IB Physics

Chapter 5 and 6 Syllabus
Gravity and Circular Motion
Work and Energy

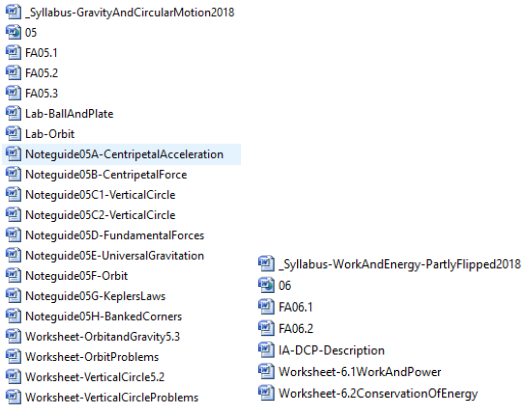
Block	Class	Due
1 Nov 30/ Dec 3	**DI**-Barrel of Bricks **GW**-Plate Lab **GW**-FA5.1-Circular Motion **DI**-Vertical Circle Demo	**VF 5A, 5B** Turn in: Plate Lab
2 Dec 4/5	**GW**-Vertical Circle **GW**-FA5.2	**VF 5C1, 5C2, 5D**
3 Dec 6/7	**SA5.2-Vertical Circle (first 30)** **VF**-5E Gravity **GW**-Gravity problems	Turn in: FA5.2
4 Dec 10/11	**GW**-5.3 Orbit Problems **VF**-5H Banked Corners (optional)	**VF 5E, 5F, 5G**
5/1 Dec 12/13	**GW**-FA5.3 **GW**-Orbit Lab	**VF 6A, 6B**
2 Dec 14/17	**SA5.3-Orbit Problems (first 30)** **VF**-6C, 6DCalculating Energy **GW**-Calculating Energy	Turin in: FA5.3
3 Dec 18/19	**DI**-Conservation of Energy **GW**-6.2 Conservation of Energy Problems	**VF 6E, 6F, 6G**
4 Dec 20/21	**DI**-Energy Labs **GW**-6.2 COE Problems **GW**-6.1 Work and Efficiency	**VF 6H, 6I, 6J**
5 Jan 7/8	**GW**-Energy lab **GW**-Problems	**VF Energy Lab**
6 Jan 9/10	**SA6.2&SA6.1 -Energy (first 60)** **IW**-Energy Lab **GW**-Energy Lab	Turn in: FA6.1, FA6.2
7 Jan 11/14	**GW**-Energy Lab **VF**-7A, 7B, 7C, 7D	**VF 7A, 7B, 7C** Turn in: Energy Lab
1 Jan 16/17	**MOMENTUM!!**	**VF 7D**

Assignments

- 3 Labs:
  - Plate lab /10 pts
  - Orbit Lab – simulation /30 pts
  - Energy Lab /30 pts
- 3 Formative/2 Summative Assessments:
  - 5.1 – Centripetal Acceleration*
  - 5.2 - Vertical Circle
  - 5.3 - Orbit and Gravity
  - 6.1-Work and Efficiency
  - 6.2-Conservation of Energy

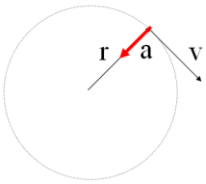
*Formative only

Handouts:



Noteguide for Centripetal Acceleration (Videos 5A) **Name** _____

Velocity = Speed + Direction



$a = v^2/r$
a = Centripetal acceleration
v = tangential velocity
r = radius of circle

Example - What is the centripetal acceleration of a 1200 kg car going 24 m/s around an 80. m radius corner?

What centripetal force is needed? What is the minimum coefficient of static friction required?

