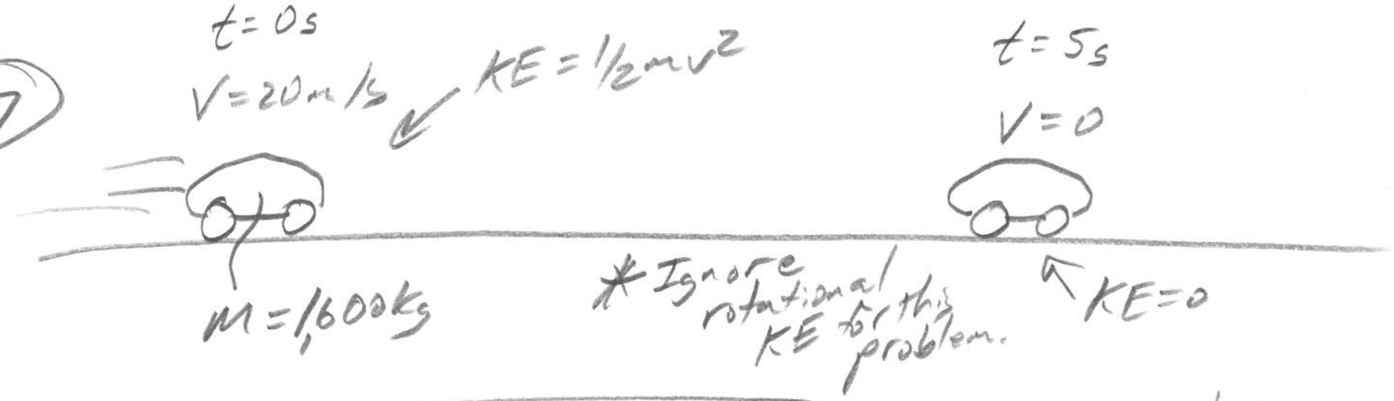
1-7



1. $\boxed{PE_0 + KE_0 + W_{NC} = PE + KE}$

$0 + \frac{1}{2}mv^2 + W_{NC} = 0 + 0$

$\frac{1}{2}(1600\text{kg})(20\text{m/s})^2 = -W_{NC}$ ← Work done by Motor/Battery — negative

Stored Electric Energy = 320,000J ← Work done on Motor/Battery — Positive

2. $\boxed{P = \frac{W}{t}}$ ← work

Power

Work = Energy put into battery

Power units $= \frac{J}{s} = W$

Work and Energy are equivalent

$P = \frac{320{,}000\text{J}}{5\text{s}}$

$P = 64{,}000\frac{J}{s} = 64{,}000\text{W}$

3. $\boxed{P = VI} \Rightarrow 64{,}000\text{W} = 400\text{V}(I)$

Power

$I = 160\text{A}$

4. $\boxed{I = \frac{Q}{\Delta t}} \Rightarrow 160A = \frac{Q}{5s}$

or

$160\frac{C}{s} = \frac{Q}{5s}$

$\Rightarrow Q = 800C$

---

5. $\boxed{Ft = m\Delta v}$ ← change in momentum (Δp)

