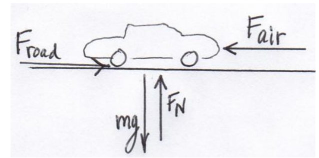
General Physics I **Exam 2 - Chs. 4,5,6 - Forces, Circular Motion, Energy** **Oct. 13, 2010**

Name Rec. Instr. Rec. Time

For full credit, make your work clear to the grader. Show formulas used, essential steps, and results with correct units and significant figures. Partial credit is available if your work is clear. Points shown in parenthesis. For TF and MC, choose the *best* answer.

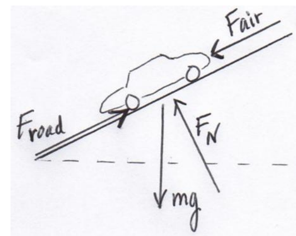
1. (6) The diagram shows the forces acting on a car accelerating to the right. The pavement is level. F_{road} is the friction force of the road on the tires, and F_{air} is the air resistance. Select the correct relationship between the force magnitudes.



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. $F_N < mg$

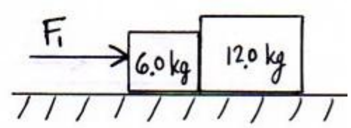
2. (6) A car is moving at constant speed up a $\theta = 30°$ incline; the forces are shown on the diagram. Choose the correct relationships between the force magnitudes.



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. $F_N = mg\sin\theta$

3. (16) A constant force $F_1 = 72.0$ N is applied to a 6.00-kg block, which contacts a 12.0-kg block. They accelerate together on a horizontal frictionless surface.



a) (6) How large is their common acceleration?

b) (5) What is the magnitude of the force on the 6.0-kg block due to the contact with the 12.0-kg block?

c) (5) What is the magnitude of the **net** force on the 6.0-kg block?

4. (2) **T F** If the acceleration of a mass is zero, then there are no forces acting on it.
5. (2) **T F** The force from the drive train turning the wheels is what accelerates a car.
6. (2) **T F** A static friction force on a mass always prevents the mass from moving.
7. (2) **T F** Earth's gravitational force on you is greater than your gravitational force on the Earth.
8. (2) **T F** Sliding on a <u>frictionless</u> incline, a box accelerates more going **downhill** rather than **uphill**.
9. (2) **T F** On an incline with <u>friction</u>, a sliding box accelerates more going **downhill** rather than **uphill**.
10. (2) **T F** For contact between two given materials, **static** friction is stronger than **kinetic** friction.

11. (10) A 2.2-kg fish is being pulled out of the water, in such a way that the tension in the fishing line is 3.0 times its weight. Draw the forces acting on the fish (free body diagram) and find the acceleration of the fish (magnitude and direction).

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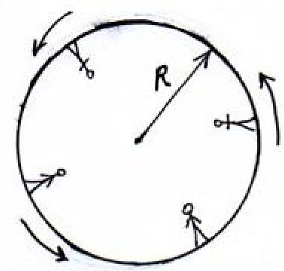
12. (14) A space station is a hollow cylinder of radius 440 m, that rotates to simulate gravity by its centripetal acceleration. The astronauts live at the radius 440 m from the center, with their heads pointing inward and their feet outward!



a) (6) What **speed** v should the rotation give the astronauts so they feel like they are in artificial gravity of strength "2.50 g" (2.5 $\times$ gravity on Earth)?

b) (4) Find the period of the rotation in **seconds**.

c) (4) Find the rotation speed in **revolutions per minute**.

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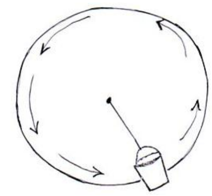
13. (2) The flying pig, suspended from a cable (demo in lecture), moves at constant speed in a horizontal circle. The net force on him must point

a) along the cable. b) horizontally, towards the center of the circle.
c) vertically, due to his weight. d) none of these, because the net force is zero.

Name Rec. Instr. Rec. Time

14. (10) A physics student takes a 5.0-kg pail of water connected on a rope, and swings it in a vertical circle of radius 90.0 cm at a constant speed of 7.0 m/s.

a) (5) When the pail passes its highest point, what are the magnitude and direction of its acceleration?



b) (5) When the pail passes its highest point, what is the tension in the rope?

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15. (10) The acceleration due to gravity at the surface of a planet of mass M, radius R, is given by the expression, $g = GM/R^2$. On Earth, this value is $g = 9.80\ \mathrm{m/s^2}$.

a) (4) If Earth's diameter were half what it is, while keeping the same mass, what would g be in $\mathrm{m/s^2}$?

b) (6) Suppose a planet is discovered that has a mass 12 times that of Earth, and a radius 2.0 times that of Earth. What is the value of g in $\mathrm{m/s^2}$ on this planet?

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16. (6) A 145-kg football player applies a force of 520 N horizontally on the opposing 125-kg quarterback, while pushing him backwards 3.3 m at constant speed before being tackled. How much work did the tackler do while pushing?

17. (2) **T** **F** Friction forces always do negative work.

18. (2) **T** **F** A car can accelerate faster if the friction between the road and its tires is smaller.

19. (2) **T** **F** The gravitational force does positive work on a rising object.

20. (2) **T** **F** Potential energy stored in springs is always negative.

21. (2) **T** **F** When ascending a flight of stairs, your gravitational potential energy decreases.

22. (2) A force $\vec{F}$ acting through a displacement $\vec{d}$ does negative work when

a. $\vec{F}$ is parallel to $\vec{d}$. b. $\vec{F}$ is perpendicular to $\vec{d}$. c. $\vec{F}$ is anti-parallel to $\vec{d}$.