Whiteboards:

1. What is the centripetal acceleration if a tuna is going 6.2 m/s around a 2.3 m radius corner? (17 m/s/s)	2. A Volkswagen can do .650 "g"s (6.3765 m/s/s) of lateral acceleration. What is the minimum radius turn at 27.0 m/s? (114 m)

$a = 4\pi^2 r/T^2$
a = Centripetal acceleration
T = Period
r = radius of circle

Example: A merry-go-round completes a revolution every 7.15 seconds. What is your centripetal acceleration if you are 3.52 m from the center of rotation?

Whiteboard	Example
What should be the period of motion if you want 3.5 "g"s (34.335 m/s/s) of centripetal acceleration 5.25 m from the center of rotation? (2.5 s)	RPM Example: What is the acceleration of a point 32 cm out on a grinding wheel spinning at 1200 RPM? (5035 m/s/s – hint – T = 60 s/1200 Rev)

Noteguide for Centripetal Force (Videos 5B) **Name** _____

$a = v^2/r$
- a = Centripetal acceleration
- v = tangential velocity
- r = radius of circle

$a = 4\pi^2 r/T^2$
- a = Centripetal acceleration
- T = Period
- r = radius of circle

Example: What force is required to swing a 5.0kg object at 6.0m/s in a 75cm radius circle?

$F = mv^2/r$
- m = mass
- a = Centripetal acceleration
- v = tangential velocity
- r = radius of circle

$F = m4\pi^2 r/T^2$
- m = mass
- a = Centripetal acceleration
- T = Period
- r = radius of circle

Whiteboards:

1. Ice skates can give 420 N of turning force. What is r_{min} for a 50. kg skater @10.m/s? (11.9 m)	2. A ride makes a 60 kg small redheaded child go in a 4.1m radius circle with a force of 470 N. What period? (4.5 s)
3. It takes 35 N of force to make a glob of Jello go in a 2.0 m radius circle with a period of 1.85 seconds What's the mass? What's its flavor? (1.5 kg)	

Name:_____ Date:_____ Period:_____

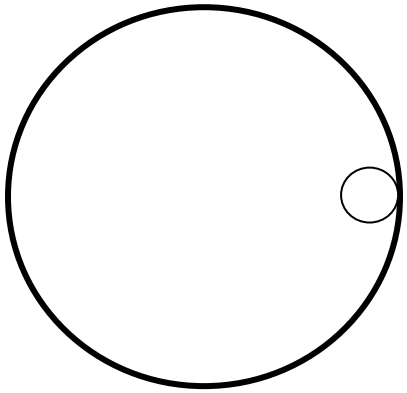
Plate Lab **(turn in)**

Goal: to analyze the forces needed for circular motion and understand what happens when those forces are removed.

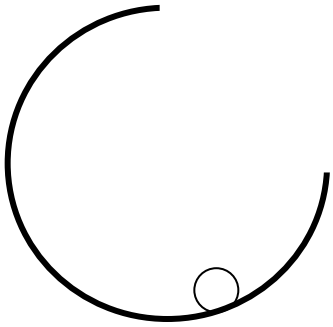
A marble on a plate can be made to go in a circle. Push a marble along the edge of a whole (uncut) plate and think about and answer the questions below. For this activity, the drawings and images will be from the viewpoint directly above the plate looking down.

After your push, what is the force causing this circular motion? _____

Make a guess and draw the forces, the acceleration, and velocity vectors. Think carefully about the direction this force acts.



A second plate has a section cut out of it. If you give the marble a push near the top so that it travels along the plate counter-clockwise, predict what path you think the marble take when it exits the plate. Draw the predicted path on the picture below. Write a short sentence why you think this will happen.



Test out your guess with the plate and marble. Do the experiment several times to make sure you know what actually happens. Now that you have seen the ball as it leaves the plate, draw the forces that apply for the two scenarios below. Discuss with a partner, be prepared to justify your drawing.

IB Physics
FA 5.1 - Centripetal Acceleration

Name_____(turn in)

Show your work, round to the correct significant figures, circle your answers, and label them with units.

