The following Exam Review is for my Physics with General Calculus I course for the Fall of 2025, which was taken during my gap year at Palm Beach State College under Professor Leo Bae.

The content covered in the final exam will be a culmination of quiz problems from the following chapters:

- Unit 1: Chapters 1, 2, 3, and 4
- Unit 2: Chapters 5, 6, and 13
- Unit 3: Chapters 7, 8, and 9

Chapter 1 Quiz Problems.

Problem 1 – Milky Way & Andromeda Scale Model.

Using Proportions for Scale Models. The disk of the Milky Way galaxy is about 1.0×10^5 ly in diameter. The distance from the center of the Milky Way to the center of the Andromeda galaxy is about 2.0×10^6 ly.

(a) **Distance between galaxy centers in the model**

If the Milky Way is represented by a circular plate of diameter $d_{\text{MW,model}} = 16\,\text{cm}$, then the scale factor is

$$\frac{d_{\text{MW,real}}}{d_{\text{MW,model}}} = \frac{1.0 \times 10^5 \text{ ly}}{16 \text{ cm}}.$$

For the model distance between the centers:

$$\frac{d_{\text{MW,real}}}{d_{\text{And,real}}} = \frac{1.0 \times 10^5 \text{ ly}}{2.0 \times 10^6 \text{ ly}} = \frac{16 \text{ cm}}{x_{\text{cm}}}.$$

Solve for x_{cm} and convert:

$$x_{\text{m}} = \frac{x_{\text{cm}}}{100}.$$

(b) **Diameter of Local Group in the same scale**

The Local Group has diameter $D_{\text{LG,real}} = 1.0 \times 10^7$ ly. Using the same scale (Milky Way $\to$ 16 cm):

$$\frac{d_{\text{MW,real}}}{D_{\text{LG,real}}} = \frac{1.0 \times 10^5 \text{ ly}}{1.0 \times 10^7 \text{ ly}} = \frac{16 \text{ cm}}{D_{\text{LG,model (cm)}}}.$$

Solve for $D_{\text{LG,model (cm)}}$, then convert:

$$D_{\text{LG,model (m)}} = \frac{D_{\text{LG,model (cm)}}}{100}.$$

Problem 4 – Rods & Cross Sections.

Mass of a Rod with Linearly Varying Density. A thin rod extends from $x = 0$ to $x = 16.0\,\text{cm}$. Cross-sectional area $A = 8.50\,\text{cm}^2$. Density increases linearly from $\rho(0) = 3.00\,\text{g/cm}^3$ to $\rho(16 \text{ cm}) = 19.0\,\text{g/cm}^3$.
Assume

$$\rho(x) = B + Cx,$$

with x in cm.

(a) **Find B from $\rho(0)$**

$$\rho(0) = B \quad \Rightarrow \quad B = 3.00\,\text{g/cm}^3.$$

(b) **Find C from $\rho(16$ cm$)$**

$$\rho(16) = B + C(16) = 19.0\,\mathrm{g/cm^3}.$$

So

$$19.0 = 3.00 + 16C \quad \Rightarrow \quad C = \frac{19.0 - 3.0}{16} = 1.00\,\mathrm{g/cm^4}.$$

(c) **Total mass of the rod**

Mass m is

$$m = \int_0^{16} \rho(x) A\,dx = A \int_0^{16} (B + Cx)\ dx.$$

Compute:

$$\begin{aligned} m &= A\left[Bx + \frac{Cx^2}{2}\right]_0^{16} \\ &= (8.50\,\mathrm{cm^2})\left[(3.00)(16) + \frac{1.00(16)^2}{2}\right] \\ &= 8.50\,(48 + 128)\ \mathrm{g} \\ &= 8.50 \times 176\ \mathrm{g} \approx 1496\ \mathrm{g}. \end{aligned}$$

Convert to kilograms:

$$m \approx 1.496\ \mathrm{kg}.$$

Chapter 2 Quiz Problems.

Problem 2 – Constant Speed Motion.

Position and Velocity for Motion at Constant Speed. For a particle moving at constant speed v along a straight line:

(a) **1D motion (along x-axis)**

$$x(t) = x_0 + vt,$$

where v is positive (right) or negative (left). Average speed and instantaneous speed are both $|v|$.

