K-1 Speed©!
"Feel the Physics!"

The physics of the sport, plus Physics Field Day Activities!

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*Teachers are invited to select which problems their students should solve, and are free to design their own for a particular class.

The Physics of Safety!

Safety Features!

1. Our **helmets** are designed for **maximum** protection of the riders to prevent sudden turn/impact injuries by **cushioning** all **accelerations**.

   The way the **cushioning** works is through the physics of **Momentum**! **Momentum** is inertia in motion! Anything **moving** has **momentum** and is represented by the letter "**p.**" It depends on how much **mass** (m) is moving and how **fast** (v) it is moving!

   $$\mathbf{p = mv}$$

   Now, an **Impulse** "J", or "I" causes a "**change in momentum**" and is determined by multiplying the **Force** (F) that caused the change in momentum, times the **time** (Δt) for the **momentum to change!**

   $$\mathbf{I = J = F\Delta t = m\Delta v = \Delta p = p_f - p_i = mv_f - mv_i}$$

   Since the end result of any accident is a kart at **rest**, the change in momentum (Δp) is exactly what the **initial momentum** was to begin with!

Safety Features!

(Continued)

The way the **impact force** (F) is minimized, is by making the **time** (t) for the **change in momentum** to be as **BIG** as possible! Therefore **CUSHIONING** extends the **time** for the **momentum to change**, which then lowers the **IMPACT FORCE** (F)!

$$\mathbf{F = \Delta p/\Delta t}$$

Bumpers are designed to absorb maximum impact force. But to say, “absorb” is not exactly correct. **Newton’s 3^{rd} Law of Motion** states that **for every action force, there is an equal and opposite reaction force**! You cannot touch something without it touching you back with an equal and opposite force. Try to touch the tabletop lightly and the table will touch you back lightly. Press **harder**, and the table presses back **harder** on you. So the bumper hits something and that something will hit the bumper. The only difference is that the bumper is attached to the kart, which has less mass than the secured track guides, so the kart moves instead of the track guides. Again the **longer the time** for the momentum to change, the **lower the impact force** will be!

FRICTION!

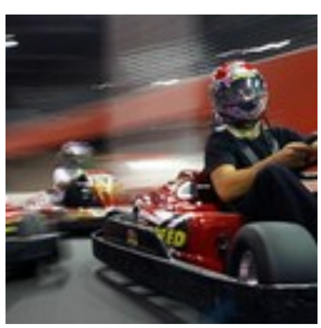
2. **Wheels** are designed for maximum friction to grip for quick starts, quick stops, and to hold their course through g-force turns!

   Did you know that the **Friction** between the wheels and the track is different for when the kart is at rest, than if the kart is in motion? **Static Friction** "μ_s" (Kart at rest) is always **more** than when the kart is in motion, which is called "**kinetic friction**" "μ_k". This is due to the inter-molecular attractive forces that are created when there is no motion between the surfaces in contact. When there is motion, these inter-molecular forces do not have the opportunity to form bonds between the 2 contact surfaces.

$$f_s = \mu_s N > f_k = \mu_k N$$

   Also, as one might imagine, the friction between 2 surfaces depends on the **roughness** of the 2 surfaces in contact. The roughness of the surface is described by the "**coefficient of friction**" and is represented by the symbol "μ." The "Normal" force (N) is the support force provided by the road and is equal to the weight of the kart plus the rider (N = mg).
   So, the **friction force depends on the type of surfaces in contact and weight (mg) of the object being supported by the surface.**

$$F = \mu N = \mu mg$$



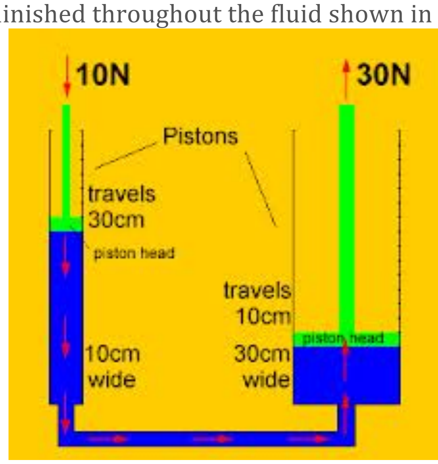
FRICTION!

