius 92.0 m, that rotates to simulate gravity by its centripetal acceleration. The astronauts live at the radius 92.0 m from the center, with their heads pointing inward and their feet outward!




a) (6) What **speed** $v$ should the rotation give the astronauts so they feel like they are in artificial gravity of strength "0.500 g", half of that on Earth?

b) (6) Find the period of the rotation in **seconds**.

13. (2) **T F** Static friction always prevents an object from accelerating.

14. (2) **T F** Kinetic friction always makes an object decelerate (or slow down).

15. (2) **T F** Centripetal acceleration is outward from the center of a circular motion.

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

17. (2) **T F** Moving on a banked curve at optimum speed, a car's tires do not need friction to hold the curve.

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18. (12) A 1660-kg car travels at constant speed around an unbanked curve of radius $r = 155$ m. The coefficients of static and kinetic friction between the tires and the road are $\mu_s = 0.850$ and $\mu_k = 0.550$ .

a) (6) Above what speed will the car's tires skid out and lose sideways traction?

b) (6) If the speed is only half of that found in (a), how large is the friction force on the car's tires (all combined)?

19. (2) **T F** A force does the most work on a mass when parallel to the displacement of the mass.

20. (2) **T F** When you walk up a hill, friction force on your shoes does positive work.

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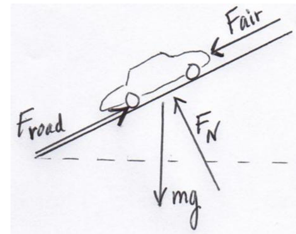
21. (18) Starting from rest, a 2240-kg car drives up a uniform 15.0° slope, making a net displacement along the road of 125 meters. There is good traction. The friction force of the road on the tires $F_{\text{road}}$ is a constant 8.88 kN. Ignore air resistance.




a) (6) Calculate the mechanical work done on the car by all forces acting on it.

b) (6) What is the final speed of the car?

c) (6) At what average rate (or average power) was mechanical work done on the car?



Score = ____________/105.

## 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

## 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

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$ $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$ $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$

$\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$ $a^2 + b^2 - 2ab\cos\gamma = c^2$ $\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$

## Chapter 1 - Measurements

Percent error: If a measurement = value ± error, the percent error $= \frac{\text{error}}{\text{value}} \times 100$ %

## Chapter 2 - Vectors - Magnitude & Direction

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|---|---|---|---|
| 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 $\to \tan\theta = a_y/a_x$ |
| Components: | $a_x = a\cos\theta$ | $a_y = a\sin\theta$ | $\theta$=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

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|---|---|---|---|
| Velocity: | $v_{\text{avg}} = \frac{\Delta x}{\Delta t}$ | $\Delta x = x - x_0$ | $v(t) = \frac{dx}{dt}$= slope of $x(t)$ |
| Acceleration: | $a_{\text{avg}} = \frac{\Delta v}{\Delta t}$ | $\Delta v = v - v_0$ | $a(t) = \frac{dv}{dt}$= slope of $v(t)$ |
| Constant acceleration: | $v = v_0 + at$ | $v_{\text{avg}} = \frac{1}{2}(v_0 + v)$ | |
| | $x = x_0 + v_0t + \frac{1}{2}at^2$ | $x = x_0 + v_{\text{avg}}t$ | $v^2 = v_0^2 + 2a\Delta x$ |
| 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

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|---|---|---|---|
| Position: | $\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$ | $\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$ | $\vec{\mathbf{r}} = (x, y, z)$ |
| Velocity: | $\vec{\mathbf{v}}_{\text{avg}} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t}$ | $\vec{\mathbf{v}} = \frac{d\vec{\mathbf{r}}}{dt}$ | $\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0$ |
| Acceleration: | $\vec{\mathbf{a}}_{\text{avg}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t}$ | $\vec{\mathbf{a}} = \frac{d\vec{\mathbf{v}}}{dt}$ | $\Delta\vec{\mathbf{v}} = \vec{\mathbf{v}} - \vec{\mathbf{v}}_0$ |
| Projectiles: | $a_x = 0$ | $v_x = v_{x0}$ | $x = x_0 + v_{x0}t$ |
| ($+y$-axis is up) | $a_y = -g$ | $v_y = v_{y0} - gt$ | $y = y_0 + v_{y0}t - \frac{1}{2}gt^2$ |
| 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: | $a_c = v^2/r = \omega^2 r$ | $v = 2\pi r/T = \omega r$ | $\omega = 2\pi/T$ |

## Chapter 5 - Newton's laws and forces

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|---|---|---|
| Newton's 1st Law: | $\vec{a} = \frac{d\vec{v}}{dt} = 0$ unless $\vec{F}_{\text{net}} \neq 0$ | $\vec{F}_{\text{net}} = \sum \vec{F}_i$ = sum of all forces on a mass. |
| Newton's 2nd 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 3rd 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 $\theta$ to horizontal. |
| Spring force: | $F_s = -kx$ | $x$ is the displacement from equilibrium. |

## Chapter 6 - Friction, circular motion

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|---|---|---|
| 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: | $a_c = \frac{v^2}{r}$ | 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: | speed $v = \frac{2\pi r}{T} = 2\pi r f$ | frequency $f = \frac{1}{T}$, $T$=period of one revolution. |

## Chapter 7 - Work and kinetic energy

| | | |
|---|---|---|
| Work done by a force: | $dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = F\ dr\ \cos\theta$ | $W_{AB} = \int_A^B \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$ (along the path $A \to B$) |
| Work of a constant force: | $W = \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$ | $\Delta\mathbf{r} = \vec{\mathbf{r}}_B - \vec{\mathbf{r}}_A$ = displacement. |
| Work done by gravity: | $W_{\text{G}} = -mg\Delta y$ | $\Delta y = y_B - y_A$ (final minus initial height) |
| Work done by a spring: | $W_s = -\frac{1}{2}k(x_B^2 - x_A^2)$ | $B$=final stretch, $A$ =initial stretch. |
| Work done by friction: | Use formula for constant force. | Friction's work can be positive or negative!! |
| Work-KE theorem: | $\Delta\text{KE} = W_{\text{net}}$ = all works on $m$. | $\text{KE} = \frac{1}{2}mv^2,\quad \Delta\text{KE} = \frac{1}{2}m(v_B^2 - v_A^2)$ |
| Instantaneous power: | $P = \frac{dW}{dt}$ | $\leftarrow$ the rate of doing work by some force. |
| When $\vec{\mathbf{F}}$ acts on $m$: | $P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$ | $\leftarrow$ power only due to $\vec{\mathbf{F}}$ |
| Average power: | $P_{\text{ave}} = \frac{\Delta W}{\Delta t}$ | $\leftarrow$ average over time interval $\Delta t$. |