1. With what maximum velocity can a car go around a 324 m radius curve if it cannot exceed 0.330 "g"s of lateral acceleration? (32.4 m/s)

2. A Centrifuge has a radius of 5.80 cm, and spins at 2500. RPM. What is the centripetal acceleration? (3980 m/s/s)

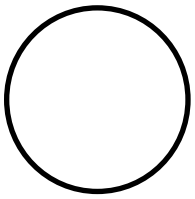
3. What centripetal force would make a 110. kg bike and rider go 14.0 m/s around a 25.0 m radius corner? (862 N)

4. A spinning carnival ride has a radius of 3.20 m. What is the period of the ride if it is exerting a centripetal force of 918 N on a 52.0 kg person? (2.68 s)

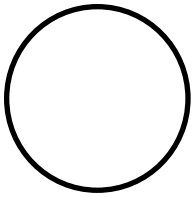
5. What is the minimum coefficient of friction needed for a 1198 kg car to go 25.0 m/s around a level corner with a radius of 310. m? What about a 3150 kg SUV? (0.206, 0.206)

Noteguide for "g" force in a Vertical Circle: (Videos 5C1) **Name_____**

Ex0 – A physics teacher twirls a bucket of water in a 1.12 m radius vertical circle. What is the minimum velocity at the top of the circle that will keep the water in the bucket?



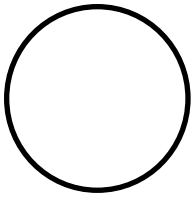
Example 1 - A Ferris wheel "pulls" 0.15 "g"s. What "g" force do they feel at the top and bottom?



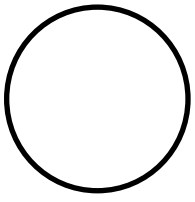
Example 2 – A rider moving in a 3.75 m radius vertical circle feels 0.80 “g”s inverted at the top of the circle.

A) How many “g”s is the ride pulling?

B) How many “g”s do they feel at the bottom?

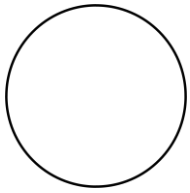


Example 3 – On the Rock-O-Plane a rider feels 1.62 "g"s at the bottom of the ride. What is the ride actually pulling, and what "g" force will they feel at the top?

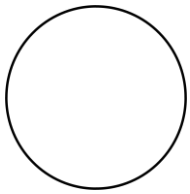


Noteguide for Vertical Circle: (Videos 5C2) **Name**_____

Example 2 – A 5.00 kg object goes 9.00 m/s in a 3.75 m radius vertical circle. Find the force needed at the top, and at the bottom.



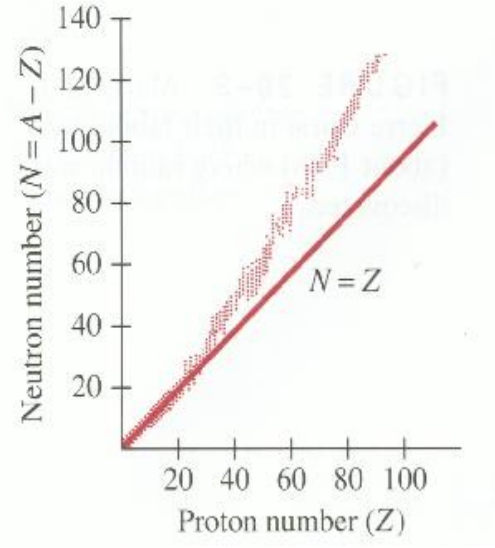
Ex4 – A 1.15 kg mass moves at a uniform speed in a 3.78 m radius circle on the end of a rod. At the top, the rod is exerting a downward force of 5.02 N on the mass.
a) What is the centripetal acceleration of the mass?
b) What is its speed?
c) What force does the rod exert at the bottom?



Noteguide for Fundamental Forces: (Videos 5D) **Name**_____

Gravity	Weak Nuclear
Electro-Magnetic	Strong Nuclear

Murray goes on a rant about how the short range nature of the Strong Nuclear (Binds neutrons and protons together) limits the number of stable nuclei (they get too big) and influences the number of neutrons.