Impulse

$F(5s) = 1600kg(-20m/s)$

$F_{brakes} = -6{,}400N$

---

6. $\boxed{PE_0 + KE_0 + W_{NC} = PE + KE}$

already did this in #1

$0 + 320{,}000J + W_{NC} = 0 + 0$

$W_{NC} = -320{,}000J$

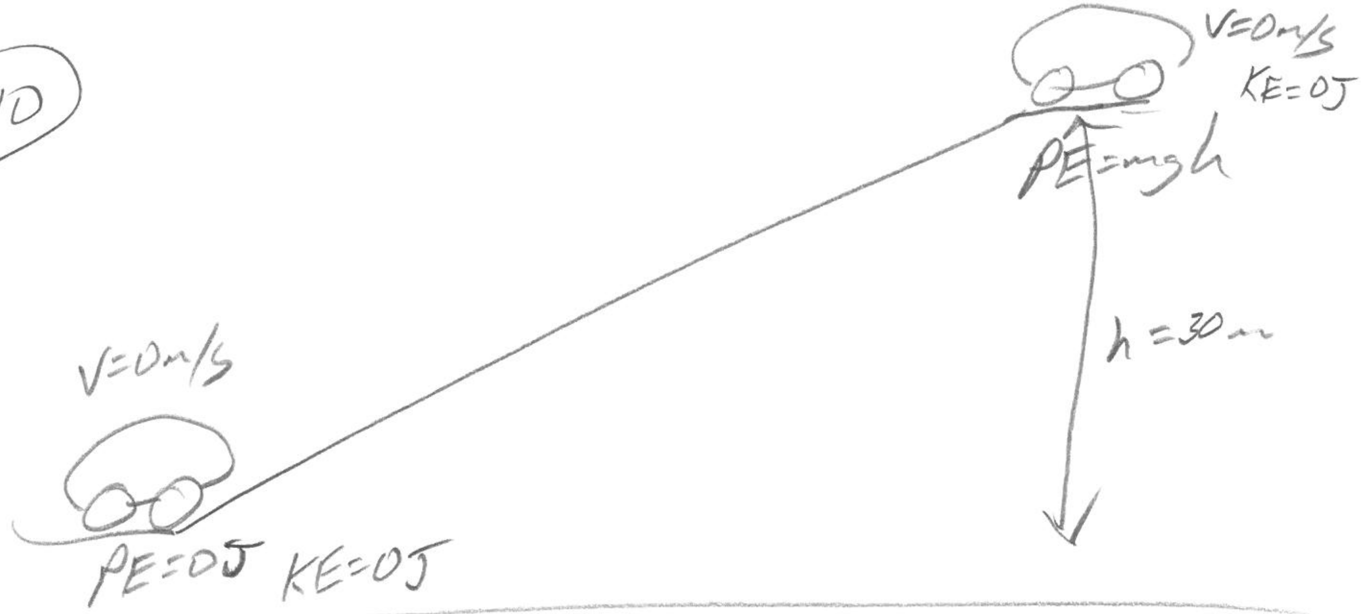
---

7. $\boxed{W = Fd}$

$-320{,}000J = -6400N(d)$

$d = 50m$

8-10



8. $\boxed{PE_0 + KE_0 + W_{NC} = PE + KE}$

$0 + 0 + W_{NC} = (1600\,kg)(9.8\,m/s^2)(30\,m) + 0$

$W_{NC} = 470{,}400\,J = E_{\text{used by battery}}$

Work done to raise car = "required energy"

9. $400\,V = 400\,\frac{J}{C}$

$\boxed{V(Q) = E}$

$\underbrace{400\,\frac{J}{C}}_{V}\;\underbrace{(Q)}_{\text{Charge}} = \underbrace{470{,}400\,J}_{\text{energy}}$

$Q = 1{,}176\,C$

* An alternative way to solve this is to do # 10 first. Then use $I = \frac{Q}{\Delta t}$ to find Q

10. a) $\boxed{P = VI} = 400V(2A) = 800W$

power

b) $W = 470,400J$ (see #8) Work = energy used

c) $\boxed{P = \frac{W}{t}}$ work time

Power

$800W = \frac{470,400J}{t} \Rightarrow t = 588s$

* Now we can check #9 $\Rightarrow$ $I = \frac{Q}{\Delta t}$

$2A = \frac{Q}{588s} \Rightarrow Q = 1,176C$

11. Not a question

12. $40\ \underbrace{kW}\ h$

$40\ (1000W)(3600s)$

$40\ (1000\frac{J}{s})(3600s) = 1.44 \times 10^8 J$

13. Power $\rightarrow$ $\boxed{P = \frac{W}{t}}$ $\leftarrow$ Energy

* for Another Solution see after #14

$P = \frac{1.44 \times 10^8 J}{2(3600s)} = 20,000W$ — 2 hours

Power to charge in 2 hrs

Current

$\boxed{P = VI}$

$20,000W = 400V(I)$

$I = 50A$

14. $\boxed{I = \frac{Q}{\Delta t}}$ $50A = \frac{Q}{2(3600s)}$ $Q = 360{,}000C$

Another solution to #13 + 14.