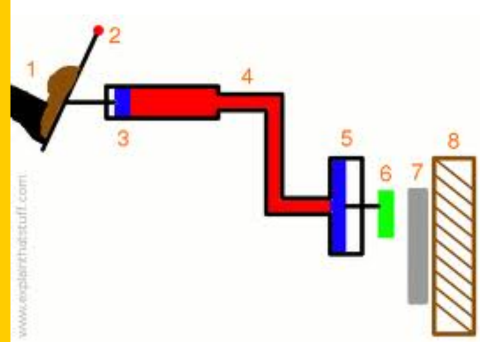
(Continued)

Friction is used to make you STOP too!
K-1 Speed karts have:

- SELF-ADJUSTABLE BRAKE PUMP
- TWO REAR HYDRAULIC BRAKES

  "Hydraulics" is the application of pressure through a fluid to increase the breaking force, and is called "Pascal's Principle." It states that the pressure applied through a fluid is transmitted undiminished throughout the fluid shown in the diagrams below.





- DOUBLE REAR SELF-VENTILATED BRAKE DISC

A result of friction is the production of heat energy. Rub your hands together briskly and they heat up quickly. Guess what? So do the brakes!

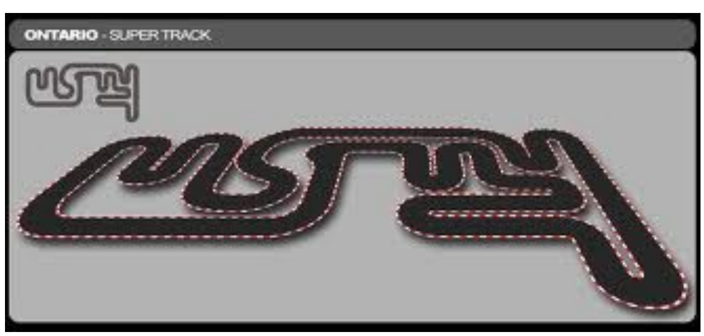
Average Velocity!

3. We all are used to driving in cars on streets at specific speeds that are safe for the type of road you are on. City streets are usually busy, so it is dangerous to travel at high speeds, while freeways are wide open, and are safe at much greater speeds. Reading a "**Speed Limit**" sign tells you how fast you can safely go in "**mph**" which means, "**miles per hour**." This is what speed depends on! A **distance divided by a time**!

Example: going 25mph, means you will travel 25 miles in 1 hour if you keep this rate of speed for an hour. Seems rather simple doesn't it? It is! By simply timing a cart to complete 1 lap, and knowing the distance you cover in 1 lap, you can determine the **average speed** of the cart!

average speed = distance travelled/time to travel = d/t

In physics, there are **two types of "speed."** One is just how far you went and how long it took. That is the **speed** limit sign on the side of the road. The other is more specific, and includes what **direction** you are going! This is what physics calls, "**velocity**."



Newton's Laws of Motion

4. Sir Isaac Newton was one of the first scientists to publish a description of natural laws concerning the motion of objects, and K-1 Speed carts are no exception!

Newton's 1st Law of Motion; Inertia

All objects **at rest tend to stay at rest**, while all objects **in motion tend to stay in motion**, unless a force causes them to change their motion. This is what Newton's 1st Law of motion called "**Inertia**" is all about! "Inertia" is also a **resistance to a change in motion** in which **larger** objects are more difficult to change their motion than **small** objects. Much like the way a small hummingbird moves and turns very quickly while a large animal like a giraffe seems to move in slow motion.

At the starting line of a race you are **at rest**, therefore you **tend to stay at rest**. But when you get the green light, you **accelerate** as fast as you can go, and feel as though you are being **pushed back** into your seat! This is because you were at **rest** while the cart began to accelerate forward, leaving you behind (things at rest tend to stay at rest!)! This also happens when you head into a **turn**! You were **moving** forward in a **straight line** when the cart began **turning.** You felt as though you would continue forward unless you are belted in, and lean into the turn! The "**center-seeking force**" or **centripetal force** (F_c) is causing you to turn instead of going straight! Without seat belts, you would **go straight**, while the cart made the turn. The result is a feeling that you are getting "pushed out, or away" from the cart during any turns!