Vertical Circle Questions from A5.2

Use the convention that up is positive. For all the forces, label them "up" or "down"

-0.60 "g"s 1.60 "g"s 8.51 N (up) 95.5 N (up) 7.84 s 38.7 N (up)	1. a. A carnival ride moves at a constant speed in a vertical circle. If the riders are feeling 2.60 "g"s at the bottom, what "g"s do they feel at the top, and what is the actual centripetal acceleration of the ride in "g"s? (Be sure to answer both questions) b-c: A 5.30 kg mass moves at a constant speed in a vertical circle on the end of a 0.440 m long rod with a velocity of 1.90 m/s. b. What force in what direction does the rod exert at the top? c. What force in what direction does the rod exert at the bottom? d-e: A 2.60 kg mass moves at a constant speed in a 7.90 m radius vertical circle on the end of a rod. At the top this requires an upward force of 12.3 N. d. What is the period of the mass? e. What force in what direction is required at the bottom?
0.88 "g"s 1.12 "g"s -7.14 N (down) 42.5 N (up) 3.78 m/s 2.09 N (up)	2. a. A carnival ride moves at a constant speed in a vertical circle. If the actual centripetal acceleration of the ride in "g"s is 0.12 "g"s, what "g"s do the riders feel at the top, what "g"s do they feel at the bottom? (Be sure to answer both questions) b-c: A 1.80 kg mass moves in a vertical circle at a constant speed with a period of 3.30 s on the end of a 3.80 m long rod. b. What force in what direction does the rod exert at the top? c. What force in what direction does the rod exert at the bottom? d-e: A 2.40 kg mass moves in a vertical circle at a constant speed on the end of a 1.60 m long rod. At the bottom this requires an upward force of 45.0 N d. What is the speed of the mass? e. What force in what direction is required at the top?
2.31 "g"s 1.31 "g"s 9.43 N (up) 31.8 N (up) 2.89 s -2.46 N (down)	3. a. A carnival ride moves at a constant speed in a vertical circle. If the riders are feeling 0.31 "g"s inverted at the top, what "g"s do they feel at the bottom, and what is the actual centripetal acceleration of the ride in "g"s? (Be sure to answer both questions) b-c: A 2.10 kg mass moves at a constant speed in a vertical circle on the end of a 0.910 m long rod at 2.20 m/s. b. What force in what direction does the rod exert at the top? c. What force in what direction does the rod exert at the bottom? d-e: A 1.20 kg mass moves at a constant speed in a vertical circle on the end of a 2.50 m long rod. This requires 26.0 N of upward force at the bottom. d. What is the period of the mass? e. What force in what direction is required at the top?
0.62 "g"s 1.62 "g"s 0.794 N (up) 28.6 N (up) 2.12 s 25.1 N	4. a. A carnival ride moves at a constant speed in a vertical circle. If the riders feel 0.38 "g"s at the top, what is the centripetal acceleration of the ride in "g"s, and what "g"s do they feel at the bottom (Be sure to answer both questions) b-c: A 1.50 kg mass moves at a constant speed of 2.30 m/s in a vertical circle with a radius of 0.570 m on the end of a rod. b. What force in what direction does the rod exert at the top? c. What force in what direction does the rod exert at the bottom? d-e: A 1.60 kg mass moves at a constant speed in a 0.670 m radius circle on the end of a rod. At the top this requires an upward force of 6.30 N. d. What is the period of motion of the mass? e. What force in what direction is required at the bottom?
-1.34 "g"s 2.34 "g"s -15.4 N (down) 42.9 N (up) 2.90 m/s 50.0 N (up)	5. a. A carnival ride moves at a constant speed in a vertical circle. If the riders are feeling 3.34 "g"s at the bottom, what "g"s do they feel at the top, and what is the actual centripetal acceleration of the ride in "g"s? (Be sure to answer both questions) b-c: A 1.40 kg mass moves in a vertical circle at a constant speed on the end of a 0.760 m long rod with a period of 1.20 s. b. What force in what direction does the rod exert at the top? c. What force in what direction does the rod exert at the bottom? d-e: A 2.20 kg mass moves in a vertical circle on the end of a rod with a radius of 0.650 m. At the top this requires a downward force of 6.80 N. d. What is the velocity of the mass? e. What force in what direction is required at the bottom?