$\boxed{E = VQ}$

voltage

charge

$1.44 \times 10^8 J = 400V(Q)$

Energy to Climb Hill

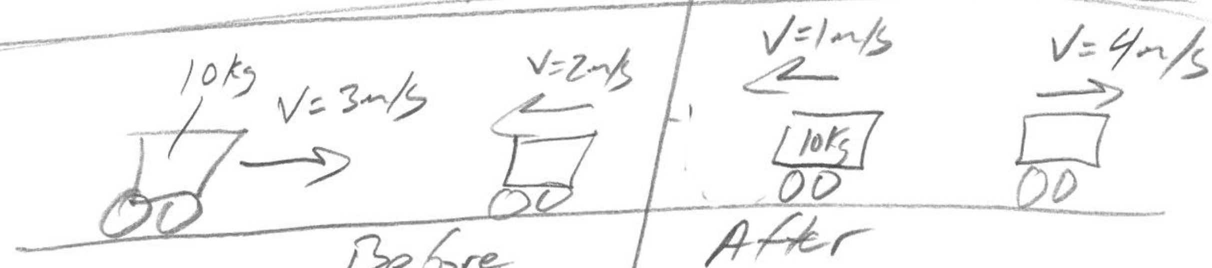
$Q = 360{,}000C$

charge

Current $\boxed{I = \frac{Q}{t}} = \frac{360{,}000C}{2(3600s)} = 50A$

time

15.



a. $\boxed{M_1V_1 + M_2V_2 = M_1V_1' + M_2V_2'}$

$10kg(3m/s) + M_2(-2m/s) = 10kg(-1m/s) + M_2(4m/s)$

$40kgm/s = M_2(6m/s)$

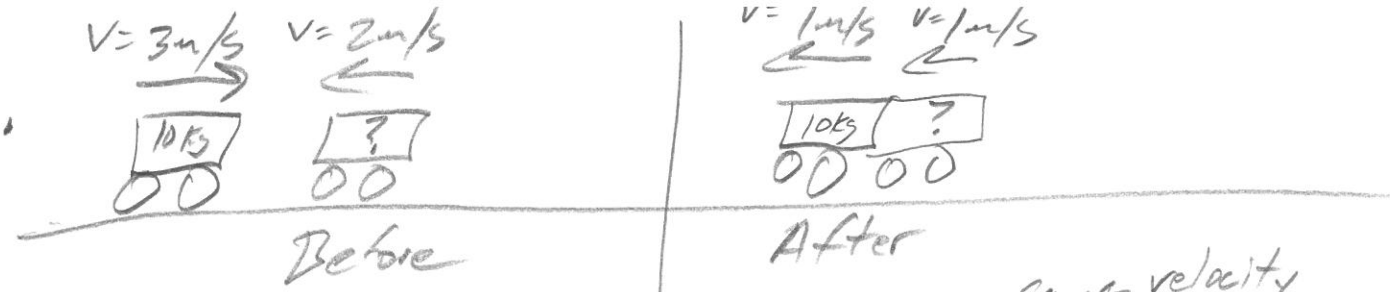
$M_2 = 6.67kg$

both are 5m/s

b. Elastic. Closing speed = separation speed = 5m/s, so e=1

c. KE is constant, since e=1 (totally elastic)

16.



