Last Name:_____First Name_____Network-ID_____

Discussion Section:_____Discussion TA Name:_____

**Turn off your cell phone and put it out of sight.**
**Keep your calculator on your own desk. Calculators cannot be shared.**
**This is a closed book exam.  You have ninety (90) minutes to complete it.**

1.  Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2.  You may find the version of **this Exam Booklet at the top of page 2**.  Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3.  Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character.  If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero.  If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column.  When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4.  Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter.  Do the same for your **FIRST NAME INITIAL**.

5.  Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles.  You need not write in or mark the circles in the SECTION box.

6.  Sign your name (**DO NOT PRINT**) on the **STUDENT SIGNATURE** *line*.

7.  On the **SECTION** *line*, print your **DISCUSSION SECTION**.  You need not fill in the COURSE or INSTRUCTOR lines.

*Before starting work, check to make sure that your test booklet is complete. You should have 10 **numbered pages** plus three (3) Formula Sheets following these instructions.*

*Academic Integrity*—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

**This Exam Booklet is Version A**.  Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

*Exam Grading Policy—*

The exam is worth a total of **128** points, composed of three types of questions.

**MC5:** *multiple-choice-five-answer questions, each worth 6 points.*
**Partial credit will be granted as follows.**

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

**MC3:** *multiple-choice-three-answer questions, each worth 3 points.*
**No partial credit.**

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

**MC2:** *multiple-choice-two-answer questions, each worth 2 points.*
**No partial credit.**

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Some helpful information:
- A reminder about prefixes: p (pico) = $10^{-12}$; n (nano) = $10^{-9}$; μ (micro) = $10^{-6}$;
  m (milli) = $10^{-3}$; k (kilo) = $10^{+3}$; M or Meg (mega) = $10^{+6}$; G or Gig (giga) = $10^{+9}$.

1) A parallel plate capacitor is connected to a 9 V battery, as shown below. At some time, the parallel plates are moved a small distance *closer* together.
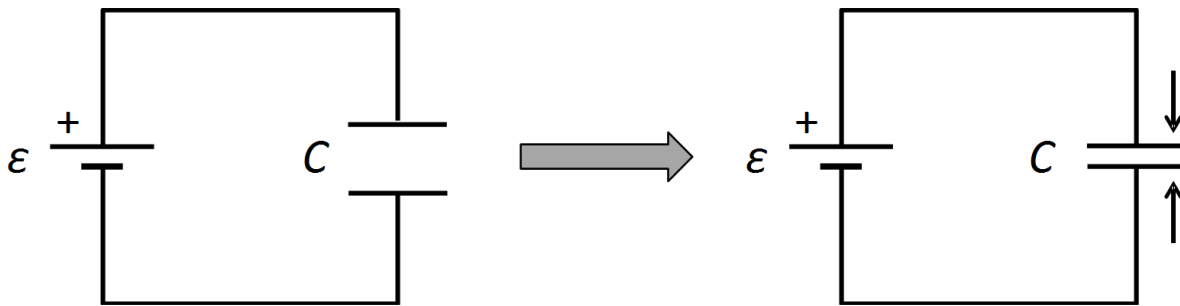


What happens to the charge $Q \geq 0$ stored on the top capacitor plate? Note that the capacitor remains connected to the battery throughout.

   a. Q increases
   b. Q remains the same
   c. Q decreases

2) The capacitor below is made of two parallel plates of area $A = 20\ cm^2$ separated by a distance $d = 3\ mm$. As shown below, two slabs of dielectric with dielectric constants $\kappa_1 = 2$ and $\kappa_2 = 4.5$ are placed between the two plates and take up *exactly half* the volume between the plates.
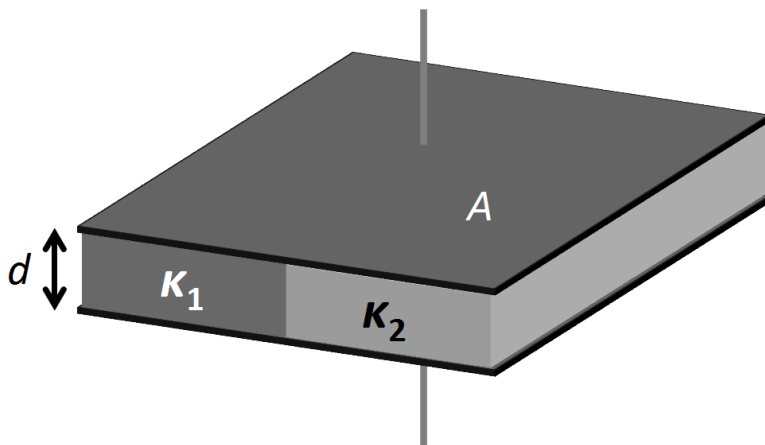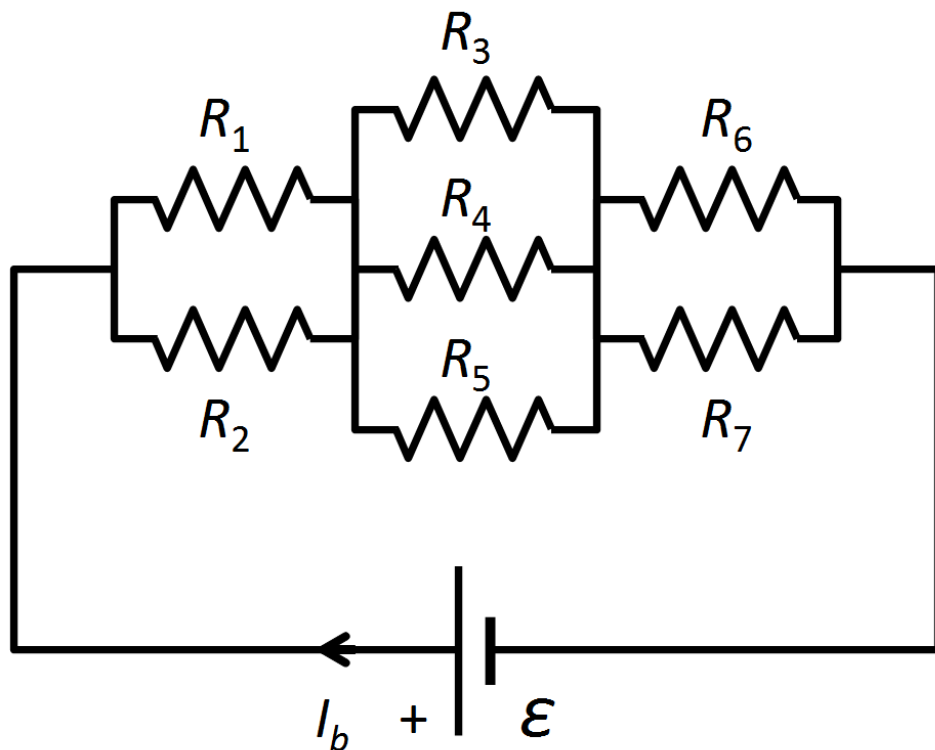


