PHYS 115 – 2020 Regular Final Examination - Solutions

Description
This set of 1 statement of commitment to academic integrity and 15 questions is the final exam for PHYS 115 Fall 2020 at the University of Saskatchewan.

33% of the exam mark is based on the answers for the 10 multiple-choice questions submitted through WebAssign. All 10 questions are weighted equally.

67% of the exam mark is based on the answers (submitted through WebAssign) and solutions (submitted through Canvas) for the 5 word problems. All 5 word problems are weighted equally.

Instructions
Answers for **all** questions need to be submitted in WebAssign.

For each of questions 12 through 16, in addition to submitting your answers in WebAssign, write the complete solution, **including a diagram**, using the problem-solving method discussed in class.

Your solutions must use the same symbols as are used on the formulae sheet.

Formulas not on the Formulae Sheet must be derived.

Keep extra decimal places throughout your calculations, and then round-off your final answer to <u>three significant figures</u>.

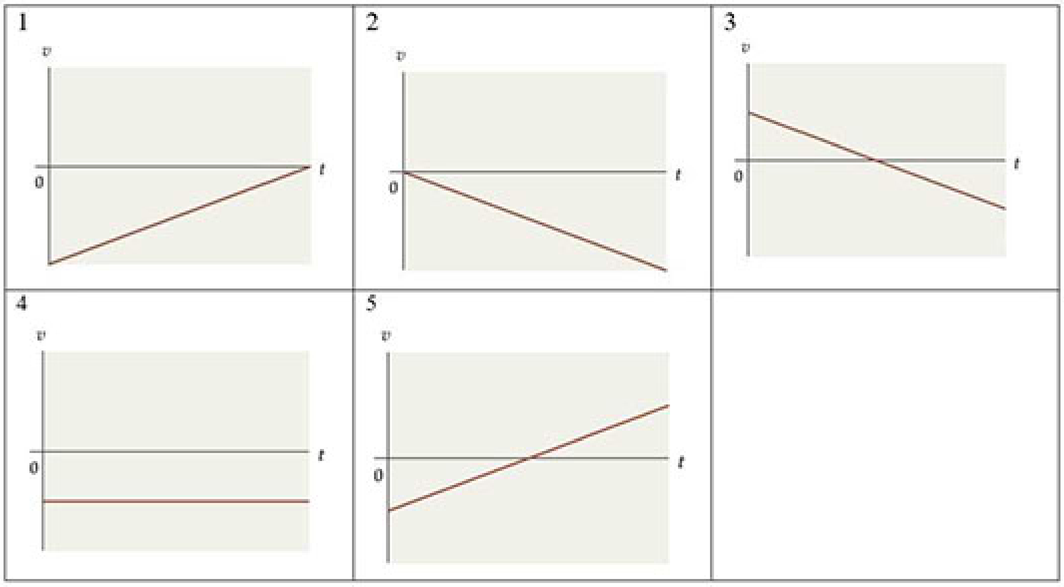
Submit your answer to each question in WebAssign.

When you have finished the entire exam, scan your written work for questions 12 through 16 and submit a single multi-page PDF file using the link in the Canvas site for your section.

Your WebAssign submission is due no later than three hours (180 minutes) after the questions become available and your Canvas submission is due no later than three-and-a-half hours (210 minutes) after the questions become available. LATE SUBMISSIONS WILL NOT BE ACCEPTED.

1. - UofS-P115-P117-Honour [4820285]
On my honour, I pledge that I will not give or receive aid during this assessment. I understand that I am expected to complete this assessment with no communication with other persons and no resource material other than the PHYS 115/117 Formulae sheet. I recognize that it is my responsibility to uphold academic integrity and I agree to follow the rules of this assessment and the guidelines laid forth in the policies of the University of Saskatchewan. Furthermore, I fully understand that disciplinary action may be taken against me if I am discovered to have communicated with another person or to have used an internet resource.