(b) **2D motion at constant speed**

If direction is given by angle θ from the $+x$ axis:

$$\begin{aligned} v_x &= v\cos\theta, \\ v_y &= v\sin\theta, \\ x(t) &= x_0 + v_x t, \\ y(t) &= y_0 + v_y t. \end{aligned}$$

Problem 15 – Helicopters & Heights.

Vertical Motion: Position vs. Time. A helicopter's height above the ground can be modeled in 1D (vertical y-axis):

(a) **Constant vertical speed**

$$y(t) = y_0 + v_y t,$$

where v_y is positive when ascending and negative when descending.

Example (constant speed): Suppose $y_0 = 20\,\mathrm{m}$ (starting height) and the helicopter climbs straight up with $v_y = 5\,\mathrm{m/s}$. After $t = 4\,\mathrm{s}$:

$$y(4) = 20 + (5)(4) = 40\,\mathrm{m}.$$

To find the time to reach $y = 80\,\text{m}$:

$$y = y_0 + v_y t \quad \Rightarrow \quad 80 = 20 + 5t \Rightarrow t = \frac{60}{5} = 12\,\text{s}.$$

(b) **With constant vertical acceleration (e.g., gravity)**

$$y(t) = y_0 + v_{0y} t + \frac{1}{2} a_y t^2,$$

with

$$v_y(t) = v_{0y} + a_y t.$$

Example (constant acceleration): Let $y_0 = 50\,\text{m}$, $v_{0y} = 2.0\,\text{m/s}$ (upward), and $a_y = -9.8\,\text{m/s}^2$ (gravity downward).

$$\begin{aligned} y(1.0) &= 50 + (2.0)(1.0) + \frac{1}{2}(-9.8)(1.0)^2 \\ &= 50 + 2.0 - 4.9 = 47.1\,\text{m}, \\ v_y(1.0) &= 2.0 + (-9.8)(1.0) = -7.8\,\text{m/s} \quad \text{(moving downward after 1 s)}. \end{aligned}$$

Use these forms to solve for *time*, *height*, or *velocity* when the helicopter passes a certain point or reaches a specified altitude.

Chapter 3 Quiz Problems.

Problems 1, 2, & 3 – Polar ↔ Cartesian Coordinates.

Converting Between Polar and Cartesian in 2D.

(a) **Given polar coordinates** (r, θ)
For a point with radius r and angle θ (measured from the $+x$ axis):

$$x = r\cos\theta, \qquad y = r\sin\theta.$$

(b) **Given partial Cartesian information**
If you know x and θ:

$$x = r\cos\theta \quad \Rightarrow \quad r = \frac{x}{\cos\theta}.$$

Then

$$y = r\sin\theta = \frac{x}{\cos\theta}\sin\theta = x\tan\theta.$$

(c) **Going from Cartesian to polar**
If x and y are known:

$$r = \sqrt{x^2 + y^2}, \qquad \theta = \tan^{-1}\left(\frac{y}{x}\right)$$

(adjust θ based on the quadrant).

Problem 4 – Forces and Boxes.

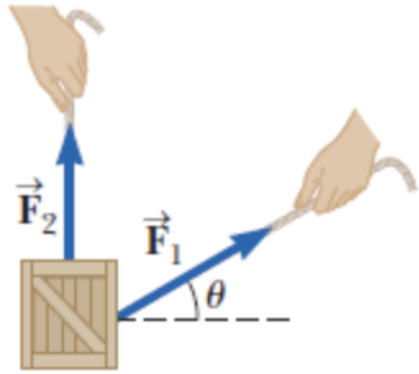

FIGURE 1. Forces $\vec{F}_1$ and $\vec{F}_2$ acting on a box at angle(s) θ_1, θ_2.

Vector Addition of Two Forces on a Box. Let $\vec{F}_1$ have magnitude F_1 and angle θ_1 from the $+x$ axis. Let $\vec{F}_2$ be vertical (for example), or at angle θ_2.