Calculate the capacitance $C$ of this capacitor.

   a. $C = 50\ pF$
   b. $C = 19\ pF$
   c. $C = 67\ pF$
   d. $C = 81\ pF$
   e. $C = 11\ pF$

**The next two questions pertain to the situation described below.**

Consider the following network of resistors. All of the resistors have the same resistance $R$. The network is connected to a battery with emf $\varepsilon$, through which a current $I_b$ passes.

$R_3$

$R_1$    $R_6$

$R_4$

$R_5$

$R_2$    $R_7$

$I_b$   +   $\varepsilon$

3) Calculate the equivalent resistance $R_{eq}$ of the network.

    a. $R_{eq} = R/3$
    b. $R_{eq} = R/2$
    c. $R_{eq} = 4R/3$
    d. $R_{eq} = R$
    e. $R_{eq} = 3R/8$

4) Calculate the current $I_4$ through resistor $R_4$ in terms of the battery current $I_b$.

    a. $I_4 = I_b / 3$
    b. $I_4 = 3I_b / 8$
    c. $I_4 = 4I_b / 3$
    d. $I_4 = I_b / 2$
    e. $I_4 = I_b$

**The next three questions pertain to the situation described below.**

The following circuit contains three capacitors $C_1 = 19\ \mu F$, $C_2 = 1\ \mu F$, and $C_3 = 7\ \mu F$ connected to a battery with an unknown emf $\varepsilon$. The charge on capacitor $C_1$ is $Q_1 = 8\ \mu C$.
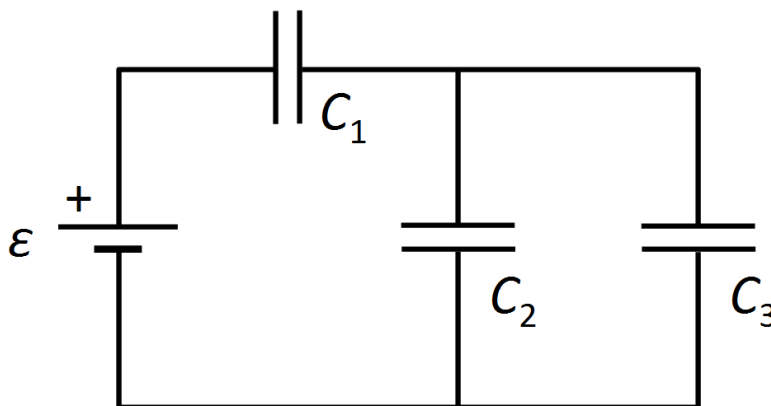


5) How much energy is stored on capacitor $C_1$?

    a. $E = 1.7 \times 10^{-6}\ J$
    b. $E = 5.9 \times 10^{-6}\ J$
    c. $E = 2.9 \times 10^{-6}\ J$
    d. $E = 4.7 \times 10^{-7}\ J$
    e. $E = 9.4 \times 10^{-7}\ J$
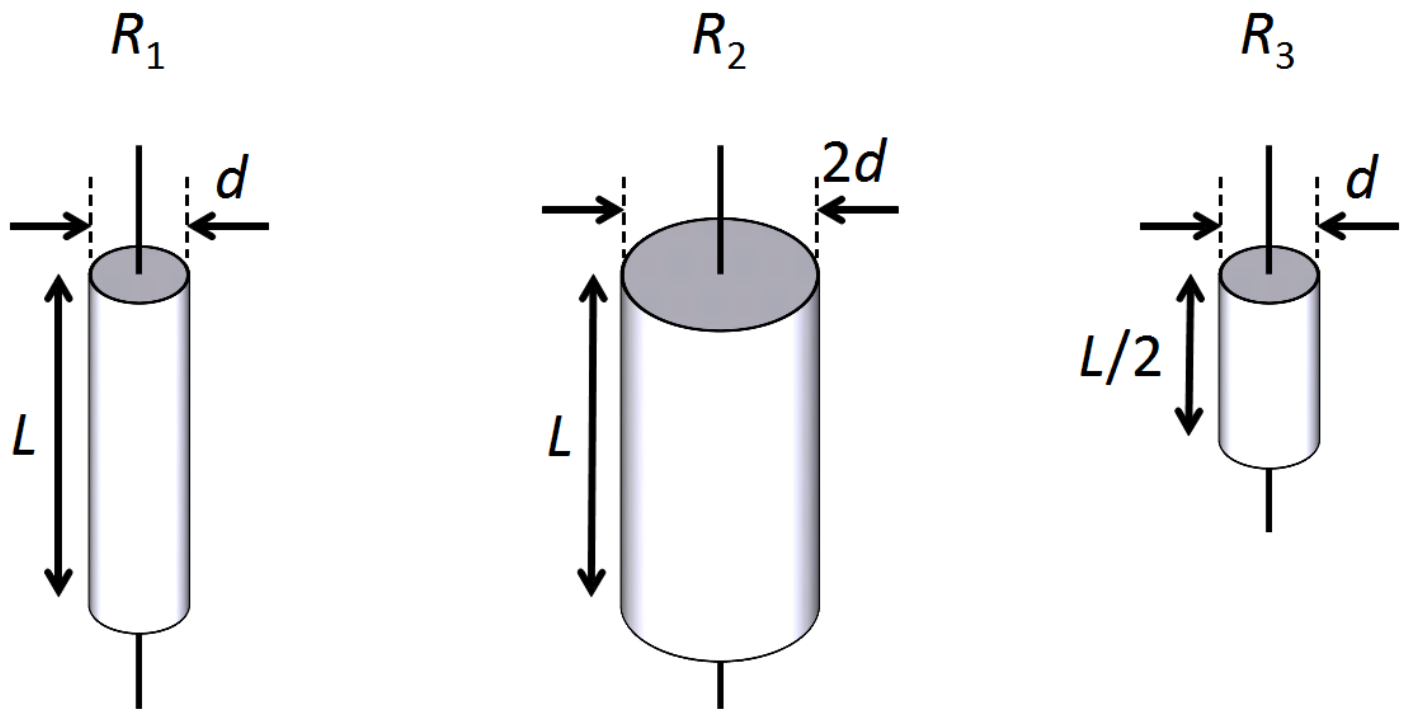
6) What is the charge $Q_2$ on capacitor $C_2$?