2. - P115-FNL-2020-REG-A1 [4878736]
For an object in one-dimensional motion, which of the following velocity versus time graphs correspond to the object having a constant negative acceleration? **Select all that apply.**

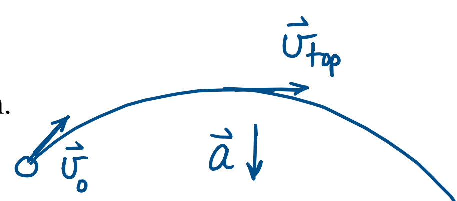


☐ Graph 5 ☐ Graph 4 ☐ Graph 1 ☐ Graph 2 ☐ Graph 3

Constant negative acceleration means that a graph of velocity vs. time is linear with a negative slope. ∴ Graphs 2 and 3.

3. - P115-FNL-2020-REG-A2 [4878755]
You and your friend are standing 10 m apart. You throw a ball to your friend in such a way that it leaves your hand at a height of 2 m above the ground, reaches a maximum height of 3 m above the ground, and then your friend catches the ball at a height of 1.5 m above the ground. When the ball reaches its maximum height, which one of the following statements is true? You may ignore any frictional effects.

- Its velocity is zero but its acceleration is not zero.
- Its velocity is perpendicular to its acceleration.
- Its acceleration depends on the angle at which the ball was thrown.
- Its velocity is not zero, but its acceleration is zero.
- Its velocity and its acceleration are both zero.



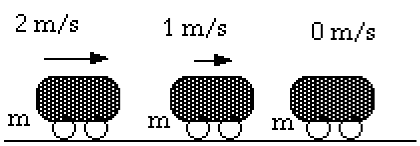
Projectile motion. Acceleration is downward with constant magnitude of g. At maximum height the ball is moving horizontally. $\therefore \vec{v} \perp \vec{a}$

4. - P115-FNL-2020-REG-A3 [4878761]
A car accelerates from rest with a constant acceleration. Ignoring friction, when does the car require the greatest power?

- When the car first accelerates from rest
- When the car reaches half its maximum speed
- Just as the car reaches its maximum speed
- More information is needed to be able to answer the question.
- The question is misleading because the power required is constant.

$P = Fv$
constant acceleration means F is constant
$\therefore P$ increases as v increases.

5. - P115-FNL-2020-REG-A4 [4878768]
Three railroad cars, each of mass *m*, on a level track couple together into a single mass 3*m*. Initially, two of the cars are moving at 2 m/s and 1 m/s, as shown. If they couple to the third car, which is at rest, what is the magnitude of the system's final velocity? You may ignore any effects due to friction.



net external force is 0, so momentum is conserved.

$\vec{P}_{tot_i} = \vec{P}_{tot_f} \Rightarrow \cancel{m}(2\,m/s) + \cancel{m}(1\,m/s) = 3\cancel{m}v_f$

- 1.0 m/s
- 0.5 m/s
- 3.0 m/s
- 1.3 m/s
- 1.5 m/s

$\therefore \boxed{v_f = 1\,m/s}$

6. - P115-FNL-2020-REG-A5 [4878769]
A child is riding on a merry-go-round which rotates without friction. Initially the child is close to the central axis of rotation of the merry-go-round. If the child moves toward the outer rim of the merry-go-round what happens to the moment of inertia of the child plus merry-go-round system and the angular speed of the merry-go-round?

- The moment of inertia decreases and the angular speed increases.
- The moment of inertia increases and the angular speed remains the same.
- The moment of inertia increases and the angular speed increases.
- The moment of inertia increases and the angular speed decreases.
- The moment of inertia decreases and the angular speed decreases.

Rotating without friction $\Rightarrow \tau_{ext} = 0 \Rightarrow$ Angular momentum is conserved.

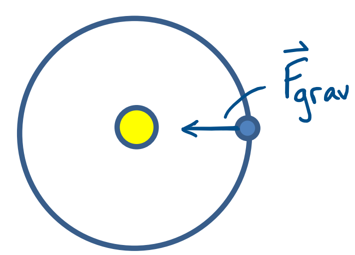
$L_{tot_i} = L_{tot_f} \Rightarrow I_{tot_i}\omega_i = I_{tot_f}\omega_f$; $I_{tot} = I_{child} + I_{mg}$

$I_{child} = m_{child}r^2$ where r = distance of child from axis of rotation.

$\therefore$ as child moves outward, $I_{child}\uparrow$ so $I_{tot_f} > I_{tot_i} \Rightarrow \omega_f < \omega_i$

7. - P115-FNL-2020-REG-A6 [4878772]
As a planet orbits the Sun in a circular orbit centred on the Sun, how much torque, relative to the centre of the Sun, does the Sun's gravitational force exert on the planet?

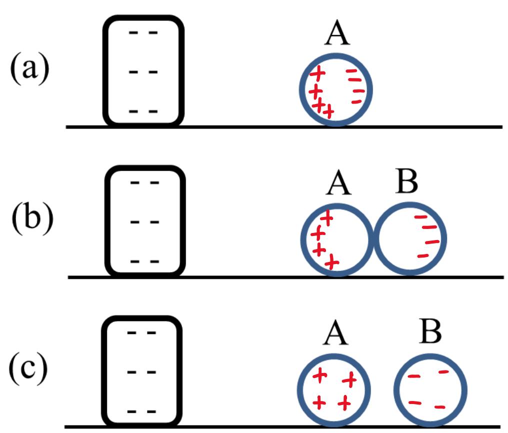
- ○ $\tau = \frac{Gm_{\text{planet}}m_{\text{sun}}}{r^2}$
- ○ $\tau = \frac{2Gm_{\text{planet}}m_{\text{sun}}}{r}$
- ○ $\tau = \frac{Gm_{\text{planet}}m_{\text{sun}}}{2r}$
- ○ $\tau = \frac{Gm_{\text{planet}}m_{\text{sun}}}{r}$
- ◉ $\tau = 0$



The centre of the Sun is the "axis of rotation" for the planet's orbit. Since the gravitational force of the Sun on the planet is directed toward the centre of the Sun, $\tau = 0$.

i.e. in $\tau = rF\sin\theta$, $\theta = 180°$ and $\sin 180° = 0$.

8. - P115-FNL-2020-REG-A7 [4878774]
A negatively charged object is placed on an insulating table. Then an uncharged conducting ball A is brought near to, but not touching, the negatively charged object as shown in diagram (a). Then a second uncharged conducting ball B is brought in so that it touches ball A on the side away from the negatively charged object as shown in diagram (b). Finally, ball B is moved a bit away from ball A as shown in diagram (c). The balls are moved by a person wearing an insulating glove so that none of the balls are ever grounded, and at no time do any of the balls touch the negatively charged object. Which statement is correct concerning the final charge on each ball?



(a) A becomes polarized

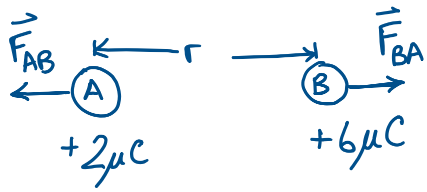
(b) some free electrons from A will flow onto B (to get further from the negatively charged object).

(c) A is now positively charged and B is negatively charged.

- ○ Both balls have a positive charge.
- ○ Both ball A and ball B are not charged.
- ○ Ball A has a negative charge and ball B has a positive charge.
- ○ Ball A has a positive charge and ball B has a negative charge.
- ○ Ball A has no charge and ball B has a positive charge

9. - P115-FNL-2020-REG-A8 [4878775]
Object A has a charge of +2 μC, and object B has a charge of +6 μC. Which one of the following statements is correct regarding the electrostatic force on each of the objects? $\vec{\mathbf{F}}_{AB}$ is the force on object A due to object B and $\vec{\mathbf{F}}_{BA}$ is the force on object B due to object A.

