These are the same instructions as given on the first exam.

Instructions for taking the exam in the Science Library:

Pick up and return the exam from the circulation desk in the Collier Science Library. You may take the exam anywhere in the Park Science Center or another nearby building. You have two hours from the moment you open the exam. Be sure to time yourself. You may take a few extra minutes to walk the exam back to the library when you are done.

When you are done, return your exam to the circulation desk. Discard the cover sheet and equation sheets.

General instructions for everybody:

This is a closed-book exam: do not use any references (text, notes, etc.). You will need a calculator capable of basic functions (arithmetic, logarithms, trigonometric functions, etc.), but you are not allowed to store formulas, etc., in the calculator memory.

This booklet contains:
- This cover page.
- Three pages of formulas.
- The exam questions.
- Three blank pages in case you need extra work space.

Remove the cover page and formula pages from your exam. Discard them when the exam is over.

Write your name, start time, and end time on the first page of questions.

Write your answers directly on the exam booklet. Show your work and box your final answers. If you write any final answers on blank pages, indicate that you have done so on the page on which the problem was posed. I don’t want to miss any of your work when grading your exam.

Good Luck!!!
Physics 101-1 Formulas

\[ \vec{v} = \frac{\Delta \vec{x}}{\Delta t} \]
\[ \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \]
\[ v_f = v_i + \alpha t \]
\[ x_f = x_i + v_{xi} t + \frac{1}{2} a_{x} t^2 \]
\[ v_{xf}^2 = v_{xi}^2 + 2a(x_f - x_i) \]
\[ a = \frac{v^2}{r} = \omega^2 r \]
\[ F_k = \mu_k n \]
\[ F_{max} = \mu_s n \]
\[ F = mg \]
\[ F = \frac{Gm_1m_2}{r^2} \]
\[ F = -k\Delta x \]
\[ \vec{F} = m\vec{a} \]
\[ \vec{F} = \frac{\Delta \vec{p}}{\Delta t} \]
\[ \vec{p} = m\vec{v} \]

\[ K = \frac{1}{2}mv^2 \]
\[ K = \frac{1}{2}I\omega^2 \]
\[ U = \frac{1}{2}kx^2 \]
\[ U = mg\gamma \]
\[ U = -\frac{Gm_1m_2}{r} \]
\[ P = \frac{\Delta E}{\Delta t} \text{ or } W = F_\parallel r = Fr \cos \theta \]
\[ \tau = F_\perp r = Fr \sin \theta \]
\[ \rho = \frac{m}{V} \]
\[ \rho = \frac{F}{A} \]
\[ \rho = \rho_g y \]
\[ Q = \frac{\Delta V}{\Delta t} = vA \]
\[ p_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \]
\[ F_B = m_{\text{displaced}} g \]

\[ v_{max} = A\omega \]
\[ a_{max} = A\omega^2 \]
\[ x(t) = A \cos(\omega t) \text{ or } A \sin(\omega t) \]
\[ v(t) = -v_{max} \sin(\omega t) \text{ or } v_{max} \cos(\omega t) \]
\[ a(t) = -a_{max} \cos(\omega t) \text{ or } -a_{max} \sin(\omega t) \]
\[ \omega = \sqrt{\frac{k}{m}} \]
\[ \omega = \sqrt{\frac{g}{l}} \]
\[ \omega = 2\pi f \]
\[ f = \frac{1}{T} \]

The solution to \( ax^2 + bx + c = 0 \) is \( x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \).

Volume of a sphere: \( V = \frac{4}{3}\pi r^3 \)  
Surface area of a sphere: \( A = 4\pi r^2 \)

Area of a circle: \( A = \pi r^2 \)  
Circumference of a circle: \( l = 2\pi r \)
Physics 102-1 Formulas

\[ y(x, t) = A \cos \left( \frac{2\pi}{\lambda} x - \omega t \right) \]

\[ v = f \lambda \]

\[ v = \sqrt{\frac{F_t}{\mu}}, \quad \mu = \frac{m}{L} \]

\[ f_0 = \frac{(1 \pm \frac{v}{c})}{(1 \pm \frac{v}{c})} f_s \]

\[ \Delta f = 2 \frac{v_t}{c} f_s \]

\[ f_{\text{beat}} = |f_1 - f_2| \]

\[ \beta = 10 \text{ dB} \log \left( \frac{I}{I_0} \right) \]

\[ I = \frac{P}{A} \]

\[ I = \frac{P}{4\pi r^2} \]

\[ v = \frac{c}{n} \]

\[ \lambda = \frac{\lambda_{\text{vac}}}{n} \]