    a. $Q_2 = 2.6\ \mu C$
    b. $Q_2 = 0.56\ \mu C$
    c. $Q_2 = 1\ \mu C$
    d. $Q_2 = 3.5\ \mu C$
    e. $Q_2 = 1.7\ \mu C$

7) What is the equivalent capacitance $C_{eq}$ of the circuit?

    a. $C_{eq} = 5.6\ \mu F$
    b. $C_{eq} = 9.6\ \mu F$
    c. $C_{eq} = 3\ \mu F$
    d. $C_{eq} = 15\ \mu F$
    e. $C_{eq} = 20\ \mu F$

**The next two questions pertain to the situation described below.**

Consider the three resistors below made of identical material but of different dimensions.

$R_1$                           $R_2$                        $R_3$

8) If the same current $I$ passes through each resistor, which resistor dissipates the *most* power?

     a. $R_1$
     b. $R_2$
     c. $R_3$

9) If the same voltage $V$ is applied across each resistor, which resistor dissipates the *most* power?

     a. $R_1$
     b. $R_2$
     c. $R_3$

10) In the following RC circuit with a switch S, two resistors $R_1$ and $R_2$ have the same resistance $R = 20\ \Omega$, C denotes a capacitor of capacitance $15\ \mu F$, and E denotes a 12 V battery.
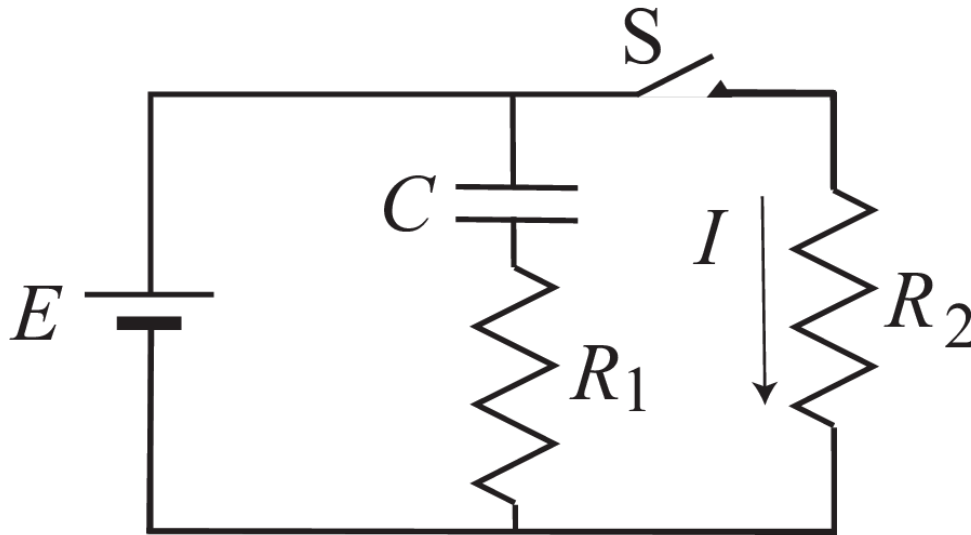


Initially, switch S is open for a long time. After $t = 0$ switch S is closed. Choose the best figure from below describing the time-dependence of the current $I$ through $R_2$. Do not forget that the battery E is still connected.