When you come to a **sudden stop**, the reverse of what happens at the beginning of a race occurs. When you are **in motion** and then come to an abrupt stop, you **tend to keep moving** and will end up in front of the cart if you are not secured in your seat!

Newton's 2nd Law of Motion

A **force** can be described simply as either a **push** or a **pull.** This push or pull will **cause the motion of an object to change**, and this change in motion is called, "**acceleration**."

The value for **acceleration** (a) depends on how fast the speed changes, or the change in **velocity** (v) divided by the **time** (t) it took for the velocity to change.

$$a = \Delta v/\Delta t = (v_f - v_i)/t$$

The **acceleration** is represented by "a" and depends on the **force** (F) applied to the object, divided by the object's **mass** (m).

$$a = F/m^*$$

***This is a corner-stone law in physics, engineering and technology!**

Newton's 3rd Law: Action/Reaction!

As previously mentioned in the "Physics of Safety" section, Newton's 3rd law describes that when **a force is applied to an object, the object applies a reaction force back.**

To **accelerate** your kart **from rest**, the electric motor causes the wheels to turn which push against the road, while the road pushes against the wheels with an equal but opposite force! The cart accelerates away since the mass of the cart plus it's driver is far less than the mass of the road (which is attached to the Earth!)**. The wheels push against the road, the road pushes against the wheels!**

Taking the Turns!

5. Friction is also responsible for the carts to be able to make the **turns**! How would the carts take the **turn on ice**? Not very well, right? In this case the friction provides a "center-seeking" force, which causes a "center-seeking" acceleration. This "center-seeking" force is called "**centripetal**" force and is represented as "$\mathbf{F_c}$" which depends on the **mass** (m) times the **centripetal acceleration** ($a_c = v^2/r$).
You have probably heard of a "centrifugal" force, or "center-fleeing;" the feeling of an outward force as a result of spinning, but this is a "reaction" force the center-seeking force of whatever is causing you to spin, or move in a curve! **If it curves, there is a centripetal force that made it curve!**

Centripetal acceleration depends of the **velocity** (v) squared, divided by the **radius** of the turn. **The tighter the turn, the greater the centripetal acceleration for the same speed**!

$$\mathbf{a_c = v^2/r}$$

So the **centripetal force** becomes;

$$\mathbf{F_c = ma_c = mv^2/r}$$

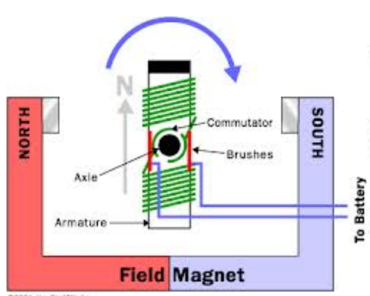
The Engine is actually a Motor!

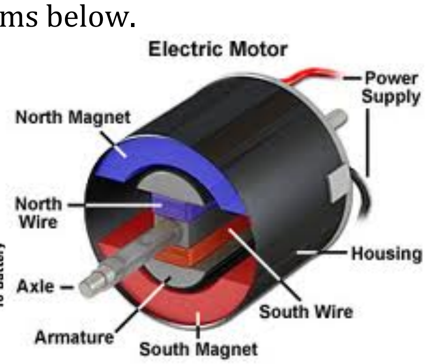
6. K-1 Speed carts are all powered by **electric motors with zero emissions** to promote a healthy indoor environment.

Let's look at how an electric motor works:

A difference in **voltage** (electric potential energy per charge) causes a current of charges to flow through a conductor (wire). This flow of charges is called an **electric current**. Each of the flowing charges is surrounded by an **electric field** (E-field). As the charges move, they create a **magnetic field** (β-field) around them as well! Magnets can exert a force on the flowing charges in the wires by interacting with the charges' magnetic field too!

