'art II: Short Answer Questions.
There are 4 short answer questions worth 10 points each.
Give a full yet concise answer to the question posed, explicitly showing any mathematical work if required.

2. Newton's Laws

a) (4 points) State Newton's Laws of Motion

1) "The law of inertia" — objects in motion stay in motion unless acted upon by an external force

2) $F = m \cdot a$ (Force = Mass · acceleration)

3) for every action, there is an equal, yet opposite, reaction.

b) (1 point) Consdier two masses, m1 and m2, with m2 twenty times larger than m1. If both masses are dropped simultaneously from the same height, which will hit the ground first?

→ From Galileo, neglecting air resistance, all objects fall at the same rate (they all fall at a constant acceleration of ~ 9.81 m/s²) Thus they hit at the same time!

c) (2 points) How does the force on m2 differ from that on m1?

$F_{m1} = m_1 \cdot a \longrightarrow F_{m1} = m_1 \cdot a$ — factor in

$F_{m2} = m_2 \cdot a \longrightarrow F_{m2} = (20\, m_1) \cdot a = 20(m_1 \cdot a)$ → $F_{m2} = 20\, F_{m1}$

d) (3 points) If mass m1 takes ten seconds to reach the ground, how fast is it going when it hits?

velocity = acceleration × time

$V = \left(10 \frac{m}{s^2}\right) \times (10\, s) = 100 \frac{m}{s} = V$

[Hint: velocity = acceleration x time. The acceleration of gravity at the Earth's surface is about 10 m/s/s. You may ignore air resistance. For scale, 1 m/s is roughly 2 miles per hour.]

33. Kepler's Laws

a) (4 points) State Kepler's three Laws of planetary motion:

1) planets orbit in ellipses, with the Sun at one focus

2) planets sweep out equal areas in equal amounts of time as they orbit

3) $P^2 = a^3$

b) (4 points) Imagine that we discover a new dwarf planet far beyond the orbit of Pluto. Let's call this new object Apate after the Greek goddess of deception. If Apate has an orbit with a semi-major axis of 100 AU, what is its orbital period?

$P^2 = a^3$ → plug-in → $P^2 = (100)^3$

given: $a = 100$ AU

want: $P = ?$

$P = (100)^{3/2}$

can apply powers in any order we want....

$P = 10^3$

**$P = 1000$ years**

c) (2 points) How many orbits has Apate completed around the sun since the peak of the Roman Empire two thousand years ago?

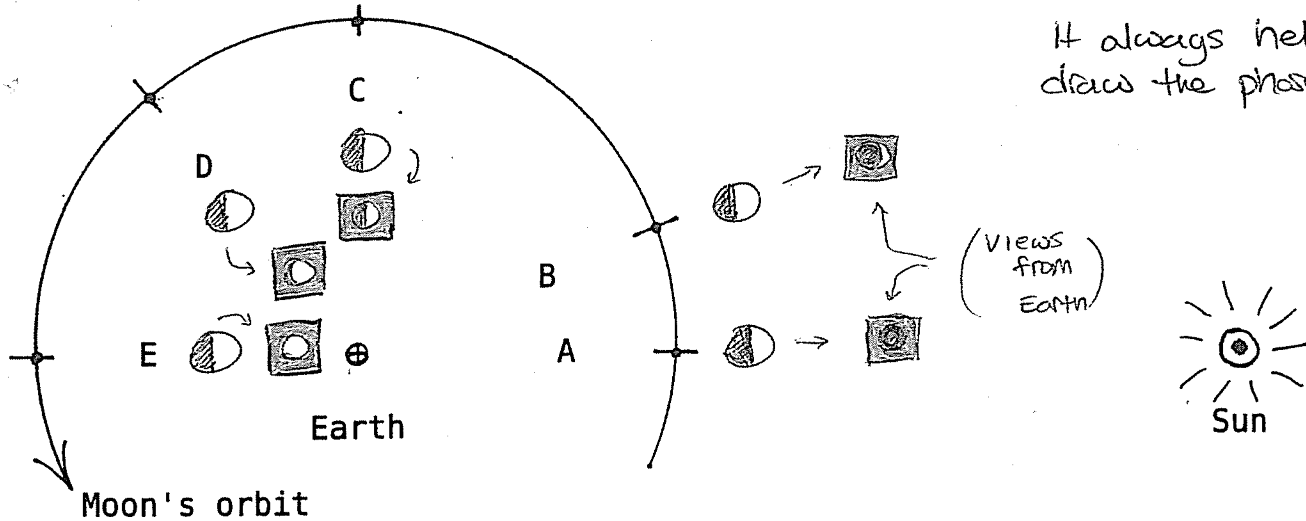
Time since peak of Roman Empire: 2000 yrs

Orbital period of Apate: 1000 yrs/orbit

$$\left(\text{Number of orbits since peak of Roman Empire}\right) = (2000\ \cancel{\text{yrs}}) \cdot \left(\frac{1\ \text{orbit}}{1000\ \cancel{\text{yrs}}}\right) = \boxed{2\ \text{orbits}}$$

34. Refer to this diagram to answer the questions posed:

It always helps to draw the phases!




a) (2 pts.) Is the moon waxing or waning as it moves from position A towards position E?

Waxing (we see more + more of the lit side as time progresses)

b) (5 pts.) Name the phase of the moon which is observed from the Earth at each of these positions:

A: New Moon

B: Waxing Crescent

C: First Quarter

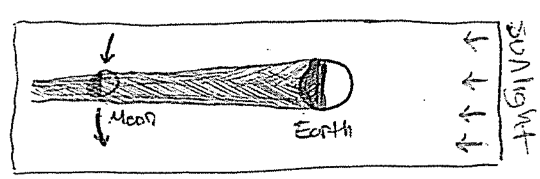
D: Waxing Gibbous

E: Full Moon

when the Moon goes into the Earth's Shadow

c) (1 pt.) At which of these positions is a lunar eclipse possible?

Position E → Full Moon




d) (2 pts.) Why doesn't a lunar eclipse occur EVERY time the moon is in this phase?

The Moon's orbit is tipped by ~ 5° to the plane of the Earth's orbit (the ecliptic). Thus to have an eclipse, we must be both in the correct phase, and perfectly lined up (the Moon must be in a node)

(see fig. 2.12 on p. 30 of the text) ←

35. The Universal Law of Gravity

Consider two masses, M and m, separated by a distance d.

a) (3 points) State Newton's Universal Law of Gravity:

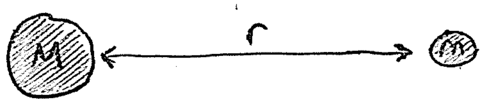
$$\boxed{F = \frac{GMm}{r^2}}$$

F = force

M, m = masses of the two objects

r = distance between the two objects

G = a constant




b) (2 points) How does the gravitational force between these two masses change if the mass of M is quadrupled?

$$F_{before} = \frac{GMm}{r^2}$$

substitute in $F_{before}$

$$F_{after} = \frac{G(M \times 4)m}{r^2} \longrightarrow F_{after} = 4\left(\frac{GMm}{r^2}\right) = \boxed{4\,F_{before} = F_{after}}$$

factor out the 4

force after M is quadrupled

(The force is 4 times larger)

c) (2 points) How does the gravitational force between these two masses change if instead the mass of m is cut in half?

$$F_{before} = \frac{GMm}{r^2}$$

$$F_{after} = \frac{GM(\frac{1}{2}m)}{r^2} = \frac{1}{2}\left(\frac{GMm}{r^2}\right) = \frac{1}{2}F_{before} \Rightarrow \boxed{F_{after} = \frac{1}{2}F_{before}}$$

(The force decreases by a factor of 2)

d) (3 points) How does the gravitational force between these two masses change if instead the distance d is doubled?

$$F_{before} = \frac{GMm}{r^2}$$

$$F_{after} = \frac{GMm}{(2r)^2} = \frac{GMm}{4r^2} = \frac{1}{4}\left(\frac{GMm}{r^2}\right) \Longrightarrow \boxed{F_{after} = \frac{1}{4}F_{before}}$$

(The force goes down by a factor of 4)