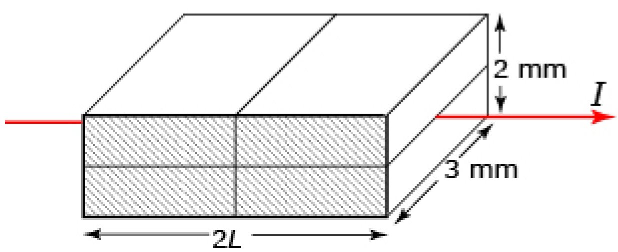
- $\vec{\mathbf{F}}_{AB} = \vec{\mathbf{F}}_{BA}$
- $\vec{\mathbf{F}}_{AB} = -\vec{\mathbf{F}}_{BA}$
- $\vec{\mathbf{F}}_{AB} = -3\,\vec{\mathbf{F}}_{BA}$
- $3\,\vec{\mathbf{F}}_{AB} = \vec{\mathbf{F}}_{BA}$
- $3\,\vec{\mathbf{F}}_{AB} = -\vec{\mathbf{F}}_{BA}$



$$F_{AB} = F_{BA} = \frac{k_e|+2\mu C||+6\mu C|}{r^2}$$

Each object experiences an electrostatic force directed away from the other object.

10. - P115-FNL-2020-REG-A9 [4878780]
Four identical 2 ohm pieces of conducting material are fused together to make a new resistor as shown. Each original 2 ohm piece has a length L and a rectangular cross section of 1 mm x 3 mm. The new resistor has a length of 2 L and a rectangular cross section of 2 mm x 3 mm. What is the resistance of the new resistor?

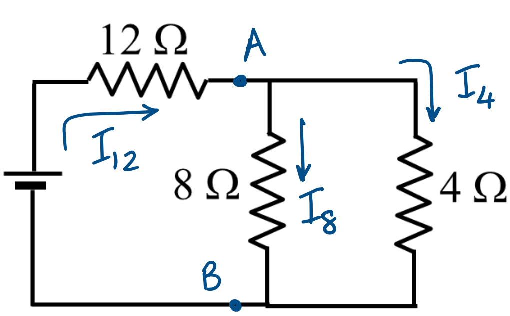


$$2\Omega = R_1 = \rho\frac{L}{A_1} = \rho\frac{L}{3\,mm^2}$$

$$R_4 = \rho\frac{2L}{6\,mm^2} = \rho\frac{\cancel{2}L}{\cancel{2}A_1} = R_1 = 2\Omega$$

- 1 ohm
- 4 ohm
- 1/2 ohm
- 8 ohm
- 2 ohm

11. - P115-FNL-2020-REG-A10 [4878786]
In the circuit shown the current through the 4 Ω resistance is I_4. What is the current, I_{12}, that flows through the 12 Ω resistance?

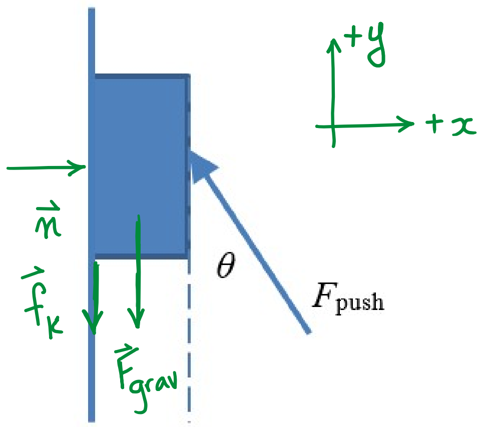


$$V_{AB} = I_8(8\Omega) = I_4(4\Omega) \Rightarrow I_8 = \tfrac{1}{2}I_4$$

$$I_{12} = I_8 + I_4 = \tfrac{1}{2}I_4 + I_4 = \tfrac{3}{2}I_4$$

- $I_{12} = 2\,I_4$
- $I_{12} = 3\,I_4$
- $I_{12} = (3/2)\,I_4$
- $I_{12} = (3/4)\,I_4$
- $I_{12} = (1/3)\,I_4$

12. - P115-FNL-2020-REG-B1 [4878787]
In preparation for painting a wall, you push a sanding block vertically up the wall by applying a force F_{push} at an angle θ of 29.0° as shown in the diagram. The coefficient of kinetic friction between the block and the wall is 0.828 and the mass of the block is 0.195 kg.



Constant velocity $\Rightarrow \sum \vec{F} = 0$

$$\sum F_x = 0 \Rightarrow +n - F_{push}\sin\theta = 0 \quad (1)$$

$$\sum F_y = 0 \Rightarrow +F_{push}\cos\theta - f_k - F_{grav} = 0 \quad (2)$$

Calculate the required magnitude of F_{push} such that the block moves with constant velocity. 4.04 N

From (1): $n = F_{push}\sin\theta$

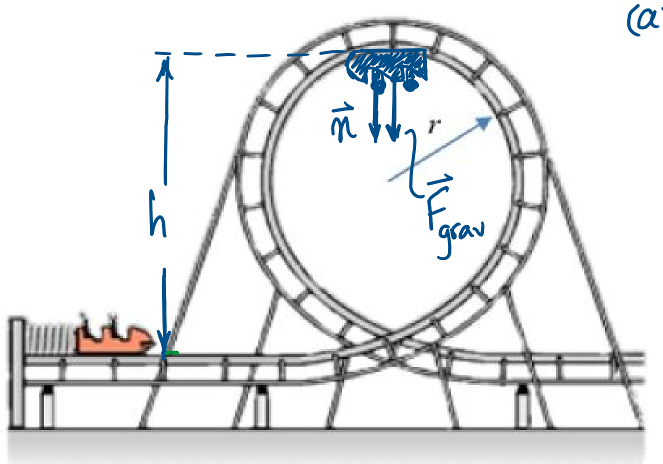
$$f_k = \mu_k n = \mu_k F_{push}\sin\theta$$

From (2): $F_{push}\cos\theta - \mu_k F_{push}\sin\theta - mg = 0$

$$F_{push}(\cos\theta - \mu_k\sin\theta) = mg$$

$$F_{push} = \frac{mg}{\cos\theta - \mu_k\sin\theta} = \frac{(0.195\text{ kg})(9.80\text{ m/s}^2)}{(\cos(29.0°) - 0.828\sin(29.0°))} = 4.04\text{N}$$

13. - P115-FNL-2020-REG-B2 [4878812]
Consider the spring-loaded roller coaster shown in the figure. The car is pushed against a spring with a spring constant of 8.97 × 10^4 N/m such that the spring is compressed a distance x from its equilibrium (relaxed) length. The mass of the fully-loaded car is 463 kg. You may assume that the loop is circular and has a radius of 10.3 m. At its highest point, the car is a height of 21.1 m above its position when it is against the spring. Ignore all frictional effects.



(a) At the top of the loop, $\vec{n}$ and $\vec{F}_{grav}$ are directed radially inward.

$$\therefore \Sigma F_r = n + F_{grav} = n + mg$$

$$\Sigma F_r = ma_c \Rightarrow n + mg = \frac{mv^2}{r}$$

At the minimum speed to just maintain contact, $n = 0 \Rightarrow \cancel{m}g = \cancel{m}v_{min}^2/r$

$$\therefore v_{min} = \sqrt{gr} = \sqrt{(9.80\,m/s^2)(10.3\,m)} = 10.0\,m/s$$

(a) Calculate the minimum speed that the car must have at the top of the loop in order for the car to maintain contact with the track at all times (that is, so that it does not fall off the track). 10 m/s

(b) Calculate the minimum distance x that the spring must be compressed to ensure that the car does not fall off the track at the top of the loop. 1.63 m

Ignoring frictional effects, mechanical energy is conserved.

$\therefore$ E when on compressed spring = $E_{\text{top of loop}}$

$$KE_i + PE_{grav_i} + PE_{s_i} = KE_f + PE_{grav_f} + PE_{s_f}$$

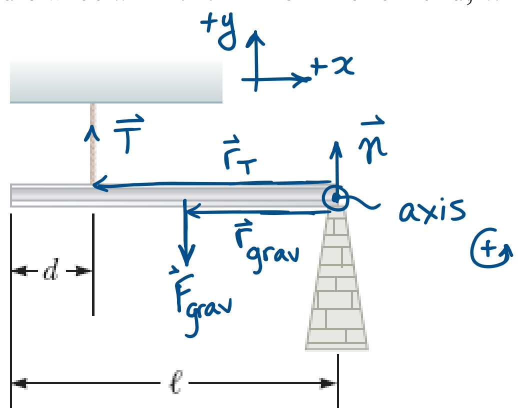
$$0 + 0 + \tfrac{1}{2}kx^2 = \tfrac{1}{2}mv_{min}^2 + mgh + 0 \Rightarrow kx^2 = mv_{min}^2 + 2mgh$$

$$x = \sqrt{\frac{m(v_{min}^2 + 2gh)}{k}} = \left[\frac{463\,kg\left((10.05\,m/s)^2 + (2)(9.80\,m/s^2)(21.1\,m)\right)}{8.97 \times 10^4\,N/m}\right]^{1/2}$$

$$\boxed{x = 1.63\,m}$$

14. - P115-FNL-2020-REG-B3 [4878850]

A horizontal, uniform beam with a mass of 33.5 kg and a length ℓ = 5.55 m is suspended from a rope at a distance d = 1.20 m from its left end, while its right end is supported by a vertical column.



Equilibrium $\Rightarrow \sum \vec{F} = 0$ and $\sum \tau = 0$.

Choose the contact point with the vertical column as the axis of rotation

$$\sum \tau = 0 \Rightarrow -\tau_T + \tau_{grav} = 0$$

$$-r_T T \sin 90^\circ + r_{grav}\, mg \sin 90^\circ = 0$$

(a) Calculate the tension (in N) in the rope. 209 N

$$-(\ell - d)T + \frac{\ell}{2} mg = 0 \Rightarrow T = \frac{mg\ell}{2(\ell - d)}$$

$$T = \frac{(33.5\,\text{kg})(9.80\,\text{m/s}^2)(5.55\,\text{m})}{2(5.55\,\text{m} - 1.20\,\text{m})} = 209.4\,\text{N} = 209\,\text{N}$$

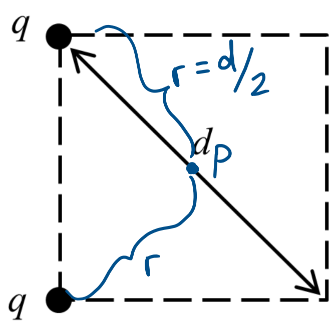
(b) Calculate the magnitude of the force (in N) that the column exerts on the right end of the beam. 119 N

$$\sum F_y = 0 \Rightarrow T + n - F_{grav} = 0$$

$$n = mg - T = (33.5\,\text{kg})(9.80\,\text{m/s}^2) - 209.4\,\text{N}$$

$$n = 119\,\text{N}$$

15. - P115-FNL-2020-REG-B4 [4878858]
Two equal charges are placed at adjacent sides of a square as shown. The charge on each is q = -7.73 μC and the diagonal of the square is d = 0.442 m.



$$r = \frac{d}{2} = \frac{0.442\,\text{m}}{2} = 0.221\,\text{m}$$

$$V_p = \frac{k_e q}{r} + \frac{k_e q}{r} = \frac{2k_e q}{r}$$

$$V_p = \frac{2(8.99\times10^9\,\text{N}\cdot\text{m}^2/\text{C}^2)(-7.73\times10^{-6}\,\text{C})}{0.221\,\text{m}}$$

(a) Calculate the electric potential (referenced to zero at infinity) at the centre of the square. -6.29e+05 V

$$V_p = -6.29\times10^5\,\text{V}$$

(b) An electron is released from rest from the centre of the square. The electron moves in a vacuum so there is no friction and gravitational effects may be ignored. Calculate the kinetic energy of the electron when it is very far away from the square (i.e. an infinite distance away). Give your answer in electron volts. 6.29e+05 eV

With no friction, and ignoring gravitational effects,

$$KE_i + PE_{el_i} = KE_f + PE_{el_f} \Rightarrow 0 + PE_{el_i} = KE_f + 0$$

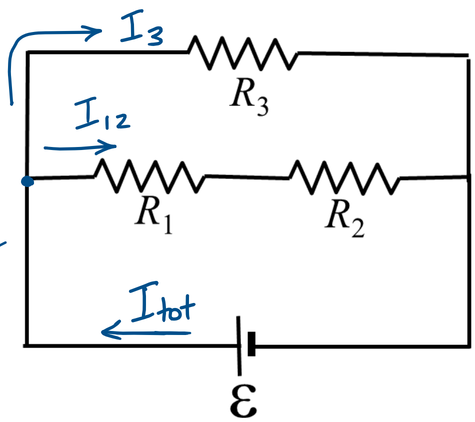
$$q_e V_p = KE_f$$

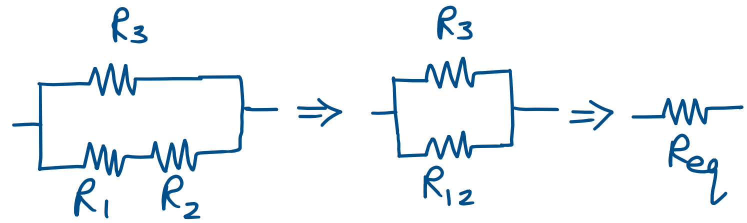
$$-e(-6.29\times10^5\,\text{V}) = KE_f$$

$$KE_f = 6.29\times10^5\,\text{eV}$$

16. - P115-FNL-2020-REG-B5 [4878859]

In the circuit shown, the emf $\mathcal{E}$ of the ideal battery is 14.8 V, and the resistances are: R_1 = 3.14 Ω, R_2 = 3.33 Ω, and R_3 = 4.96 Ω.



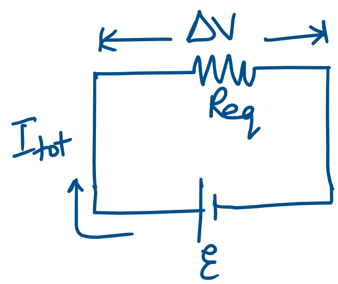


$$R_{12} = R_1 + R_2 = 3.14\Omega + 3.33\Omega = 6.47\Omega$$

$$R_{eq} = \left(\frac{1}{R_{12}} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{6.47\Omega} + \frac{1}{4.96\Omega}\right)^{-1}$$

$$R_{eq} = 2.808\Omega$$

(a) Calculate the total current drawn from the battery. 5.27 A



From KVL, $\mathcal{E} = \Delta V = I_{tot} R_{eq}$

$$I_{tot} = \frac{\mathcal{E}}{R_{eq}} = \frac{14.8\text{V}}{2.808\Omega} = 5.27\text{A}$$

(b) Calculate the power delivered to the resistance R_3. 44.2 W

Note that $\Delta V_3 = \mathcal{E}$, $P_3 = \frac{(\Delta V_3)^2}{R_3} = \frac{(14.8\text{V})^2}{4.96\Omega} = 44.2\text{W}$

Alternate Solution: $I_{tot} = I_{12} + I_3$; $\Delta V_3 = \Delta V_1 + \Delta V_2 \Rightarrow I_3 R_3 = I_{12} R_1 + I_{12} R_2$

$$I_{12} = \frac{R_3}{R_1 + R_2} I_3 = \frac{4.96\Omega}{6.47\Omega} I_3 = 0.7666 I_3 \Rightarrow I_{tot} = 1.7666 I_3$$

$$I_3 = \frac{5.271\text{A}}{1.7666} = 2.984\text{A} \Rightarrow P_3 = I_3^2 R_3 = 44.2\text{W} \; ; \; P_3 = \Delta V_3 I_3 = 44.2\text{W}$$