(a) **Resolve each force into components**

$$F_{1x} = F_1 \cos\theta_1, \qquad F_{1y} = F_1 \sin\theta_1,$$
$$F_{2x} = F_2 \cos\theta_2, \qquad F_{2y} = F_2 \sin\theta_2.$$

(If $\vec{F}_2$ is purely vertical, then $F_{2x} = 0$ and $F_{2y} = F_2$.)

(b) **Resultant force components**

$$F_{Rx} = F_{1x} + F_{2x},$$
$$F_{Ry} = F_{1y} + F_{2y}.$$

(c) **Magnitude and direction of resultant**

$$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2},$$
$$\theta_R = \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right)$$

(again, adjust θ_R based on the quadrant of $\vec{F}_R$).

Chapter 5 Quiz Problems.

Problem 1 – Resultant Forces & Magnitudes.

From Cartesian Components to Magnitude (and Direction). Given a mass m and acceleration

$$\vec{a} = a_x\hat{i} + a_y\hat{j},$$

the net force is

$$\vec{F} = m\vec{a} = (ma_x)\hat{i} + (ma_y)\hat{j}.$$

(a) **Find components of $\vec{F}$**

$$F_x = ma_x, \qquad F_y = ma_y.$$

(b) **Magnitude of the force**

$$|\vec{F}| = \sqrt{F_x^2 + F_y^2}.$$

(c) (Optional) **Direction (angle from $+x$ axis)**

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right).$$

Problem 2 – Normal Force on a Box with Hanging Weights.

Vector Addition of Two Vertical Forces on a Box. Let the box weight be W_{box} and the upward tension from the hanging mass be T. Taking up as positive, the normal force F_N satisfies:

$$F_N + T - W_{\text{box}} = 0 \quad \Rightarrow \quad F_N = W_{\text{box}} - T.$$

(a) **Case A: Box on the ground, no cord attached**

$$F_N = W_{\text{box}} = 15.5\,\text{lb}$$

(normal force equals the weight).

(b) **Case B: Hanging weight smaller than box weight**

$$F_N = W_{\text{box}} - W_{\text{hang}}.$$

The cord *reduces* the load on the floor but cannot lift the box.

(c) **Case C: Hanging weight larger than box weight**

$$W_{\text{hang}} > W_{\text{box}} \quad \Rightarrow \quad F_N = 0$$

(the box is lifted off the floor, so the floor exerts no force).

Problem 3 – Sailboats & Constant Velocity.

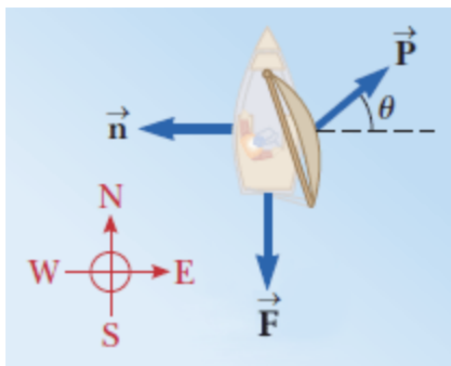

FIGURE 2. Sailboat being pulled by forces $\vec{F}$, $\vec{n}$, and $\vec{P}$.

Constant Velocity $\Rightarrow$ Net Force is Zero. For constant velocity,

$$\sum \vec{F} = \vec{0}.$$

Given a drag force

$$\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath},$$

and two other forces $\vec{n}$ and $\vec{P}$, we require

$$\vec{F} + \vec{n} + \vec{P} = \vec{0}.$$

(a) **Resolve the known force $\vec{F}$ into components**

$$F_x = F\cos\theta, \qquad F_y = F\sin\theta$$

(signs depend on the direction of $\vec{F}$).

(b) **Write component equations**

$$F_x + n_x + P_x = 0, \qquad F_y + n_y + P_y = 0,$$

and solve for the magnitudes of $\vec{n}$ and $\vec{P}$.

Problem 4 – Stabilizing Broken Legs (Traction System).