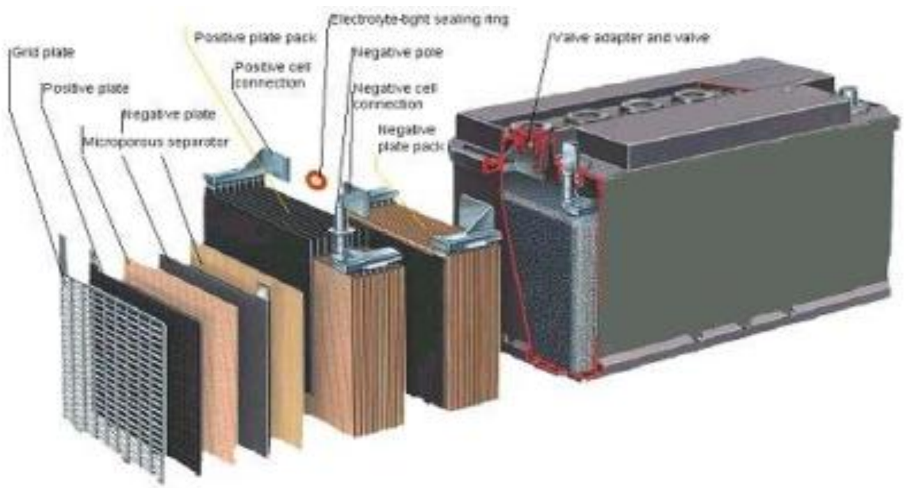
Recall that a magnet has strong forces at the ends of the magnet. These areas of concentrated force are called "**poles.**" You may also recall that **opposite poles attract**, while **like poles repel**. These same forces from the magnet can cause an acceleration of the charges in the wires! By placing the wires in the right position in the magnet's field, the wire itself will move! This is the basis of creating a turning axle in an electric motor. See the diagrams below.





Batteries!

7. Driving an electric cart is not the same as driving a gasoline car. The fuel is completely different, and it has zero noxious emissions! The power to drive the K-1 Speed carts comes from regular 12-V Direct Current car batteries!



The battery delivers a **direct current** (DC) of electricity to the motor where permanent magnets cause the coil of current-carrying wire to spin, which makes the wheels turn!

$$F = qv\beta \sin\theta$$

Where F = Force, q = charge, v = velocity and β = magnetic field strength

The energy of the batteries is **Electrical Potential Energy per charge,** or **Voltage** that gets converted to energy of motion called **Kinetic Energy** (KE), which is equal to ½ mass (m) times the velocity (v) squared, or ½ rotational inertia (I) times angular velocity (ω) squared.

$$KE = 1/2mv^2 = 1/2I\omega^2$$

Work (W) is equal to the change in energy ($W = \Delta E = KE_f - KE_i$).

The Finish Line!

K-1 Speed Go Cart Specifications

- LENGTH: 200 CM
- WIDTH: 143 CM
- SEAMLESS SPECIAL CHROMIUMMOLYBDENUM STEEL FRAME OF 32MM IN DIAMETER
- ADJUSTABLE CASTER / CAMBER
- ANODIZED ALUMINUM FOOTPLATE
- SELF-ADJUSTABLE BRAKE PUMP
- TWO REAR HYDRAULIC BRAKES
- DOUBLE REAR SELF-VENTILATED BRAKE DISC
- DIFFERENTIAL
- REGULATION OF TENSION FOR STEERING WHEEL
- STEEL SPORTIVE STEERING WHEEL
- ADJUSTABLE SEAT TO ACCOMODATE SHORT TO TALL DRIVERS
- DC CURRENT ENGINE
- ENGINE WITH WATERPRROF TREATMENT FOR OUTSIDE USE
- 4 HICAPACITY DRY BATTERIES 48V
- AUTONOMY: UP TO 20 MINUTES
- RAPID CHARGE: 5 TO 15 MINUTES
- MULTI-FUNCTION DIGITAL ELECTRONICS WITH ENERGY RECOVERY
- ADJUSTABLE SPEED FROM 0-90 KM/H (0-60 MPH)

The Physics of K-1 Speed Karts!