1

2

3
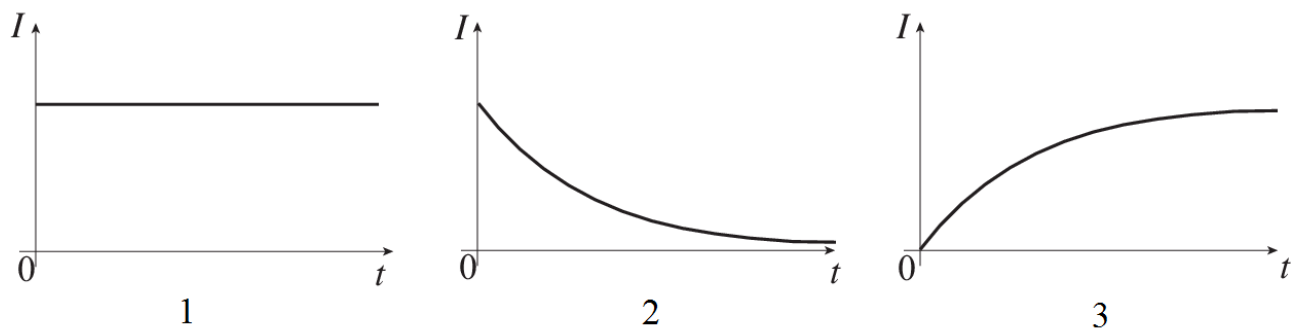
a. 3
b. 2
c. 1

**The next two questions pertain to the situation described below.**

In the following RC circuit with a switch S, two resistors $R_1$ and $R_2$ have the same resistance $R = 29\ \Omega$, $C$ denotes a capacitor of capacitance $7\ \mu F$, and $E$ denotes a 12 V battery.
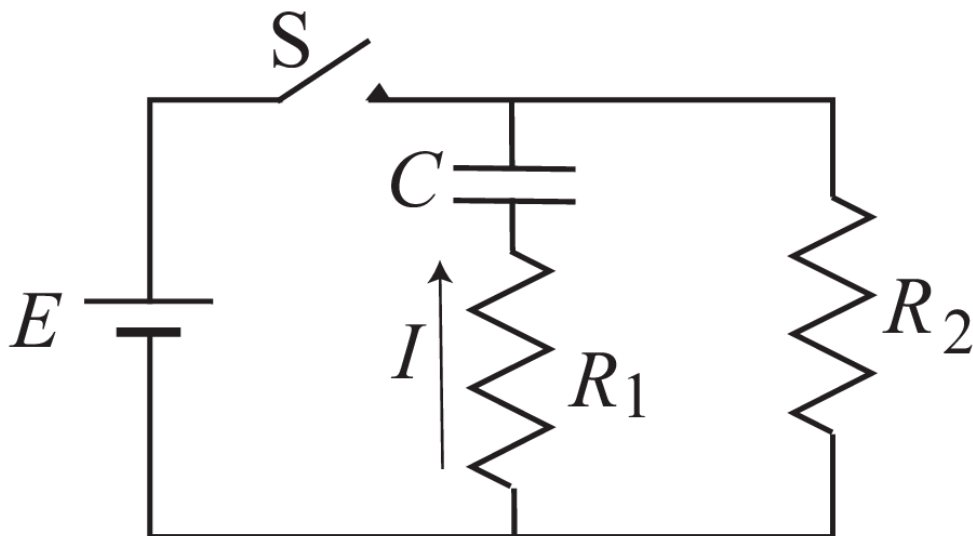
11) Switch S has been closed for a long time. What is the current $I$ through $R_1$ immediately after S is opened? Pay attention to the direction of the current arrow in the figure.

    a.  $I = +0.41\ A$
    b.  $I = -0.21\ A$
    c.  $I = +0.21\ A$
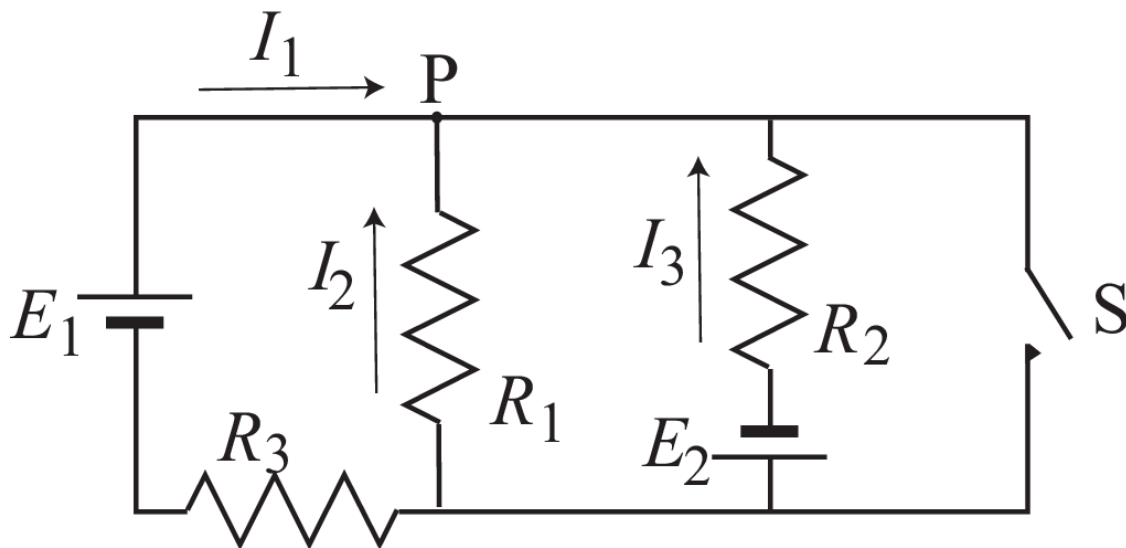    d.  $I = 0\ A$
    e.  $I = -0.41\ A$

12) What is the voltage $V_2$ across resistor $R_2$ at a time of 0.5 ms after switch S is opened?

    a.  $V_2 = 3.2\ V$
    b.  $V_2 = 0.51\ V$
    c.  $V_2 = 1.8\ V$

**The next two questions pertain to the situation described below.**

In the following figure, $E_1 = 12\ V$, $E_2 = 4\ V$, $R_1 = 7\ \Omega$, $R_2 = 12\ \Omega$, and $R_3 = 4\ \Omega$. Initially, the switch S is open.



13) At junction P three currents $I_1$, $I_2$, and $I_3$ meet. Choose the correct relation among them from below.

   a. $I_1 + I_2 + I_3 = 0$
   b. $I_1 - I_2 - I_3 = 0$
   c. $-I_1 + I_2 - I_3 = 0$
   d. $I_1 - I_2 + I_3 = 0$
   e. $I_1 + I_2 - I_3 = 0$

14) When the switch S is closed, what is the current $I_3$?

   a. $I_3 = 0\ A$
   b. $I_3 = -0.57\ A$
   c. $I_3 = -0.75\ A$
   d. $I_3 = -0.33\ A$
   e. $I_3 = -0.7\ A$

**The next three questions pertain to the situation described below.**

In the following figure, $E_1 = 12\ V$,
$E_3 = 7\ V$, $R_1 = R_2 = R_3 = R_4 = 3\ \Omega$. $E_2$
is not known.
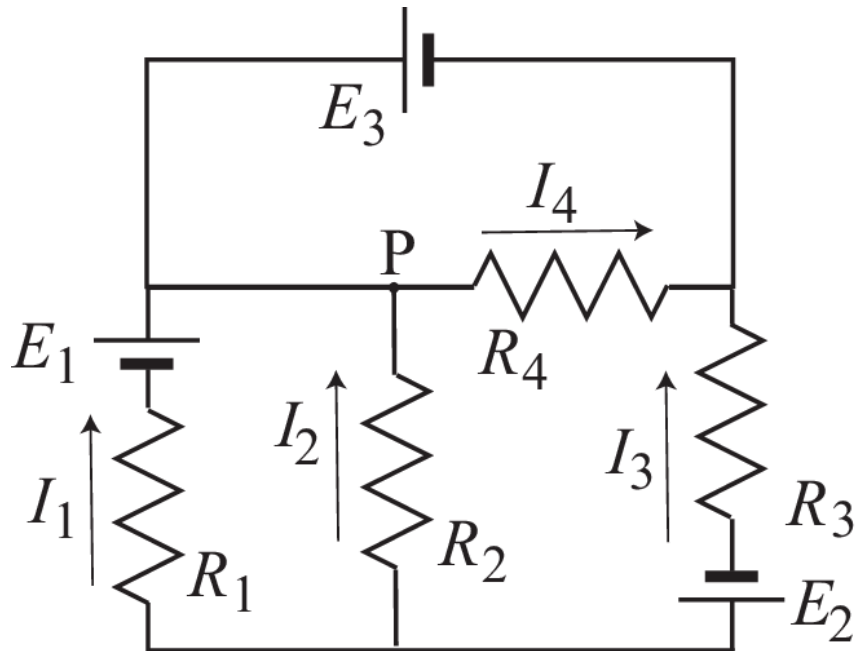