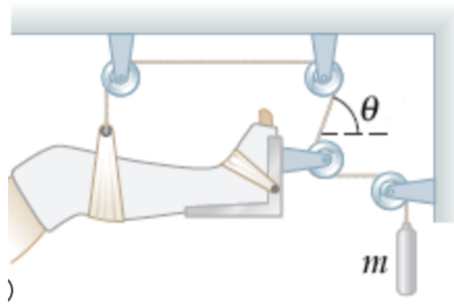

FIGURE 3. Leg traction system with pulleys and a hanging mass m.

Leg Traction System Tension.

(a) **Tension from hanging mass**

$$T = mg$$

because the mass is in equilibrium and its weight is supported by the rope.

(b) **Horizontal force pulling the leg** If two segments of rope pull on the leg at angle θ above/below the horizontal:

$$F_{\text{right}} = 2T\cos\theta.$$

Problem 5 – Chin-up Forces from a Velocity–Time Graph.

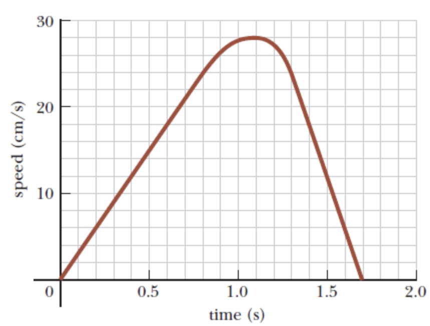

FIGURE 4. Speed–time curve for the chin-up motion. Convert cm/s to m/s.

Convert Graph Slope to Acceleration, then Use $F = m(g + a_y)$.

(a) **Find acceleration from the slope**

$$a_y = \frac{\Delta v_y}{\Delta t}$$

using the velocity–time graph (convert cm/s to m/s).

(b) **Force from the bar**

$$F_{\text{bar}} = N = mg + ma_y = m(g + a_y).$$

For $a_y = 0$ (flat part of the graph), $F_{\text{bar}} = mg$ (true bodyweight).

Problem 6 – Tension in Elevator Strings.

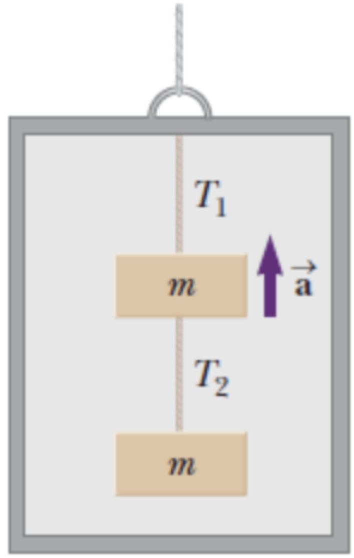

FIGURE 5. Two masses m suspended in an elevator, held by tensions T_1 and T_2.

Two Masses Suspended in an Accelerating Elevator.

(a) **Lower string (tension T_2) supports one mass**

$$T_2 - mg = ma \quad \Rightarrow \quad T_2 = m(g + a).$$

(b) **Upper string (tension T_1) supports two masses**

$$T_1 - 2mg = 2ma \quad \Rightarrow \quad T_1 = 2m(g + a).$$

(c) **Max elevator acceleration** comes from setting T_1 or T_2 equal to the maximum safe tension and solving for a.

Chapter 6 Quiz Problems.

Problem 1 – Station Rotation.

Artificial Gravity in a Rotating Space Station.

(a) Given diameter $D = 119\,\mathrm{m}$, radius $r = D/2 = 59.5\,\mathrm{m}$ and desired centripetal acceleration $a_c = 3.60\,\mathrm{m/s^2}$:

$$a_c = \omega^2 r$$
$$\omega = \sqrt{\frac{a_c}{r}}$$
$$f = \frac{\omega}{2\pi} \quad \Rightarrow \quad \text{rev/min} = 60f \approx 2.35 \text{ rev/min}.$$

(b) For $a_c = g = 9.80\,\mathrm{m/s^2}$ with the same radius:

$$\omega = \sqrt{\frac{g}{r}}, \quad f = \frac{\omega}{2\pi}, \quad \text{rev/min} = 60f \approx 3.88 \text{ rev/min}.$$

Problem 2 – Coins on a Turntable.

Static Friction as Centripetal Force.