same velocity

A. $10(3) + M_2(-2) = 10(-1) + M_2(-1)$

$40kg = M_2$

B. Inelastic. They stick together.
Separation speed is zero, so e=0.
Totally inelastic.

C. KE is lost (because this is not elastic)

Total KE before $= \frac{1}{2}(10kg)(3m/s)^2 + \frac{1}{2}(40kg)(2m/s)^2$

$= 45J + 80J = 125J$

Total KE after $= \frac{1}{2}(50kg)(1m/s)^2 = 25J$

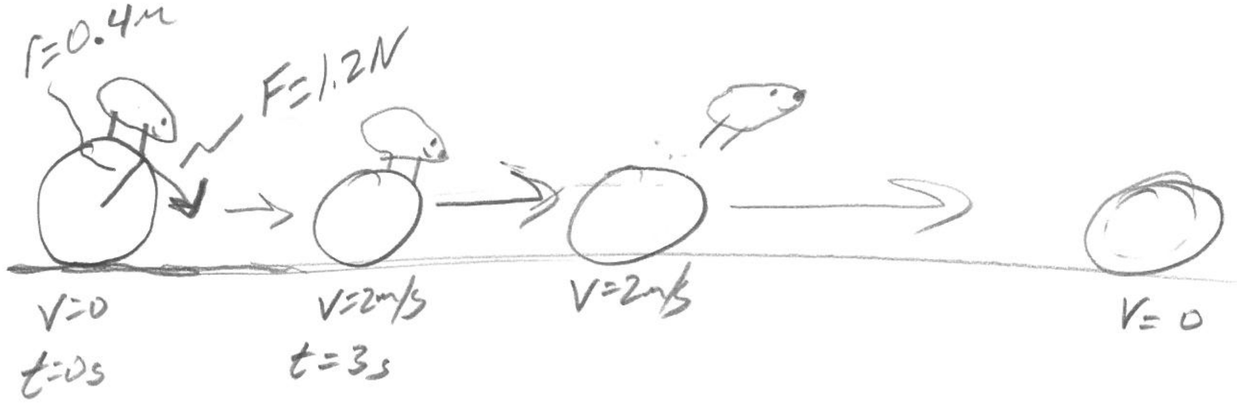
100J was lost

80% of original KE

total mass

they're moving at the same speed

17-26



17. a) $\boxed{\tau = Fr}$ $\tau = 1.2N(0.4m) =$ 0.48 Nm

b) $\alpha = 0$, and $\boxed{\tau = I\alpha}$, so $\tau = I(0) =$ 0

no angular acceleration

c) $\boxed{\tau = I\alpha}$ $\Rightarrow$ $\tau = 0.287\,kgm^2(-0.2\ rad/s^2)$

Wait until we find these

from #22 from #25

$\tau = -0.0574\ Nm$

or

0.0574 Nm CCW

---

18. $\boxed{\alpha = \dfrac{\Delta w}{\Delta t}}$ $\boxed{v = wr}$ $\Rightarrow 2m/s = w(0.4m)$

$w = 5\ rad/s$

$\Downarrow$

$\alpha = \dfrac{5\ rad/s}{3s} = \boxed{1.67\ rad/s^2}$

---

19. $\boxed{\Theta = w_0 t + \tfrac{1}{2}\alpha t^2}$

$\Theta = 0 + \tfrac{1}{2}(1.67\ rad/s^2)(3s)^2$

$\Theta = 7.52\ rad$

20. $\boxed{s = \theta r}$ angular displacement

linear distance $s = 7.52\,rad\,(0.4\,m/rad) = 3\,m$

---

21. $3\,m + (3\,s)(2\,m/s) + 25\,m = 34\,m$

Accelerating (from #20)

constant v. ($d=rt$)

deceleration (given in problem)

---

22. $\boxed{\tau = I\alpha}$

During acceleration,

$0.48\,Nm = I\,(1.67\,rad/s^2)$

from #18

From #17a.

$I = 0.287\,kgm^2$

---

23. Max $V = 2\,m/s$

*Already found in #18

$\boxed{V = \omega r} \Rightarrow 2\,m/s = \omega\,(0.4\,m)$

$\omega = 5\,rad/s$

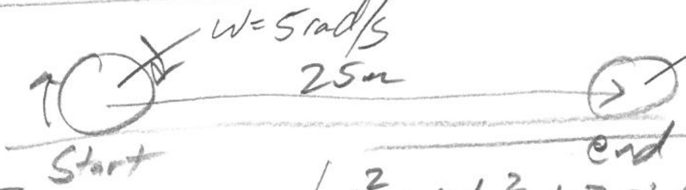
---

24. $\boxed{L = I\omega}$ $\quad L = 0.287\,kgm^2\,(5\,rad/s)$

Angular Momentum

$L = 1.44\,\frac{kgm^2}{s}$

25.



$\boxed{s = \theta r}$

$25\,m = \theta\,(0.4)$

Angular Displacement → $\theta = 62.5\,rad$

$\boxed{\omega^2 = \omega_0^2 + 2\alpha\Delta\theta}$

$0 = (5\,rad/s)^2 + 2(\alpha)(62.5\,rad)$

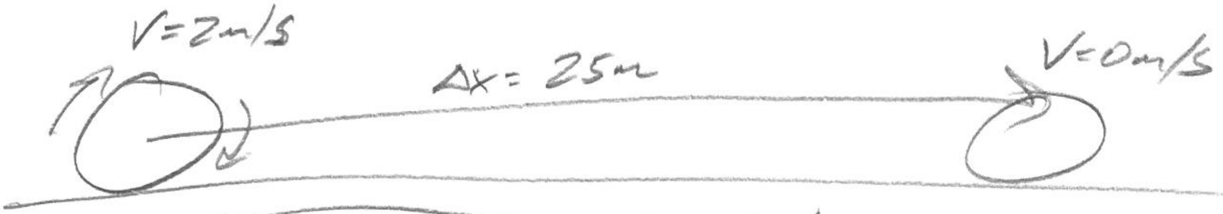
$\alpha = -0.2\,rad/s^2$

$\boxed{\omega = \omega_0 + \alpha t}$

$0 = 5\,rad/s + (-0.2\,rad/s^2)\,t$

$t = 25\,s$

25. A simpler way... (not rotational)



$$\boxed{\bar{v} = \frac{v+v_0}{2}} = \frac{0\,m/s + 2\,m/s}{2} = 1\,m/s$$

$$\boxed{\bar{v} = \frac{\Delta x}{\Delta t}} \Rightarrow 1\,m/s = \frac{25\,m}{\Delta t}$$

$$\Delta t = 25\,s$$

26. $I = \frac{2}{5}mr^2$

$0.287\,kg\,m^2 = \frac{2}{5}(m)(0.4m)^2$

I, from #22

$m = 4.48\,kg$

---

27. a) frictionless block

b)

$PE_0 + KE_0 = PE + KE$

$mgh + 0 = 0 + \frac{1}{2}mv^2$

$\Rightarrow \cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v = \sqrt{2gh} = \sqrt{2(9.8\,m/s^2)(1m)} = 4.43\,m/s$

---

c) Hollow Hoop (because it has the most mass farthest from its axis of rotation)

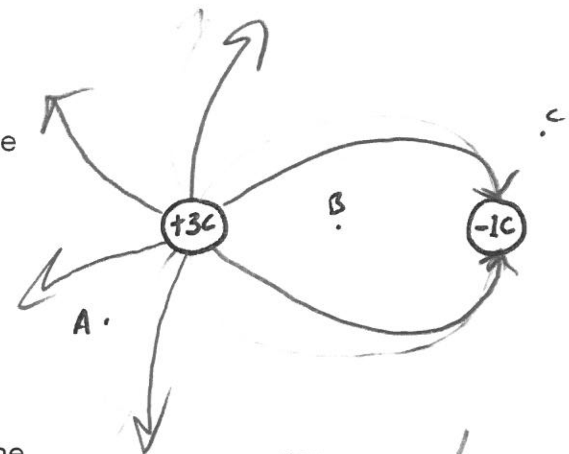
d) The frictionless block does not rotate. The other objects "spend" some of their PE on rotational KE, but the block uses all of its energy for translational KE.

$\frac{1}{2}I\omega^2$ — ω: rotational velocity, rotation around axis

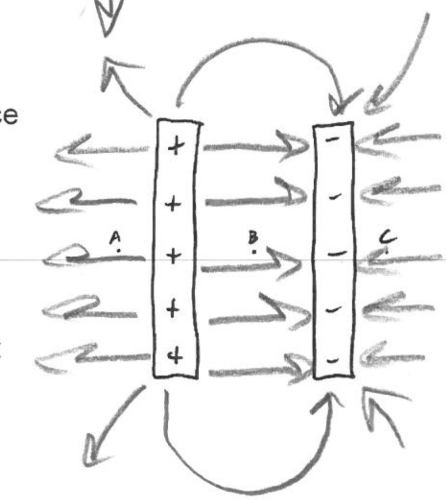
$\frac{1}{2}mv^2$ — v: linear velocity, speed down the hill

Electric Charge and Electric Field (electrostatics)

28. a. Use electric field lines to draw the electric field around the point charges on the right.
b. For each lettered location, describe the direction of the force experienced by a proton and an electron at that location.



29. a. Use electric field lines to draw the electric field around the charged plates on the right.
b. For each lettered location, describe the direction of the force experienced by a proton and an electron at that location.



30. If a proton ($+1.6\times10^{-19}$C) located somewhere in one of your diagrams experience an electric force of 1N, what is the magnitude of the electric field at that location?

31. What magnitude force would be experienced by an electron at that same location?

32. What is the root cause of the forces that charges experience when they are in an electric field.

33. Using only field lines, draw..
a. a weak, uniform electric field
b. a stronger, uniform electric field
c. a non-uniform electric field; label a stronger and a weaker part of the field

34. Which force -- electric force or gravitational force -- is dominant on large scales, and which force is dominant on small scales? Explain why.

Current and Circuits

35. Find VIRP (source and individual resistors for the circuit on the right, with the switch open (as shown).

36. Find VIRP again for the circuit with the switch closed.

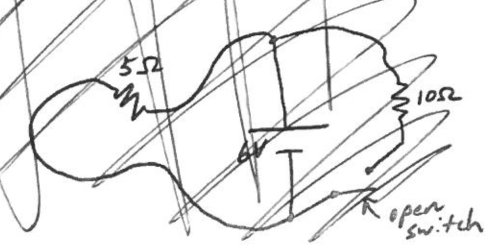
37. When the switch is closed, are the resistors in parallel or in series? What qualifies it as that type of circuit?

38. Find VIRP (source and individual resistors for the circuit on the right, with the switch open (as shown).

39. Find VIRP again for the circuit with the switch closed.

40. Which existing values change when the switch is closed? How do they change? Why do they change?

41. When the switch is closed, are the resistors in parallel or in series? What qualifies it as that type of circuit?



28. b. Direction of Forces

	Point A	Point B	Point C
Proton	↙	→	↙
Electron	↗	←	↗

29. b

	A	B	C
Prot.	←	→	←
Elect.	→	←	→

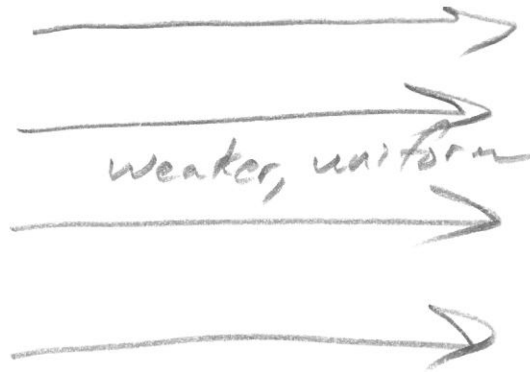
30. $\boxed{E = \frac{F_e}{q}}$ $E = \frac{1N}{1.6\times10^{-19}C} = 6.25\times10^{18}\frac{N}{C}$

31. Same force, but opposite direction (opposite field arrows)

32. Charges in a field experience an electric force because there are other charges creating that field. The push or pull of the other charges is what the "test" charge is experiencing.

attraction or repulsion

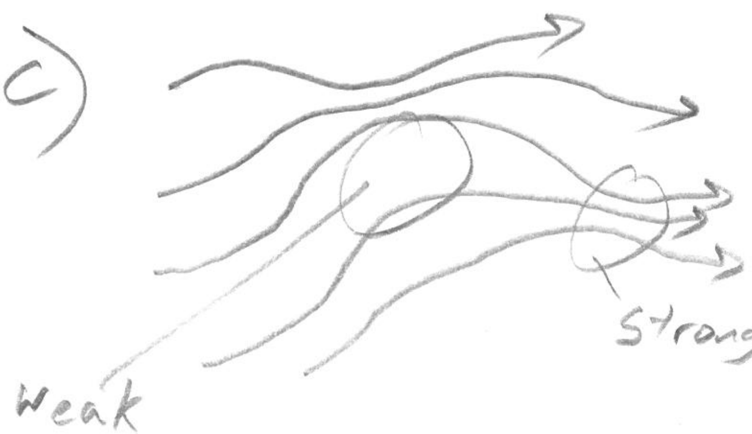
33. a)



Uniform
⇑
even spacing of field lines
Same force everywhere

b)

c)



Non-uniform field

~~34. Electric forces cancel (e.g. +1 -1 = 0) while gravitational forces are always additive.~~

~~Very large objects usually have nearly equal numbers of positive + negative charges. Their electric forces cancel, but their gravitational force is large~~

~~Very small objects, like electrons, can have huge charge imbalances (e.g. no positive charges and one negative charge)~~

34. There are two factors:

1. Electric force is inherently stronger, as evidenced by the difference in the magnitudes Coulomb's Law constant (k=8.99*10^9) vs the Gravitational constant ($G=6.67x10^{-11}$).

2. Electric charges can cancel (e.g. +1-1=0), but gravitational force is always additive.

At baseline, the electric force is inherently stronger and gravity is inherently weaker, but at large scales the fact that electric charges cancel (and masses do not) tips the balance. When tiny objects (like electrons) have very small masses and very small (but non-canceling) charges, the electric force of those charges is much stronger than the gravitational force of that small amount of mass.

However, at large scales (like the size of planets), objects usually have roughly equal numbers of positive and negative charges (protons and electrons), so most of their charges cancel. This means their *net charges* are low, and they are subject to weak electric forces despite having trillions upon trillions of charges. At the same time, even an inherently weak gravitational force between bits of matter can add up to something huge when there are enough bits of matter.

35.

Circuit #1

	V	I	R	P
Source	6V	1.2A	5Ω	7.2W
R_1	6V	1.2A	5Ω	7.2W

Circuit #2
(Parallel)

$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{10} \Rightarrow R_{eq} = \frac{10}{3}$$

	V	I	R	P
Source	6V	1.8A	3.33Ω	10.8W
R_1	6V	1.2A	5Ω	7.2W
R_2	6V	0.6A	10Ω	3.6W

Circuit #3
(series)

$$R_{eq} = 5\Omega + 10\Omega = 15\Omega$$

	V	I	R	P
Source	6V	0.4A	15Ω	2.4W
R_1	2V	0.4A	5Ω	0.8W
R_2	4V	0.4A	10Ω	1.6W

36. Circuit #2 is parallel because current can flow through one resistor without flowing through the other.

37. Circuit #1 is series because all current must flow through every resistor.

38. Source Voltage : Source voltage does not change. It is a property of the battery. The same battery should provide the same number of joules per Coulomb of charge, regardless of the type of circut $\left(\text{Volts} = \frac{\text{Joules}}{\text{Coulomb}} \right)$

Source Current : Source current decreases in series, because there is only one path. Every new resistor increasingly clogs the path, reducing the flow of current. In parallel, even though a new resistor is added, a new path opens up for charge to flow. Any new path will allow more current to flow, even if it is fairly clogged.

~~Source Power : P=VI. Therefore, since V does not change, and there is more current (I) when a parallel branch is added, P~~

38 (continued)

Source Power: Power = Voltage (Current)

Therefore,

- If adding a parallel branch doesn't change voltage, but it does increase current, more power will be used.
- If adding a resistor in series doesn't change voltage, but it does reduce current, less power will be used.