<u>Physics Relationships;</u>

$v = \Delta x/\Delta t$	$v_f = v_i + at$	$f = \mu N = \mu mg$
$a = \Delta v/\Delta t = (v_f - v_i)/t$	$v_f^2 = v_i^2 + 2a\Delta x$	$x = x_i + v_i t + 1/2at^2$
$a_c = v_t^2/r = (2\pi r/T)^2/r = F_c/m$	$\omega = \Delta\theta/t$	$\alpha = \Delta\omega/t$
$p = mv$ $\quad$ $F\Delta t = m\Delta v = \Delta p$	$L = I\omega = mvr$	
$F_c = ma_c = mv_2/r = \mu N = \mu mg$	$F_{net} = F_1 + F_2 + F_3 \ldots = ma$	$P = F/A$
$v_t = 2\pi r/T = r\omega$	$F_1A_1 = F_2A_2$	$\tau = (F\sin\theta)\ell$
$V = IR$ $\quad$ $P = IV = W/t$	$V_{series} = V_1 + V_2 + V_3\ldots = V_{total}$	
$E = kq/r$	$R_{series} = R_1 + R_2 + R_3\ldots = R_{total}$	
$W = \Delta E = KE_f - KE_i = Fd$	$R_{parallel} = (1/R_1 + 1/R_2 + 1/R_3\ldots)^{-1}$	
$\varepsilon = n(\Delta\phi/\Delta t)$	E-field $= F/q$	
β-field $= F/qv\sin\theta$		

Applying Physics!

Show all work in the space provided.

The RACE!

1. Determine the **average velocity** (in m/s, then convert to miles/hour) of the fastest cart by timing a cart to complete one lap.

2. Determine the **acceleration** (a) of the cart (in m/s^2) for the first straight away, assuming you start from rest, and travel 20 meters in 3 seconds. (hint: use the average velocity from #1 as v_f).

3. Using the mass of the cart plus driver equals 160kg, determine the **net force** acting on the cart to create the acceleration determined from #2 above?

4. Determine the **centripetal acceleration** of the cart through the first turn with radius of 3 meters at a speed of 5 m/s.

Applying Physics!

Show all work in the space provided.

The RACE!

5. What is the **friction force** that allows the cart to make the first turn?

6. If the cart plus driver from #3 comes to rest in 3s, what is the **friction force** that acts on the brakes?

7. What is the **momentum** of a cart plus driver with a velocity of 12m/s?

Applying Physics!

Show all work in the space provided.

The RACE!

8. Draw a **free-body diagram** of the cart as it **accelerates** from rest, labeling all forces acting on the cart, including friction.

9. Draw a **free-body diagram** of the cart as it **accelerates through a turn,** labeling all forces acting on the cart, including friction.

10. When you finish the race going 20 m/s initially, what is the **impulse** delivered to the cart if you **come a stop** in 3s? (hint: use mass of driver plus cart from #3)

Applying Physics!

Show all work in the space provided.

The Pit/Shop

11. If the resistance of the wires leading to the motor is 4 Ω, determine the **current** delivered by a 48 V power source.

12. If you press on the brakes with a force of 20 N over an area of 50 cm^2, what will be the **force applied** to the disc brake with an area of 5 cm^2?

13. If you have 4 car batteries of 12 V each connected in series, **how many Volts** of electricity will be produced?

Applying Physics!

Show all work in the space provided.

14. Determine the **torque** applied to the wheels if a force of 1000N is applied at .1 meters radius.

15. If the cart tires are in contact with the road surface over an area that is 20cm long and 10cm wide per tire, what is the **pressure on 1 tire** if the cart + driver has a mass of 160 kg?

16. Describe which of Newton's Laws is applied when you accelerate from rest and feel as though you are being pushed back into your seat, and why you feel as though you will fall away from a turn?

Applying Physics!

Show all work in the space provided.

The Electric Motor!

17. If the motor produces up to 3200 RPM and starts from rest, what is the **angular acceleration** if the motor reaches its maximum RPM in 3 seconds?

18. If the combined batteries produce a total voltage of 48 V, and the maximum power produced by the motor is 4000W, what is the maximum **current** applied?

19. If 1 Horsepower is equal to 745.7 Watts, how many **Horsepower** is produced by the electric motor that produces 4000Watts maximum power?

20. If the wheels have a radius of .10 meters, and have a maximum of angular velocity of 2800 RPM, what is the **tangential velocity** of the wheel? What cart **speed** does this translate into in **miles per hour**?

Solutions to Problems

1.Determine the **average velocity** (in m/s, then convert to miles/hour) of the fastest cart.

assume distance travelled in 1 lap is 250 meters, and the time is 30s…

d = 250m — from v =d/t, and plugging in values we obtain; v = 250m/30s **= 8.3m/s**

t = 30s

2. Determine the **acceleration** (a) of the cart (in m/s^2) for the first straight away, assuming you start from rest, and travel 20 meters in 2 seconds. (hint: use the average velocity from #1 as v_f).

v_i = 0m/s — from $v_f = v_i + at$ and solving for a, we obtain $a = v_f - v_i/t$ = (8.3m/s)/2s **= 4.2m/s^2**

v_f = 8.3m/s

t = 3s

a =?