(a) The force providing centripetal acceleration is **static friction**:

$$F_c = f_s = \mu_s N.$$

(b) Given radius $r = 0.294\,\mathrm{m}$ and speed $v = 0.484\,\mathrm{m/s}$:

$$a_c = \frac{v^2}{r},$$
$$\mu_s = \frac{a_c}{g} = \frac{v^2}{rg} \approx 0.0813.$$

Problem 3 – Apollo Astronaut in Lunar Orbit.

Circular Orbit Using $a_c = g_{\mathbf{orbit}}$.

(a) Radius of orbit:

$$R_{\text{Moon}} = 1.70 \times 10^6\,\mathrm{m}, \quad h = 4.43 \times 10^5\,\mathrm{m},$$
$$r = R_{\text{Moon}} + h.$$

Given $a_c = g_{\text{orbit}} = 1.07\,\mathrm{m/s^2}$ and $a_c = v^2/r$:

$$v = \sqrt{a_c r} \approx 1.51 \times 10^3\,\mathrm{m/s}.$$

(b) Orbital period:

$$T = \frac{2\pi r}{v} \approx 8.89 \times 10^3\,\mathrm{s}.$$

Problem 4 – Space Station Rotation (Again).

Artificial Gravity with Different Diameter.

(a) Diameter $D = 138\,\mathrm{m}$, radius $r = 69.0\,\mathrm{m}$, $a_c = 4.00\,\mathrm{m/s^2}$:

$$a_c = \omega^2 r \Rightarrow \omega = \sqrt{\frac{a_c}{r}}$$
$$f = \frac{\omega}{2\pi}, \quad \text{rev/min} = 60f \approx 2.30 \text{ rev/min}.$$

Problem 5 – Stuntman on a Rope Swing.

Tension at Bottom of Circular Arc.

(a) Given $m = 86.5\,\text{kg}$, $L = 12.0\,\text{m}$, $v = 8.60\,\text{m/s}$, $T_{\text{max}} = 1000\,\text{N}$. At the bottom of the swing:

$$\sum F_r = T - mg = \frac{mv^2}{L} \quad \Rightarrow \quad T = mg + \frac{mv^2}{L}.$$

Numerically, $T \approx 1.38 \times 10^3\,\text{N} > 1000\,\text{N}$, so the rope **breaks** at $v = 8.60\,\text{m/s}$.

(b) Maximum safe speed (set $T = T_{\text{max}}$):

$$T_{\text{max}} = mg + \frac{mv^2}{L}$$
$$v = \sqrt{L\left(\frac{T_{\text{max}}}{m} - g\right)} \approx 4.60\,\text{m/s}.$$

Problem 6 – Hawk in Circular Flight.
Centripetal and Tangential Accelerations.

(a) Given $r = 11.4\,\text{m}$, $v = 3.65\,\text{m/s}$:

$$a_c = \frac{v^2}{r} \approx 1.17\,\text{m/s}^2.$$

(b) With tangential acceleration $a_t = 1.15\,\text{m/s}^2$:

$$a = \sqrt{a_c^2 + a_t^2} \approx 1.64\,\text{m/s}^2,$$
$$\theta = \tan^{-1}\left(\frac{a_c}{a_t}\right) \approx 45^\circ,$$

where θ is measured from the direction of velocity **towards the center** of the circle.

Problem 7 – Scale Reading in an Elevator.
Using Two Scale Readings to Find mg and a.

(a) Let $N_{\text{start}} = 600\,\text{N}$ (starting upward), $N_{\text{stop}} = 394\,\text{N}$ (stopping):

$$N_{\text{start}} = mg + ma,$$
$$N_{\text{stop}} = mg - ma.$$

Add:

$$N_{\text{start}} + N_{\text{stop}} = 2mg \quad \Rightarrow \quad mg = 497\,\text{N}.$$

So the person's weight is $W = 497\,\text{N}$.

(b) Mass:

$$m = \frac{W}{g} = \frac{497}{9.8} \approx 50.7\,\text{kg}.$$

(c) Subtract the equations to find a:

$$N_{\text{start}} - N_{\text{stop}} = 2ma$$
$$600 - 394 = 2ma$$
$$a = \frac{206}{2m} \approx 2.03\,\text{m/s}^2.$$

Chapter 13 Quiz Problems.