15) Choose the correct formula exhibiting Kirchhoff's loop law from the following formulas.

   a. $I_2R_2 + I_4R_4 - I_3R_3 - E_2 = 0$
   b. $I_2R_2 - I_4R_4 - I_3R_3 + E_2 = 0$
   c. $I_2R_2 + I_4R_4 - I_3R_3 + E_2 = 0$
   d. $I_2R_2 + I_4R_4 + I_3R_3 - E_2 = 0$
   e. $I_2R_2 + I_4R_4 + I_3R_3 + E_2 = 0$

16) What is the current $I_4$? Pay attention to the direction of the current arrow in the figure.

   a. $I_4 = 0\ A$
   b. $I_4 = +1.2\ A$
   c. $I_4 = -2.3\ A$
   d. $I_4 = +2.3\ A$
   e. $I_4 = -1.2\ A$

17) The current $I_2$ is measured to be $-1.5\ A$. What is the current $I_1$? Again, pay attention to the direction of the current arrow in the figure.

   a. $I_1 = +2.5\ A$
   b. $I_1 = -2.5\ A$
   c. $I_1 = -5.5\ A$
   d. $I_1 = +5.5\ A$
   e. $I_1 = 0\ A$

**The next two questions pertain to the situation described below.**

A current carrying loop of radius $r = 14\ cm$ is oriented horizontally, with its area parallel to the x-z-plane in the figure below, and a uniform magnetic field is applied that has no z-component. The x-component of the B field is $3\ T$ and its y-component is $4\ T$. The current $I = 7\ A$ is flowing into the (–z) direction at the rightmost point of the loop, as denoted in the figure that shows a side view of the loop. (The (–z)-direction points into the page).
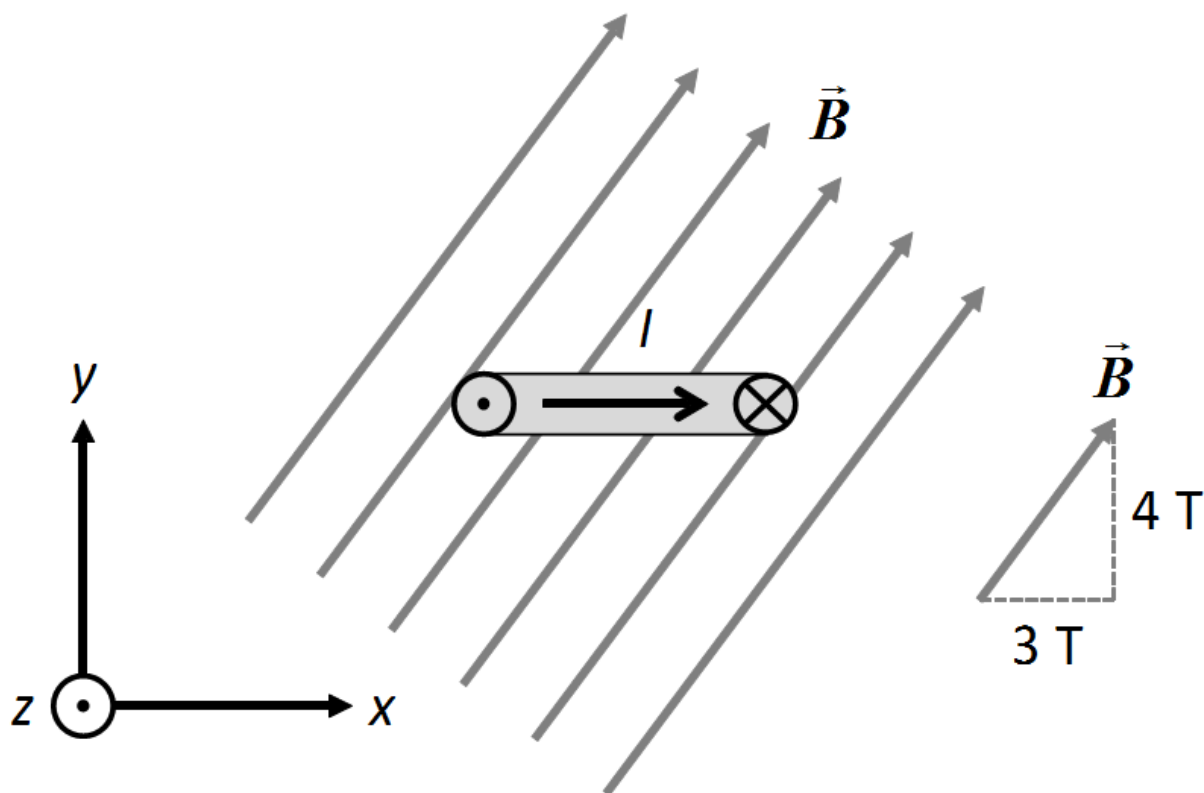


18) What is the **magnitude** of the torque on the current loop?

    a. $\tau = 1.7\ N{\cdot}m$
    b. $\tau = 2500\ N{\cdot}m$
    c. $\tau = 2.2\ N{\cdot}m$
    d. $\tau = 1.3\ N{\cdot}m$
    e. $\tau = 1800\ N{\cdot}m$

19) In which direction will the loop *start to turn* if left free?

    a. Clockwise about an axis parallel to the z-axis
    b. Counter-clockwise about an axis parallel to the z-axis
    c. Around an axis that is *not* parallel to the z axis.