3. Using the mass of the cart plus driver equals 160kg, determine the **net force** acting on the cart to create the acceleration determined from #2 above?

m = 160kg — from F_{net} = ma, and plugging in values we obtain F_{net} = (160kg)(4.2m/s^2) **= 672N**

a = 4.2m/s2

F_{net} = ?

4. Determine the **centripetal acceleration** of the cart through the first turn with radius of 3 meters at a speed of 5 m/s.

r = 3m — from $a_c = v^2/r$ and plugging in values we obtain; ac = (5m/s)^2/3m **= 8.3m/s^2**

v = 5m/s

a_c = ?

5. What is the **friction force** that allows the cart to make the first turn?

m = 160kg — knowing that **friction** provides the center-seeking force (F_c), and $F_c = ma_c$

a_c = 8.3m/s2 — plugging in values we obtain, F_c = (160kg)(8.3m/s^2) **= 1328N**

f = ?

Solutions to Problems
-Continued-

6. If the cart plus driver from #3 comes to rest in 3s, what is the **friction force** that acts on the brakes?

t = 3s
m = 160kg
v_i = 8.3m/s
v_f = 0m/s

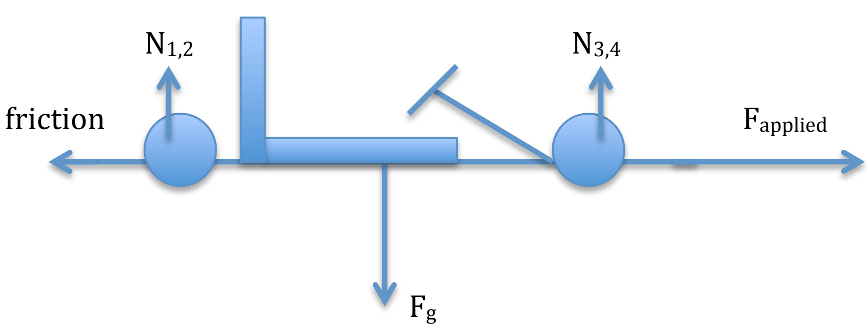
from F = ma = m(v_f – v_i)/t, and plugging in values we obtain;
F = (160kg)(-8.3m/s)/3s **= 442.7N**

7. What is the **momentum** (p) of a cart plus driver with a velocity of 12m/s?

v = 12m/s
m = 160kg

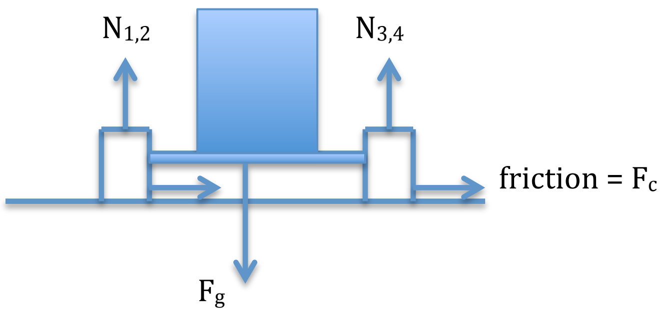
from p = mv, plugging in values we obtain; p = (160kg)(12m/s) **= 1920kgm/s**

8. Draw a **free-body diagram** of the cart as it **accelerates** from rest, labeling all forces acting on the cart, including friction.



Solutions to Problems
-Continued-

9. Draw a **free-body diagram** of the cart as it **accelerates through a turn at constant speed,** labeling **all forces** acting on the cart, including friction. Center of turn is to the right



10. When you finish the race going 20 m/s initially, what is the **impulse** delivered to the cart if you **come a stop** in 3s? (hint: use mass of driver plus cart from #3)

v_i = 20m/s — using impulse relationship; $I = F\Delta t = m\Delta v = m(v_f - v_i)/t$
v_f = 0m/s — plugging in values we obtain; (160kg)(-20m/s)/3s **= 1066.7kgm/s**
t = 3s
m = 160kg
I = ?