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

\[ \lambda = \frac{h}{p} = \frac{h}{mv} \]

\[ \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \]

\[ M = \frac{h'}{h} = -\frac{s'}{s} \]

\[ M_{\text{angular}} = \frac{\theta'}{\theta} \]

\[ P = \frac{1}{f}, \quad P \text{ in diopeters, } f \text{ in m} \]

\[ \theta \approx \frac{\lambda}{D} \]

String or open-open tube: \[ f_1 = \frac{v}{2L}, \quad f_m = mf_1, \quad m = 1, 2, 3, \ldots \]

Open-closed tube: \[ f_1 = \frac{v}{4L}, \quad f_m = mf_1, \quad m = 1, 3, 5, \ldots \]

Bragg scattering (X-rays): \[ 2d \cos \theta = m\lambda \]

\[ \Delta L = \begin{cases} \quad m\lambda & \text{constructive} \\ (m + \frac{1}{2})\lambda & \text{destructive} \end{cases} \]

\[ \frac{L_1}{\lambda_1} - \frac{L_2}{\lambda_2} = \begin{cases} \quad m & \text{constructive} \\ m + \frac{1}{2} & \text{destructive} \end{cases} \]

Single-slit interference:

(small angle) \[ y = \begin{cases} \quad 0 & \text{constructive} \\ mL \frac{\lambda}{a} & \text{destructive, } m \neq 0 \end{cases} \]

Two-slit or Multi-slit interference:

(any angle) \[ \sin \theta = \begin{cases} \quad m \frac{\lambda}{d} & \text{constructive} \\ (m + \frac{1}{2}) \frac{\lambda}{d} & \text{destructive} \end{cases} \]

(small angle) \[ y = \begin{cases} \quad mL \frac{\lambda}{d} & \text{constructive} \\ (m + \frac{1}{2}) L \frac{\lambda}{d} & \text{destructive} \end{cases} \]
More Physics 102-1 Formulas

\[ F = K \frac{q_1 q_2}{r^2} \]
\[ E = K \frac{q}{r^2} \]
\[ E = \frac{Q}{\epsilon_0 A} \]
\[ \vec{F} = q \vec{E} \]
\[ V = \frac{1}{4\pi \epsilon_0} \frac{q}{r} \]
\[ U_{\text{elec}} = qV \]
\[ E = \frac{\Delta V}{\Delta x} \]
\[ Q = CV \]
\[ C = \frac{\kappa \epsilon_0 A}{d} \]
\[ U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} QV = \frac{1}{2} CV^2 \]
\[ R_{\text{equiv}} = \frac{1}{R_1} + \frac{1}{R_2} \]
\[ R_{\text{equiv}} = R_1 + R_2 \]
\[ \Sigma I_{\text{in}} = \Sigma I_{\text{out}} \]
\[ \Sigma \Delta V = 0 \]
\[ \tau = RC \]
\[ V = V_0 e^{-\frac{t}{\tau}} \]
\[ V = V_f \left( 1 - e^{-\frac{t}{\tau}} \right) \]

Fundamental Constants and Commonly Used Data

- Gravitational constant: \( G = 6.67 \times 10^{-11} \text{N m}^2 \text{kg}^{-2} \)
- Electrostatic constant: \( K = 8.99 \times 10^9 \text{N m}^2 \text{C}^{-2} \)
- Permittivity of free space: \( \epsilon_0 = 8.85 \times 10^{-12} \text{C}^2 \text{N}^{-1} \text{m}^{-2} \)
- Stefan-Boltzmann constant: \( \sigma = 5.678 \times 10^{-8} \text{W m}^{-2} \text{K}^{-4} \)
- Planck constant: \( h = 6.63 \times 10^{-34} \text{Js} \)
- Gravitational acceleration at Earth surface: \( g = 9.80 \text{m s}^{-1} \)
- Threshold of hearing: \( I_0 = 1 \times 10^{-12} \text{W m}^{-2} \)
- Speed of light in vacuum: \( c = 3.00 \times 10^8 \text{m s}^{-1} \)
- Fundamental charge: \( e = 1.60 \times 10^{-19} \text{C} \)
- Electron mass: \( m_e = 9.11 \times 10^{-31} \text{kg} \)
- Proton mass: \( m_p = 1.67 \times 10^{-27} \text{kg} \)
- Speed of sound in air: \( v = 343 \text{ m s}^{-1} \) at 20°
- Atmospheric pressure: \( 1 \text{ atm} = 1.013 \times 10^5 \text{ N m}^{-2} \)
- Specific heat capacity of water: \( c_{\text{water}} = 4186 \frac{\text{J}}{\text{kg K}} \)
- Density of water: \( \rho_{\text{water}} = 1000 \frac{\text{kg}}{\text{m}^3} \)
- Power output of the Sun: \( 3.83 \times 10^{26} \text{ W} \)
- Radius of Sun: \( 6.96 \times 10^8 \text{ m} \)
- Radius of Earth: \( 6.38 \times 10^6 \text{ m} \)
- Radius of Moon: \( 1.74 \times 10^6 \text{ m} \)
- Mass of Sun: \( 1.99 \times 10^{30} \text{ kg} \)
- Mass of Earth: \( 5.97 \times 10^{24} \text{ kg} \)
- Mass of Moon: \( 7.35 \times 10^{22} \text{ kg} \)
- Distance from Sun to Earth: \( 1.50 \times 10^{11} \text{ m} \)
1. [20 points] The equipotentials in some region are shown. Equipotential contours are drawn at intervals of 10 V. Distances in meters are given along the axes.