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23. (18) A 2200-kg car is initially coasting at a speed of 24 m/s when it comes to a $\theta = 12.0°$ incline. It coasts without friction or air resistance, up the incline.

a) (6) How large is the initial kinetic energy of the car, in kJ?

b) (6) After it travels 75.0 m along the incline, how large is the gravitational potential energy of the car, in kJ? Take the zero of PE to be at the bottom of the incline.

c) (6) How fast is the car coasting now after it went 75.0 m along the incline?

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24. (8) A 62-kg athlete runs up a flight of stairs at constant speed, gaining an elevation of 50.0 m in 40.0 s. What was the average mechanical power output of her body, in watts?

Score = ___________/132.

Prefixes

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}

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 299792458$ m/s (speed of light)

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (Gravitational constant)
$R_E = 6380$ km (mean radius of Earth)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Units and Conversions

1 inch = 1 in = 2.54 cm (exactly)
1 mile = 5280 ft
1 m/s = 3.6 km/hour
1 acre = 43560 ft^2 = (1 mile)^2/640

1 foot = 1 ft = 12 in = 30.48 cm (exactly)
1 mile = 1609.344 m = 1.609344 km
1 ft/s = 0.6818 mile/hour
1 hectare = 10^4 m^2

Trig summary

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$, $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$, $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$, $\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$.
$\sin\theta = \sin(180^\circ - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180^\circ + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

Chapter 1 Equations

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

Chapter 2 Equations

Motion:
$\bar{v} = \frac{\Delta x}{\Delta t}$, $\Delta x = x - x_0$, slope of $x(t)$ curve = $v(t)$.
$\bar{a} = \frac{\Delta v}{\Delta t}$, $\Delta v = v - v_0$, slope of $v(t)$ curve = $a(t)$.

For constant acceleration in one-dimension:
$\bar{v} = \frac{1}{2}(v_0 + v)$, $v = v_0 + at$, $x = x_0 + v_0 t + \frac{1}{2}at^2$, $v^2 = v_0^2 + 2a(x - x_0)$.

For free fall on Earth, using an upward y-axis, with $g = 9.80$ m/s^2 downward:
$\bar{v}_y = \frac{1}{2}(v_{y0} + v_y)$, $v_y = v_{y0} - gt$, $y = y_0 + v_{y0}t - \frac{1}{2}gt^2$, $v_y^2 = v_{y0}^2 - 2g\Delta y$.

Chapter 3 Equations

Vectors
Written $\vec{V}$ or $\mathbf{V}$, described by magnitude=V, direction=θ or by components (V_x, V_y).
$V_x = V\cos\theta$, $V_y = V\sin\theta$,
$V = \sqrt{V_x^2 + V_y^2}$, $\tan\theta = \frac{V_y}{V_x}$. θ is the angle from $\vec{V}$ to x-axis.
Addition: $\mathbf{A} + \mathbf{B}$, head to tail. Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$, $-\mathbf{B}$ is $\mathbf{B}$ reversed.

Projectiles
$a_x = 0$, $v_x = v_{x0}$, $x = x_0 + v_{x0}t$. For a horizontal x-axis.
$a_y = -g$, $v_y = v_{y0} - gt$, $y = y_0 + v_{y0}t - \frac{1}{2}gt^2$. For an upward y-axis.
$R = \frac{v_0^2}{g}\sin 2\theta_0$, (For level ground only.)

Relative Motion
$\vec{V}_{\text{BS}} = \vec{V}_{\text{BW}} + \vec{V}_{\text{WS}}$, B=Boat, S=Shore, W=Water.
BS means "boat relative to shore", etc.
Must be applied as a vector equation!

Chapter 4 Equations

Newton's Second Law:

$\vec{F}_{\text{net}} = m\vec{a}$, means $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$. $\vec{F}_{\text{net}} = \sum \vec{F}_i$, sum over all forces on a mass.

Friction (magnitude):

$f_s \le \mu_s N$ or $F_{\text{fr}} \le \mu_s F_N$ (static friction). $f_k = \mu_k N$ or $F_{\text{fr}} = \mu_k F_N$. (kinetic or sliding friction)

Gravitational force near Earth:

$F_G = mg$, downward.

Chapter 5 Equations

Centripetal Acceleration:

$a_R = \frac{v^2}{r}$, towards the center of the circle.

Circular motion:

speed $v = \frac{2\pi r}{T} = 2\pi r f$, frequency $f = \frac{1}{T}$, where T is the period of one revolution.

Gravitation:

$F = G\frac{m_1 m_2}{r^2}$; $g = \frac{GM}{r^2}$, where $G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$;

Orbits:

$\frac{v^2}{r} = g = \frac{GM}{r^2}$; $v = \sqrt{\frac{GM}{r}}$. centripetal acceleration = free fall acceleration.

Chapter 6 Equations

Work & Kinetic & Potential Energies:

$W = Fd\cos\theta$, $\text{KE} = \frac{1}{2}mv^2$, $\text{PE}_{\text{gravity}} = mgy$, $\text{PE}_{\text{spring}} = \frac{1}{2}kx^2$. θ = angle btwn $\vec{F}$ and $\vec{d}$.

Conservation or Transformation of Energy:

Work-KE theorem:

$\Delta\text{KE} = W_{\text{net}}$ = work of all forces.

General energy-conservation law:

$\Delta\text{KE} + \Delta\text{PE} = W_{\text{NC}}$ = work of non-conservative forces.

Power:

$P_{\text{ave}} = \frac{W}{t}$, or use $P_{\text{ave}} = \frac{\text{energy}}{\text{time}}$.