11. If the resistance of the wires leading to the motor is 4 Ω, determine the **current** delivered by a 48 V power source.

R = 4Ω — using Ohm's law; V = IR and solving for I, we obtain I =V/R
V = 48V — I = 48V/4Ω = **12Amperes**
I = ?

Solutions to Problems
-Continued-

12. If you press on the brakes with a force of 20 N over an area of 50 cm^2, what will be the **force applied** to the disc brake with an area of 5 cm^2?

$F_1 = 20N$ using Pascal's Principle; $F_1A_1 = F_2A_2$ and solving for F_2
$A_1 = 50cm^2$ we obtain; $F_2 = (F_1A_1)/(A_2)$. Plugging in values… $F_2 = (20N)(50cm^2)/(5cm2)$ **= 200N**
$F_2 = ?$
$A_2 = 5cm^2$

13. If you have 4 car batteries of 12 V each connected in series, **how many Volts** of electricity will be produced?

$V_1 = V_2 = V_3 = V_4 = 12V$ using the relationship for voltage sources in a series circuit;
V_{total} **= ?** $\Sigma V_{series} = V1 + V2 + V3 + V4 = V_{total}$ **= 48V**

14. Determine the **torque** applied to the wheels if a force of 1000N is applied perpendicularly at a radius of .1 meter.

F = 1000N using the relationship for torque, $\tau = F\ \ell$ and plugging in values we obtain
l = .1m $\tau = (1000N)(.1m)$ **= 100Nm**
$\tau = ?$

15. If the cart tires are in contact with the road surface over an area that is 20cm long and 10cm wide per tire, what is the **pressure on 1 tire** if the Cart + driver has a mass of 160 kg?

L = 20cm using the relationship for pressure P = F/A, where F = ma = W = mg, and A = L x W, We plug in
W = 10cm values to obtain $P = mg/(L \times W) = (160kg)(9.8m/s^2)/(20cm \times 10cm)$ **= 7.8N/cm²**
M = 160kg
$G = 9.8m/s^2$
P = ?

Solutions to Problems
-Continued-

16. Describe which of Newton's Laws is applied when you accelerate from rest and feel as though you are being pushed back into your seat, and why you feel as though you will fall away from a turn?

Answers may vary, but the main concept is that an object at rest will continue in a state of rest, so the driver will resist a change in their state of rest, resulting in the sensation of feeling pushed **into** their seat as a reaction to the seat pushing them forward along with the cart. The same applies when the driver turns, they are in a state of motion, and will continue in a straight-line, constant speed motion which will tend to feel as though you will fall away from the direction the cart is turning!

17. If the motor produces up to 3200 RPM and starts from rest, what is the **angular acceleration** if the motor reaches its maximum RPM in 3 seconds?

ω_f = 3200RPM — using the relationship for angular acceleration; $\alpha = \Delta\omega/t = \omega_f - \omega_i/t$

ω_i = 0RPM — plugging in values we obtain α = 3200RPM/3s **= 1066.7RPM/s**

t = 3s

α = ?

18. If the combined batteries produce a total voltage of 48 V, and the maximum power produced by the motor is 4000W, what is the maximum **current** applied?

V= 48V — using the relationship for electric power P = IV and solving for I, we obtain

P = 4000W — I = P/V = 4000W/48V **= 83.3Amperes**

I = ?

19. If 1 Horsepower is equal to 745.7 Watts, how many **Horsepower** is produced by the electric motor that produces 4000Watts maximum power?

P = 4000W — use relationship to convert between Horsepower and Watts,

1HP = 745.7W — 4000W(1HP/745.7W) **= 5.4HP**

Solutions to Problems
-Continued-

21. If the wheels have a radius of .10 meters, and have a maximum of angular velocity of 2800 RPM, what is the **tangential velocity** of the wheel? What cart **speed** does this translate into in **miles per hour**?

r = .10m	using the relationship for tangential velocity $v_t = r\omega$, and converting to radians
ω = 2800RPM	we obtain, ω = (2800rev/min)(2πradians/rev) = 17584rad/min, convert 17584rad/min to
v_t = ?	meters/sec = (17584rad/min)(1min/60sec)(6.28x.1m)/6.28rad) **= 29.3m/s**
	now convert to mph = (29.3m/s)(1mile/1609meters)(3600s/hr)**= 65.6mph**