20) Four long straight wires carrying currents of equal magnitude ($I_1 = I_2 = I_3 = I_4 = I$) are parallel or antiparallel to each other such that their cross sections form the corners of a square, as shown in the figures. The figures indicate the directions of the current in each wire. In which case is the magnitude of the total magnetic field at the center of the square (O) the largest?

a.

b.

c.

d.
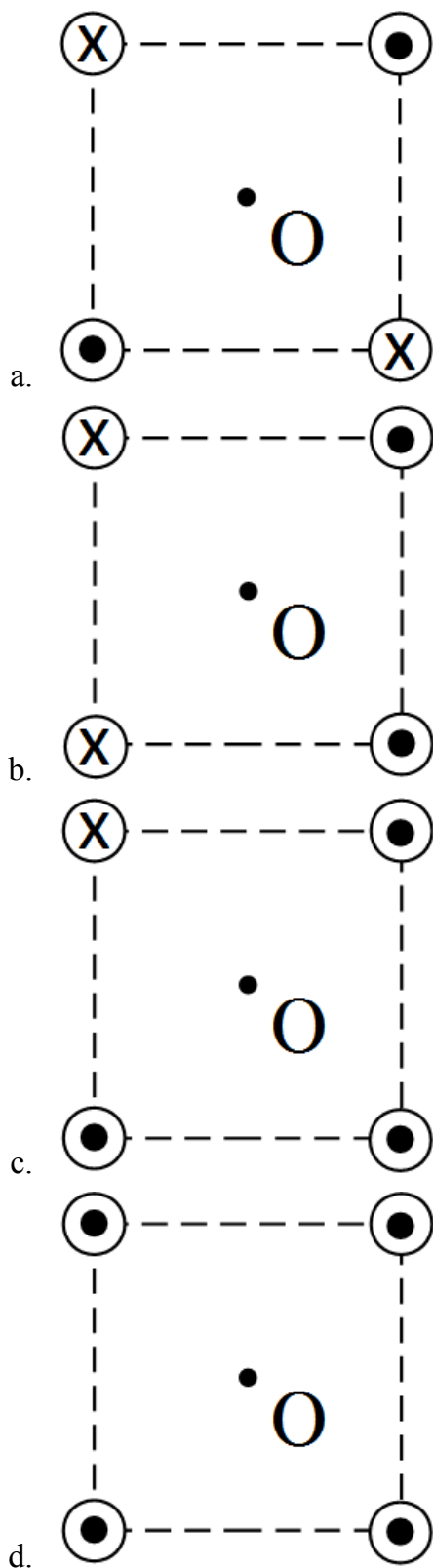
21) A charged particle travels counterclockwise with speed $v$ on a circle in the plane of the page, while a uniform magnetic field $B$ is applied in a perpendicular direction, pointing into the page (as shown below). The period $T$ is the amount of time the particle takes to travel around one complete circle. How would the period change if the speed of the particle was doubled?

$B$ is pointing into the page
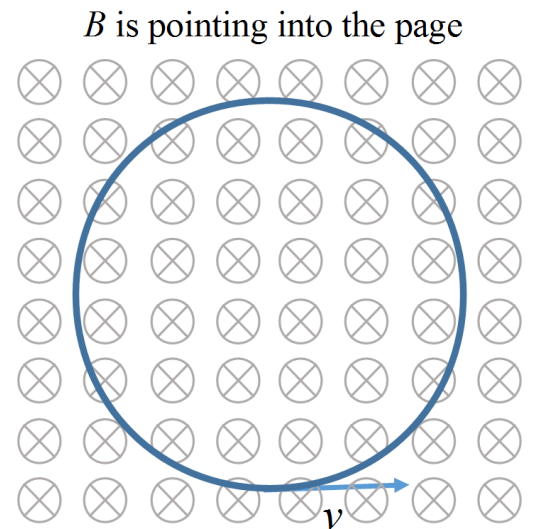


   a.  $T$ would increase by a factor of 4.
   b.  $T$ would remain unchanged.
   c.  $T$ would increase by a factor of 2.
   d.  $T$ would decrease by a factor of 2.
   e.  $T$ would decrease by a factor of 4.

22) Three long, parallel straight wires A, B and C carry a constant current of $I = 3\ A$ each. The direction of the current of each wire is as indicated in the figure below. The length of the wires is $L = 1\ m$ and the diameter is $D = 8\ mm$. Wires A and B are stuck to each other but electrically insulated from each other. We call the combination of wires A and B a "double wire AB". The distance from the center of C to the center of A is $r = 2\ cm$.
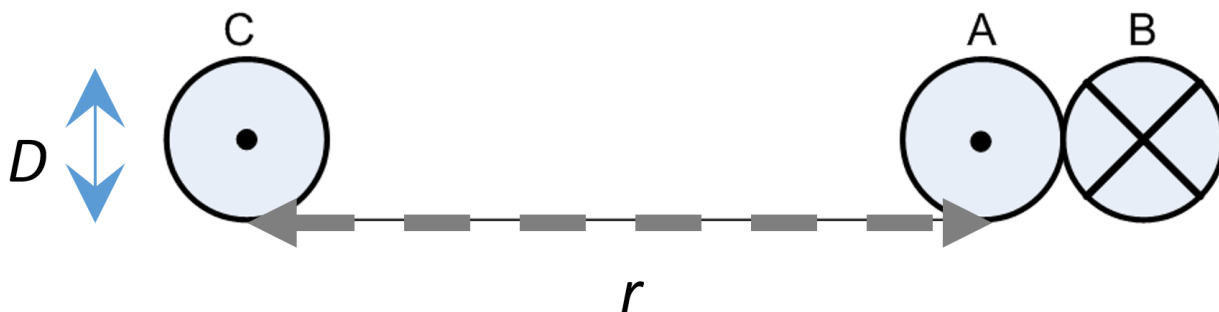


What is the net force on the double wire AB due to wire C?

   a.  $F = 1.5 \times 10^{-4}\ N$
   b.  $F = 0\ N$
   c.  $F = 2.6 \times 10^{-5}\ N$