(a) Estimate the electric field at point $B$ (direction and magnitude).
(b) A proton is released from rest at point $B$. As it moves away from $B$, it passes through either point $A$ or $C$. Which is it, point $A$ or point $C$?

(c) An electron is released from rest at point $B$. As it moves away from $B$, it passes through either point $A$ or $C$. Which is it, point $A$ or point $C$?

(d) What is it the speed of the electron as it passes through this point? (Physical constants needed for this calculation can be found on the equation sheet at the front of the exam booklet.)
2. [20 points] Four identical resistors of resistance $R = 1.0 \text{k\Omega}$, a capacitor of capacitance $C = 2.0 \times 10^{-3} \text{F}$, and a battery of voltage $V_b = 10 \text{V}$ are arranged as shown.

(a) The three resistors $R_1$, $R_2$, and $R_3$, can be reduced to a single equivalent resistor. What is the resistance of this equivalent resistor?

(b) The switch has been closed for a long time. What is the charge on the capacitor?

*This problem is continued on the next page....*
(c) The switch is opened at time \( t = 0 \). What is the charge on the capacitor as a function of time, \( t \)? Give a formula. Your formula should be a numerical expression with \( t \) as the only variable. (Substitute in numbers for any other variables.)

(d) At what time is the charge on the capacitor one tenth of the value you calculated in part (b)?
3. [15 points] Imagine a space probe (satellite) in the shape of a cube, orbiting a star. The space probe orbits in such a way that the same face of the cube is always facing the star.

The power output of the star is $P_\star = 1.0 \times 10^{28}$ W.
The distance from the star to the cubic probe is $d = 6 \times 10^{11}$ m.
The edges of the cube are $l = 2.0$ m in length.

The entire surface of the space probe (all six sides) always maintains the same temperature $T$. It has emissivity $e = 1$.

What is $T$?
4. [15 points] Copper and aluminum are denoted by symbols Cu and Al, respectively.

The resistivity of copper is $\rho_{\text{Cu}} = 1.7 \times 10^{-8} \Omega \text{ m}$.

The resistivity of aluminum is $\rho_{\text{Al}} = 2.8 \times 10^{-8} \Omega \text{ m}$.

Calculate the resistance of each of the following. The diagrams below show how each would be connected into a circuit.

(a) A cube of copper, 0.1 m × 0.1 m × 0.1 m.

(b) A cube of aluminum, 0.1 m × 0.1 m × 0.1 m.

(c) A cube of copper and a cube of aluminum, each 0.1 m × 0.1 m × 0.1 m, next to each other.

(d) A cube of copper and a cube of aluminum, each 0.1 m × 0.1 m × 0.1 m, one on top of the other.
5. [15 points] A wall of a house is 7 m long and 3 m high. It is constructed of solid brick of thickness 0.2 m. There are two windows in the wall, each 1 m × 1 m, made of glass 0.005 m thick. Inside, it is 22°C. Outside, it is 2°C. Electricity costs $0.10 per kilowatt hour. How much does it cost to replace the heat lost through this wall in one day? Thermal conductivities: $\kappa_{\text{brick}} = 0.63 \frac{\text{W}}{\text{m}^2\text{C}}$, $\kappa_{\text{glass}} = 1.05 \frac{\text{W}}{\text{m}^2\text{C}}$. 
6. [15 points] Sketch electric field lines and equipotential lines for the following charge distribution. There is a $-6 \mu C$ charge in the center and two $+3 \mu C$ charges, one to the left and one to the right, as shown below. Either make a single drawing or two separate drawings.
This is the first of three pages provided as extra work space for this exam.
This is the second of three pages provided as extra work space for this exam.
This is the third of three pages provided as extra work space for this exam.