Problem 1 – Gravitational Attraction Between Two Ships.

Using Newton's Law of Gravitation to Find Acceleration. Two ships of equal mass $m = 4.0 \times 10^7$ kg are separated by $r = 105\,\text{m}$.

(a) Gravitational force:

$$F = G\frac{m^2}{r^2}.$$

(b) Acceleration of either ship:

$$a = \frac{F}{m} = G\frac{m}{r^2} \approx 2.45 \times 10^{-7}\ \text{m/s}^2.$$

Problem 2 – Mass of Jupiter from Europa's Orbit.

Using Circular Orbit Data to Find Planet Mass. Europa:

$$r = 6.70 \times 10^5\ \text{km} = 6.70 \times 10^8\ \text{m}, \qquad T = 3.55\ \text{days} = 3.55 \times 86400\ \text{s}.$$

For a circular orbit,

$$\frac{GM_J}{r^2} = \frac{v^2}{r}, \qquad v = \frac{2\pi r}{T}.$$

(a) Combine to solve for Jupiter's mass:

$$M_J = \frac{4\pi^2 r^3}{GT^2} \approx 1.90 \times 10^{27}\ \text{kg}.$$

Problem 3 – Work Done on a Meteor by Moon's Gravity.

Change in Gravitational Potential from Infinity to Surface. Meteor of mass $m = 1075\,\text{kg}$ falls from rest at infinity to the Moon's surface.
Moon:

$$M_M = 7.35 \times 10^{22}\ \text{kg}, \quad R_M = 1.70 \times 10^6\ \text{m}.$$

(a) Gravitational potential energy:

$$U = -\frac{GM_M m}{r}.$$

From $r = \infty$ to $r = R_M$:

$$\Delta U = U_{\text{final}} - U_{\text{initial}} = -\frac{GM_M m}{R_M} - 0.$$

(b) Work done by gravity (on the meteor):

$$W = -\Delta U = \frac{GM_M m}{R_M} \approx 3.10 \times 10^9\ \text{J}.$$

Problem 4 – Energy to Raise a Mass to Altitude $2R_E$.

Gravitational Potential Energy in the $-GMm/r$ Form. Move $m = 900\,\text{kg}$ from Earth's surface ($r_1 = R_E$) to altitude $2R_E$, so $r_2 = 3R_E$.

(a) Gravitational potential:

$$U = -\frac{GM_E m}{r}.$$

Energy required:

$$\begin{aligned}\Delta E &= U_2 - U_1 \\ &= -\frac{GM_E m}{3R_E} - \left(-\frac{GM_E m}{R_E}\right) \\ &= GM_E m\left(\frac{1}{R_E} - \frac{1}{3R_E}\right) = GM_E m\left(\frac{2}{3R_E}\right) \\ &\approx 3.75 \times 10^{10}\ \text{J}.\end{aligned}$$

Problem 5 – Orbital Period Where $g_{\text{orbit}} = 4.42\ \text{m/s}^2$.

Using g_{orbit} as the Centripetal Acceleration. At the satellite's orbit,

$$a_c = g_{\text{orbit}} = \frac{v^2}{r}, \qquad v = \frac{2\pi r}{T}.$$

Combine to get:

$$g_{\text{orbit}} = \frac{4\pi^2 r}{T^2} \quad \Rightarrow \quad T = 2\pi\sqrt{\frac{r}{g_{\text{orbit}}}} \approx 153\ \text{min}.$$

Problem 6 – Raising a Satellite from 97 km to 209 km.