IB Physics
FA 5.2 - Vertical Circle

Name_____

Show your work, round to the correct significant figures, circle your answers, and label them with units. Use the convention that up is positive. When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. A carnival ride moves at a constant speed in a vertical circle. If the riders are feeling 0.85 "g"s inverted at the top, what "g"s do they feel at the bottom, and what is the actual centripetal acceleration of the ride in "g"s? (Be sure to answer both questions)

2-3: A 2.50 kg mass moves at a constant speed in a vertical circle at the end of a 0.310 m long rod with a period of 1.30 s.

2. What force in what direction does the rod exert at the top?

3. What force in what direction does the rod exert at the bottom?

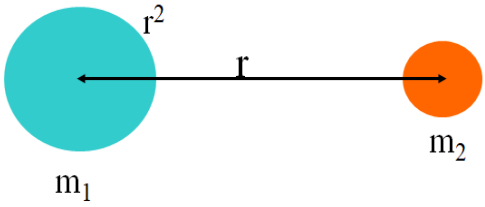
4-5: A 1.20 kg mass moves in a 0.45 m radius circle at a constant speed. At the top this requires a downward force of 5.75 N

4. What is its velocity?

5. What force in what direction is required at the bottom?

Noteguide for Universal Gravitation: (Videos 5E) **Name**_____

$$F = \frac{Gm_1m_2}{r^2}$$



r = Center to center distance
m_1 = One of the masses
m_2 = The other mass
G = Universal gravitation constant

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

Example 1 - Find the force of gravity between a 0.756 kg stapler, and a 0.341 kg marker that is 1.75 m away?

Example 2 - What is the force of gravity between a 1.0 kg mass, and the earth?
($r = 6.38 \times 10^6$ m, $m_{earth} = 5.97 \times 10^{24}$ kg)

Whiteboards:

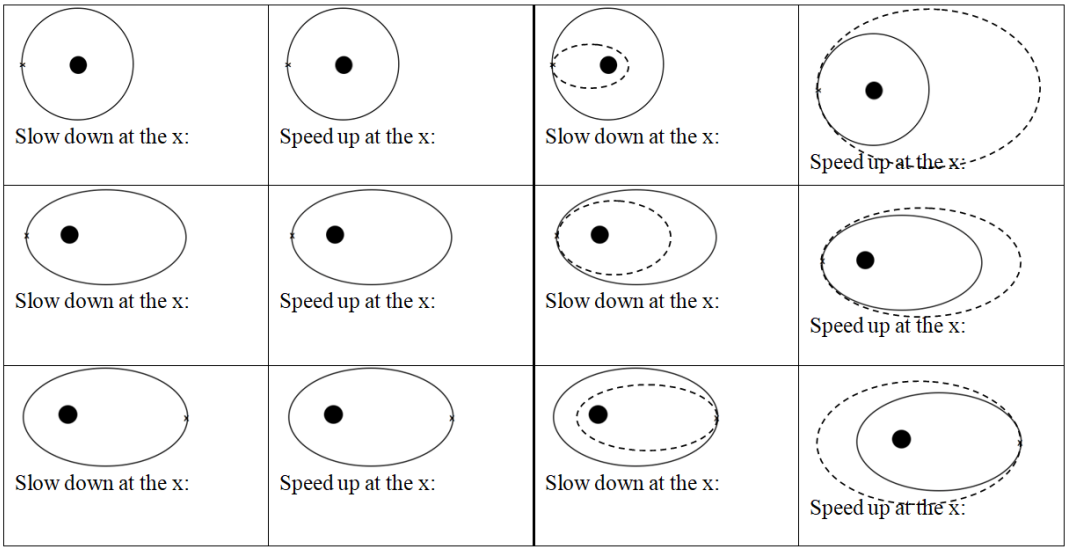
1. What is the force of gravity between a 5.2 kg shot and a 250. kg wrecking ball whose centers are 2.45 m distant? (1.44×10^{-8} N)	2. Another shot is 1.45 m from the center of a 250. kg wrecking ball and experiences a force of 1.55×10^{-7} N, what is the mass of the shot? (19.5 kg)
3. What distance from the center of a 512 kg wrecking ball must a 4.5 kg bowling ball be to experience a force of 1.13×10^{-9} N? (11.7 m)	4. The moon has a mass of 7.36×10^{22} kg, and a radius of 1.74×10^6 m. What does a 34.2 kg mass weigh on the surface? (55.5 N)