23) A particle of charge $-|q|$ moves in the positive x-direction with speed $v$. There is a uniform electric field $\boldsymbol{E}$ of magnitude $|E|$ pointing in the positive y-direction and a uniform magnetic field $\boldsymbol{B}$ pointing in the *negative z-direction*. What must be the magnitude of the magnetic field, $|E|$, such that the particle does not accelerate? (Hint: Pay careful attention to the given direction of $\boldsymbol{E}$ and $\boldsymbol{B}$).
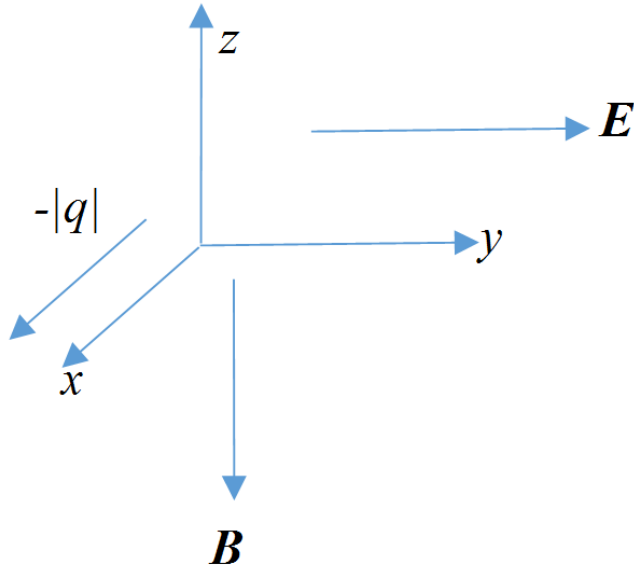


a. $|B| = |E|$
b. The charge will accelerate for any magnetic field $\boldsymbol{B}$ pointing in the negative z-direction.
c. $|B| = |E|/v$

24) A negatively charged particle enters a uniform magnetic field from the south and is pushed to the east.

In which direction does the magnetic field point?
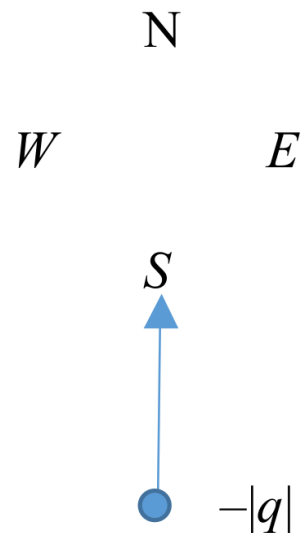


a. The magnetic field points into the page.
b. The magnetic field points out of the page.

**The next two questions pertain to the situation described below.**

A negatively charged particle with charge $q = -3e$ enters a uniform magnetic field $B = 0.3\ T$ pointing out of the page with a speed of $v = 10^6\ m/s$ and sweeps out a half circle of radius $r = 5.9\ cm$ before leaving the field.
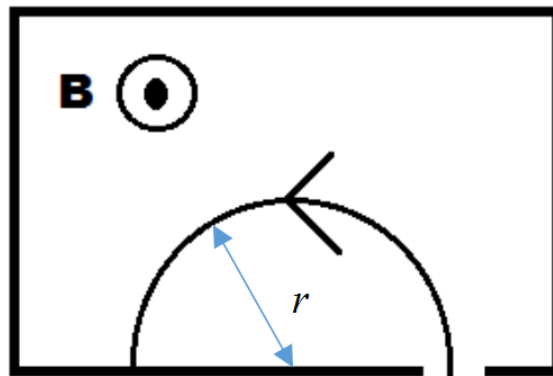


25) What is the particle's mass?

    a. More information is required to determine the mass of the particle.
    b. $m = 2.8 \times 10^{-20}\ kg$
    c. $m = 8.5 \times 10^{-27}\ kg$
    d. $m = 8.5 \times 10^{-21}\ kg$
    e. $m = 2.8 \times 10^{-26}\ kg$

26) What is the speed $v$ of the particle upon exiting the region with the $B$ field?

    a. $v = 10^5\ m/s$
    b. $v = 10^7\ m/s$
    c. $v = 10^4\ m/s$
    d. $v = 0\ m/s$
    e. $v = 10^6\ m/s$

Physic 102 formula sheet (SP2015)

## Kinematics and mechanics

$$x = x_0 + v_0 t + \frac{1}{2}at^2 \qquad v = v_0 + at \qquad v^2 = v_0^2 + 2a\Delta x$$

$$F = ma \qquad a_c = \frac{v^2}{r}$$

$$E_{\text{tot}} = K + U \qquad K = \frac{1}{2}mv^2 = \frac{p^2}{2m} \qquad p = mv \qquad W_F = Fd\cos\theta$$

## Electrostatics

$$F_{12} = k\frac{q_1 q_2}{r^2} \qquad E = \frac{F}{q_0} \qquad U_{12} = k\frac{q_1 q_2}{r} \qquad V \equiv \frac{U}{q_0} \qquad W_E = -\Delta U = -W_{\text{you}}$$

Point charge $\qquad E = k\frac{q}{r^2} \qquad V = k\frac{q}{r}$

Electric dipole $\qquad p = qd \qquad \tau_{\text{dip}} = pE\sin\theta \qquad U_{\text{dip}} = -pE\cos\theta$

## Resistance

$$R = \frac{V}{I} \qquad I = \frac{\Delta q}{\Delta t} \qquad \text{Physical resistance: } R = \rho\frac{L}{A}$$

$$P = IV = I^2 R = \frac{V^2}{R} \qquad R_{\text{S}} = R_1 + R_2 + \cdots \qquad \frac{1}{R_{\text{P}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

## Capacitance

$$C = \frac{Q}{V} \qquad \text{Parallel plate capacitor: } C = \frac{\kappa\epsilon_0 A}{d} \qquad E = \frac{Q}{\epsilon_0 A} \qquad V = Ed$$

$$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} \qquad C_{\text{P}} = C_1 + C_2 + \cdots \qquad \frac{1}{C_{\text{S}}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$$

## Circuits

$$\sum \Delta V = 0 \qquad \sum I_{\text{in}} = \sum I_{\text{out}}$$

$$q(t) = q_\infty(1 - e^{-t/\tau}) \qquad q(t) = q_0 e^{-t/\tau} \qquad I(t) = I_0 e^{-t/\tau} \qquad \tau = RC$$