Total, Kinetic, and Potential Energy Changes in Orbit. Satellite mass $m = 985\,\text{kg}$. Earth radii:

$$r_1 = R_E + 97 \times 10^3\,\text{m}, \qquad r_2 = R_E + 209 \times 10^3\,\text{m}.$$

Total orbital energy:

$$E = -\frac{GM_E m}{2r}.$$

(a) **Total energy change**

$$\Delta E = E_2 - E_1 = -\frac{GM_E m}{2}\left(\frac{1}{r_2} - \frac{1}{r_1}\right) \approx 5.16 \times 10^8\ \text{J} \approx 5.16 \times 10^2\ \text{MJ}.$$

(b) **Kinetic energy change**

$$K = +\frac{GM_E m}{2r} \quad \Rightarrow \quad \Delta K = K_2 - K_1 \approx -5.16 \times 10^8\ \text{J} \approx -5.16 \times 10^2\ \text{MJ}.$$

(c) **Potential energy change**

$$U = -\frac{GM_E m}{r}, \qquad \Delta U = U_2 - U_1 \approx 1.03 \times 10^9\ \text{J} \approx 1.03 \times 10^3\ \text{MJ}.$$

Problem 7 – Satellite at Altitude 2.08×10^6 m.

Circular Orbit: Period, Speed, and Acceleration. Altitude:

$$h = 2.08 \times 10^6 \text{ m}, \qquad r = R_E + h.$$

(a) **Period**

$$T = 2\pi\sqrt{\frac{r^3}{GM_E}} \approx 2.15 \text{ h}.$$

(b) **Speed**

$$v = \sqrt{\frac{GM_E}{r}} \approx 6.86 \text{ km/s}.$$

(c) **Acceleration**

$$a = \frac{v^2}{r} = \frac{GM_E}{r^2} \approx 5.58 \text{ m/s}^2$$

directed toward the center of the Earth.

Key Constants and Equations (with Uses).

Physical Constants (approximate).

$$g \approx 9.80\,\mathrm{m/s^2} \qquad \text{(surface gravity on Earth)}$$
$$G \approx 6.67 \times 10^{-11}\ \mathrm{N\,m^2/kg^2} \qquad \text{(universal gravitational constant)}$$
$$R_E \approx 6.37 \times 10^6\ \mathrm{m} \qquad \text{(radius of Earth)}$$
$$M_E \approx 5.97 \times 10^{24}\ \mathrm{kg} \qquad \text{(mass of Earth)}$$
$$R_M \approx 1.70 \times 10^6\ \mathrm{m} \qquad \text{(radius of Moon)}$$
$$M_M \approx 7.35 \times 10^{22}\ \mathrm{kg} \qquad \text{(mass of Moon)}$$

Newton's Laws and Basic Dynamics.

$$\vec{F}_{\text{net}} = m\vec{a} \qquad \text{(Newton's 2nd law; relate net force and acceleration)}$$
$$W = mg \qquad \text{(weight near Earth's surface)}$$
$$N = mg \pm ma \qquad \text{(apparent weight / scale reading in an elevator)}$$
$$T = mg + \frac{mv^2}{r} \qquad \text{(tension at bottom of a vertical circular arc)}$$

Circular Motion.

$$a_c = \frac{v^2}{r} = \omega^2 r \qquad \text{(centripetal acceleration)}$$
$$v = \omega r \qquad \text{(relation between speed and angular speed)}$$
$$\omega = 2\pi f \qquad \text{(angular speed from frequency)}$$
$$T = \frac{1}{f} \qquad \text{(period \& frequency relation)}$$

Work & Energy.

$$W = \vec{F} \cdot \Delta\vec{r} \qquad \text{(work by a constant force)}$$
$$K = \frac{1}{2}mv^2 \qquad \text{(kinetic energy)}$$
$$\Delta K = W_{\text{net}} \qquad \text{(work–energy theorem)}$$
$$U_{\text{near Earth}} = mgh \qquad \text{(approx. gravitational potential energy for small } h\text{)}$$

Gravitation and Orbits.

$$F_g = G\frac{m_1 m_2}{r^2} \qquad \text{(Newton's law of universal gravitation)}$$

$$U(r) = -\frac{GMm}{r} \qquad \text{(gravitational potential energy for point mass / sphere)}$$

$$a_g(r) = \frac{GM}{r^2} \qquad \text{(gravitational acceleration at distance } r\text{)}$$

$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}} \qquad \text{(speed in a circular orbit)}$$

$$T_{\text{orbit}} = 2\pi\sqrt{\frac{r^3}{GM}} \qquad \text{(period of a circular orbit)}$$

$$E_{\text{orbit}} = -\frac{GMm}{2r} \qquad \text{(total mechanical energy of a circular orbit)}$$