Orbit and Gravity Questions from A5.3

Use the value of $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

38,600 N 44.5 kg 2.53×10^{24} kg 2.43×10^{6} s	1. a. What is the force of gravity between a 6.50×10^{16} kg asteroid and a 18,700 kg spaceship if their centers are 1,450 m distant? b. The centers of two lead spheres are separated by 6.70 m. If one sphere has a mass of 56.0 kg, and there is an attractive force of 3.70×10^{-9} N, what is the mass of the other sphere? c. You are orbiting the planet Qwrmczl at a radius of 1.45×10^{7} m, at a velocity of 3410 m/s. What is its mass? d. What is the period of an orbit that is 3.90×10^{8} m from earth's center? ($m = 5.97 \times 10^{24}$ kg)
7.68 N 175 m 5.31×10^{23} kg 5.38×10^{11} m	2. a. What is the force of gravity between a 2.60×10^{13} kg asteroid and a 56,100 kg spaceship if their centers are 3,560 m distant? b. What distance separates the centers of two lead spheres if one has a mass of 123 kg, the other a mass of 12.0 kg and there is an attractive force of 3.20×10^{-12} N? c. You are orbiting the planet Wnnydrydrl at a radius of 7.80×10^{6} m, and a period of 2.30×10^{4} seconds. What is the planet's mass? d. What is the radius of an orbit around earth ($m = 5.97 \times 10^{24}$ kg) that has an orbital velocity of 27.2 m/s?
3,980 N 2.84 kg 2.51×10^{8} m 4.89×10^{5} s	3. a. What is the force of gravity between a 2.10×10^{15} kg asteroid and a 23,800 kg spaceship if their centers are 915 m distant? b. The centers of two lead spheres are separated by 1.35 m. If one sphere has a mass of 125 kg, and there is an attractive force of 1.30×10^{-8} N, what is the mass of the other sphere? c. What is the radius of the orbit that has an orbital velocity of 1260 m/s around the earth? ($m = 5.97 \times 10^{24}$ kg) d. What is the period of an orbit with a radius of 3.10×10^{7} m around the moon? (Moon's mass is 7.36×10^{22} kg)
72.4 N 1.67 m 2.92×10^{5} s 7.54×10^{25} kg	4. a. What is the force of gravity between a 2.30×10^{14} kg asteroid and a 12,700 kg spaceship if their centers are 1,640 m distant? b. What distance separates the centers of two lead spheres if one has a mass of 215 kg, the other a mass of 125 kg and there is an attractive force of 6.40×10^{-7} N? c. What is the period of the orbit that has a radius of 9.50×10^{7} m around the earth? ($m = 5.97 \times 10^{24}$ kg) d. You orbit the planet Kssnndnnwrr at a radius of 8.20×10^{7} m with a velocity of 7830 m/s. What is its mass?
40.0 N 9.60 kg 986 m/s 2.15×10^{23} kg	5. a. What is the force of gravity between a 23.6×10^{12} kg asteroid and a 14,600 kg spaceship if their centers are 758 m distant? b. The centers of two lead spheres are separated by 4.90 m. If one sphere has a mass of 45.0 kg, and there is an attractive force of 1.20×10^{-9} N, what is the mass of the other sphere? c. What is the velocity of the orbit that has a radius of 4.10×10^{8} m around the earth? ($m = 5.97 \times 10^{24}$ kg) d. You are in an orbit with a radius of 8.50×10^{7} m and a period of 1.30×10^{6} s around the planet Rjxnstdnnr. What is its mass?

Questions: Answers:



In general, speeding up brings the far side <u>out</u>, slowing down brings the far side <u>in</u>. Speeding up brings the entire trajectory <u>outside</u> the old one, and slowing down brings entire trajectory <u>inside</u> the old one.

Noteguide for Orbit problems (Videos 4F) **Name**_____

Use $\frac{m_s v^2}{r} = \frac{G m_c m_s}{r^2}$ or $\frac{m_s 4\pi^2 r}{T^2} = \frac{G m_c m_s}{r^2}$

G = 6.67 x 10^{-11} Nm^2/kg^2

These come from these formulas:

$F = \frac{G m_c m_s}{r^2}$ $a = \frac{4\pi^2 r}{T^2} = \frac{v^2}{r}$ $F = ma$

Example 1 - What is the velocity of orbit 250 miles above the earth?

r = 6.38x10^6 m + (250 mi)(1609 m/mi) = 6782250 m, me = 5.97 x 10^{24} kg

Example 2 - What is the radius of a geosynchronous orbit?

T = 23:56:04 = 23(3600) + 56(60) + 4 = 86164 s, m_e = 5.97 x 10^{24} kg

Fill in the Solutions: **(This side is optional)**

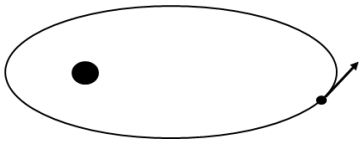
$\frac{m_s v^2}{r} = \frac{G m_c m_s}{r^2}$ **Formula:**	**Calculator:**
v =	
m_c =	
r =	

$\frac{m_s 4\pi^2 r}{T^2} = \frac{G m_c m_s}{r^2}$ **Formula:**	**Calculator:**
T =	
m_c =	
r =	

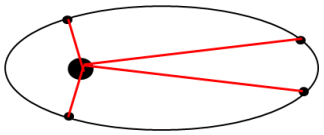
Noteguide for Kepler's Laws: (Videos 5G) **Name**_____

Johannes Kepler **1571 - 1630**
Tycho Brahe **1546 - 1601**

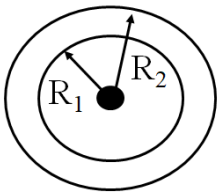
1. Orbits are ellipses.
(Central body a focal point)



2. Objects sweep equal area in equal time
(closer = faster)



3. Period – Radius



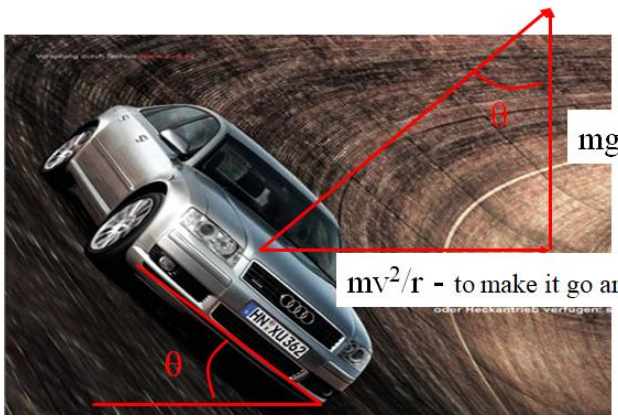
$$\frac{R_1^3}{T_1^2} = \frac{R_2^3}{T_2^2}$$

Example 1: What is the radius of a geostationary orbit (T = 1 day) if for the moon T = 27.4 days, R = 3.8×10^8 m

Example 2: Mars is 1.524 AUs from the sun. If our year is 365.26 days long, how many earth days is Mars's year?

Noteguide for Banked Corners: (Videos 5H) **Name**_____

$$\theta = \tan^{-1}(v^2/rg)$$



mg - to hold it up

mv^2/r - to make it go around the corner

Example: The on ramp from onto I-5 from Nyberg is 40. m in radius maybe. What should be the bank angle to go 27 m/s around it?

Whiteboards:

1. One of the Terwilliger curves has a radius of 270 m. What is the bank angle for cars to go 29 m/s around it? (18^o)	2. The on ramp from onto I-5 from Nyberg is 40. m in radius maybe. What should be the bank angle to go 45. m/s (101 mph) around it? (79^o) What about 112. m/s (250 mph) around it? (88^o) What does the angle approach? (90^o)

Orbit Problems: Name_____

1. What is the orbital velocity 3400 m from the center of a 5.6×10^{18} kg asteroid? ($331.4 \approx 330$ m/s)

2. You find that you can orbit at 516 m/s 12,150 m from the center of a small moon. What is its mass?
3. (4.85×10^{19} kg)

4. A satellite orbits a planet at a distance of 7.5×10^{6} m from the center every 8900 seconds. What is the mass of the planet? (3.2×10^{24} kg)

5. What distance from the center of Earth's moon is your orbital velocity 120 m/s? (3.4×10^8 m)

6. What is the period of orbit of a satellite that orbits 1.95×10^6 m from the center of Earth's moon? (7730 s)

7. What is the radius of an orbit with a period of 3.16×10^7 s around the sun?
8. (1.50×10^{11} m – yep – it's the earth)

Use $\frac{m_s v^2}{r} = \frac{G m_c m_s}{r^2}$ or $\frac{m_s 4\pi^2 r}{T^2} = \frac{G m_c m_s}{r^2}$ Which come from: $F = \frac{G m_c m_s}{r^2}$, and $a = \frac{4\pi^2 r}{T^2} = \frac{v^2}{r}$ and $F = ma$

Useful things to know:

Mass of the Earth	5.97×10^{24} kg	Radius of the Moon	1.738×10^6 m
Mass of the Moon	7.35×10^{22} kg	Radius of the Earth	6.38×10^6 m
Mass of the Sun	1.99×10^{30} kg	Earth-Moon Distance	3.84×10^8 m
$G = 6.67 \times 10^{-11}$ Nm^2/kg^2		Earth-Sun Distance	1.496×10^{11} m

IB Physics
FA 5.3 - Orbit

Name_____

Show your work, round to the correct significant figures, circle your answers, and label them with units.
When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. What is the force of gravity between the Philae probe with a mass of 100. kg and comet 67P with a mass of 1.05×10^{13} kg if the probe is resting on the surface of the 2.05 km (2.05×10^{3} m) radius comet. (That we will pretend is spherical - it's highly not)

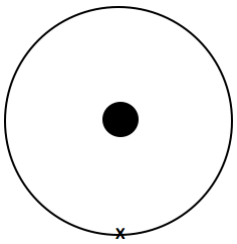
2. What distance needs to separate the centers of two 5.20 kg spheres so that the force of gravity between them is 1.20×10^{-9} N

3. Your 12,500 kg spaceship is orbiting 1.16×10^{7} m from the center of a planet every 17,500 s. What is the mass of the planet?

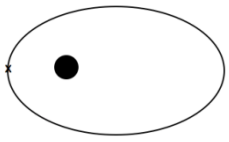
4. At what distance from the center of our 7.35×10^{22} kg moon is the orbital velocity 340. m/s?

5. Draw the new orbit: (Circle or oval indicates your <u>current</u> orbit)

Slow at x:
(elliptical, inside, tangent at x)



Speed up at x:
(more elliptical, outside orbit, tangent at x)



Speed up at x:
(less elliptical, outside orbit, tangent at x)