## Magnetism

$$F = qvB\sin\theta \qquad r = \frac{mv}{qB} \qquad F_{\text{wire}} = ILB\sin\theta \qquad \tau_{\text{loop}} = NIAB\sin\varphi$$

Magentic dipole: $\qquad \mu = NIA \qquad \tau_{\text{dip}} = \mu B\sin\varphi \qquad U_{\text{dip}} = -\mu B\cos\varphi$

$$B_{\text{wire}} = \frac{\mu_0 I}{2\pi r} \qquad B_{\text{sol}} = \mu_0 n I$$

## Electromagnetic induction

$$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} \qquad \Phi = BA\cos\varphi$$

$$|\mathcal{E}_{\text{bar}}| = BLv \qquad \mathcal{E}_{\text{gen}} = \mathcal{E}_{\text{max}}\sin\omega t = \omega NAB\sin\omega t \qquad \omega = 2\pi f$$

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \qquad I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} \qquad \frac{V_{\text{p}}}{V_{\text{s}}} = \frac{I_{\text{s}}}{I_{\text{p}}} = \frac{N_{\text{p}}}{N_{\text{s}}}$$

## Electromagnetic waves

$$\lambda = \frac{c}{f} \qquad E = cB$$

$$u_E = \frac{1}{2}\epsilon_0 E^2 \qquad u_B = \frac{1}{2\mu_0}B^2 \qquad \bar{u} = \frac{1}{2}\epsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0}B_{\text{rms}}^2 = \epsilon_0 E_{\text{rms}}^2 = \frac{B_{\text{rms}}^2}{\mu_0} \qquad S = I = \bar{u}c = \frac{P}{A}$$

$$f_0 = f_e\sqrt{\frac{1 + v_{\text{rel}}/c}{1 - v_{\text{rel}}/c}} \approx f_e\left(1 + \frac{v_{\text{rel}}}{c}\right) \qquad I = I_0\cos^2\theta$$

## Reflection and refraction

$$\theta_r = \theta_i$$

$$\frac{1}{d_o} + \frac{1}{d_1} = \frac{1}{f}$$

$$f = \pm\frac{R}{2}$$

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$v = \frac{c}{n}$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$M = \frac{\theta'}{\theta} \approx \frac{d_{\text{near}}}{f}$$

Compound microscope:

$$m_{\text{obj}} = \frac{L_{\text{tube}}}{f_{\text{obj}}}$$

$$M_{\text{eye}} = \frac{d_{\text{near}}}{f_{\text{eye}}}$$

$$M_{\text{tot}} = M_{\text{eye}} m_{\text{obj}}$$

## Interference and diffraction

Double-slit interference: $\quad d\sin\theta = m\lambda \quad\quad d\sin\theta = \left(m + \frac{1}{2}\right)\lambda \quad\quad m = 0, \pm 1, \pm 2, \cdots$

Single-slit diffraction: $\quad a\sin\theta = m\lambda \quad\quad m = 0, \pm 1, \pm 2, \cdots$

Circular aperture: $\quad a\sin\theta \approx 1.22\lambda$

## Quantum mechanics

$$E = hf = \frac{hc}{\lambda} \quad\quad\quad \lambda = \frac{h}{p} \quad\quad\quad \Delta p_x \Delta x \geq \frac{\hbar}{2} \quad\quad\quad \hbar = \frac{h}{2\pi}$$

Bohr atom: $\quad 2\pi r_n = n\lambda \quad\quad n = 1, 2, 3, \cdots \quad\quad L_n = m_e v_n r_n = n\hbar$

$$r_n = \left(\frac{\hbar^2}{m_e k e^2}\right)\frac{n^2}{Z} \approx (5.29 \times 10^{-11} \text{ m})\frac{n^2}{Z} \quad\quad E_n = -\left(\frac{m_e k^2 e^4}{2\hbar^2}\right)\frac{Z^2}{n^2} \approx -(13.6 \text{ eV})\frac{Z^2}{n^2}$$

$$\frac{1}{\lambda} \approx (1.097 \times 10^7 \text{ m}^{-1})Z^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Quantum atom: $\quad L = \sqrt{\ell(\ell+1)}\hbar \quad\quad\quad L_Z = m_{\epsilon,}\hbar \quad\quad\quad S_z = ms\hbar$

Atomic magnetism: $\quad \mu_{e,z} = -\frac{e}{2m_e}L_z \quad\quad\quad \mu_{s,z} = -\frac{ge}{2m_e}S_z, g \approx 2 \quad\quad \mu_B \equiv \frac{e\hbar}{2m_e} \approx 5.8 \times 10^{-5} \text{ eV/T}$

## Nuclear physics and radioactive decay

$$A = Z + N \quad\quad\quad\quad r \approx (1.2 \times 10^{-15} \text{ m})A^{1/3} \quad\quad\quad\quad E_0 = mc^2$$

$$m_{\text{nucleus}} = Zm_{\text{proton}} + Nm_{\text{neutron}} - \frac{|E_{\text{bind}}|}{c^2}$$

$$\frac{\Delta N}{\Delta t} = \lambda N \quad\quad\quad\quad N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}} \quad\quad\quad\quad T_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$$

## Constants and unit conversion

$$g = 9.8 \text{ m/s}^2 \quad\quad\quad\quad e = 1.60 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \quad\quad k \equiv \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2 \quad\quad \mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$$

$$c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 3 \times 10^8 \text{ m/s} \quad\quad h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} \quad\quad hc = 1240 \text{ eV}\cdot\text{nm}$$

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \quad\quad\quad\quad m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg} = 511 \text{ keV}/c^2$$

$$m_{\text{proton}} = 1.673 \times 10^{-27} \text{ kg} = 938 \text{ MeV}/c^2 \quad\quad m_{\text{neutron}} = 1.675 \times 10^{-27} \text{ kg} = 939.5 \text{ MeV}/c^2$$

### SI Prefixes

| Power | Prefix | Symbol |
|-------|--------|--------|
| $10^9$ | giga | G |
| $10^6$ | mega | M |
| $10^3$ | kilo | k |
| $10^0$ | — | — |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | $\mu$ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |