

## 2022 Physics Bowl Exam Equations

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$v = v_0 + at$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$\sum \vec{F} = m\vec{a}$$

$$F_{fric} \leq \mu F_N$$

$$F_g = G \frac{m_1 m_2}{r^2}$$

$$F_g = mg$$

$$\vec{p} = m\vec{v}$$

$$a = \frac{v^2}{r}$$

$$v_t = r\omega$$

$$a_t = r\alpha$$

$$\tau = RF \sin \theta = R_{\perp} F = RF_{\perp}$$

$$\sum \vec{\tau} = I\vec{\alpha}$$

$$KE = \frac{1}{2} m v^2$$

$$\Delta PE_g = mg\Delta y$$

$$W = Fd \cos \theta = F_{\parallel} d = Fd_{\parallel}$$

$$PE_s = \frac{1}{2} k x^2$$

$$P = \frac{W}{\Delta t}$$

$$\vec{F} = -k\vec{x}$$

$$T = 2\pi \sqrt{\frac{m}{k}}$$

$$T = 2\pi \sqrt{\frac{L}{g}}$$

$$\rho = \frac{m}{V}$$

$$F_{buoy} = \rho g V$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$$

$$P = \frac{F}{A}$$

$$PV = nRT = Nk_B T$$

$$\Delta U = Q + W_{on\ system}$$

$$Q = mc\Delta T$$

$$Q = \pm mL$$

$$\Delta S = \frac{Q}{T}$$

$$v = f\lambda$$

$$f_o = f_s \left( \frac{v_{snd} \pm v_{obs}}{v_{snd} \mp v_{src}} \right)$$

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

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

$$m\lambda = d \sin \theta$$

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

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

$$F_e = k \frac{q_1 q_2}{r^2}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$V = \frac{kq}{r}$$

$$V = \frac{W}{q}$$

$$\Delta V = -Ed \cos \theta = -E_{\parallel} d = -Ed_{\parallel}$$

$$PE_e = \frac{kq_1 q_2}{r}$$

$$Q = CV$$

$$PE = \frac{1}{2} CV^2$$

$$V = RI$$

$$P = IV$$

$$F = qvB \sin \theta = qvB_{\perp}$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \mu_0 n I$$

$$F = ILB \sin \theta = ILB_{\perp}$$

$$\varepsilon = vBL = \left( \frac{B\Delta A}{t} \right)$$

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$$E = \gamma m_0 c^2 = mc^2$$

$$E = hf$$

$$p = \frac{h}{\lambda}$$

$$hf = KE_e + W_0$$

$$Q = e\sigma T^4 At$$

$$p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Moments of Inertia:

Solid disk or cylinder for a perpendicular axis through its center:  $I = \frac{1}{2}MR^2$

Thin rod about the center, perpendicular to rod:  $I = \frac{1}{12}MR^2$

Solid sphere about a diameter:  $I = \frac{2}{5}MR^2$

## **2022 Physics Bowl Exam Constants**

Use the following values in determining the answers on this exam. If you use other values in calculating answers, you may obtain values that do not exactly match answer selections found on this exam. You will then need to choose the answer on the test closest to your value.

acceleration due to gravity	$g$	$= 10 \text{ m/s}^2$
gravitational constant	$G$	$= 6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2$
mass of the Earth	$M_E$	$= 6.0 \times 10^{24} \text{ kg}$
radius of the Earth	$R_E$	$= 6.4 \times 10^6 \text{ m}$
atomic mass unit	$1 \text{ u}$	$= 1.7 \times 10^{-27} \text{ kg} = 9.3 \times 10^2 \text{ MeV}/c^2$
electron volt	$1 \text{ eV}$	$= 1.6 \times 10^{-19} \text{ J}$
rest mass of electron	$m_e$	$= 9.1 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.7 \times 10^{-27} \text{ kg}$
elementary charge	$e$	$= 1.6 \times 10^{-19} \text{ C}$
Coulomb's constant	$k$	$= 9.0 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2$
permittivity constant	$\epsilon_0$	$= 8.9 \times 10^{-12} \text{ C}^2 / \text{N} \cdot \text{m}^2$
permeability constant	$\mu_0$	$= 4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A}$
speed of sound in air (20° C)	$v_s$	$= 340 \text{ m/s}$
speed of light in vacuum	$c$	$= 3.0 \times 10^8 \text{ m/s}$
Planck's constant	$h$	$= 6.6 \times 10^{-34} \text{ J} \cdot \text{s} = 4.14 \times 10^{-15} \text{ eV} \cdot \text{s}$
Boltzmann constant	$k_B$	$= 1.38 \times 10^{-23} \text{ J/K}$
Universal Gas Constant	$R$	$= 8.21 \times 10^{-2} \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}}$
Avogadro's Number	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
Atmospheric Pressure	$P_{atm}$	$= 1.013 \times 10^5 \text{ Pa}$

### **Water Properties:**

Latent Heat of Vaporization	$L_v$	$= 540 \text{ kcal/kg} = 2.3 \times 10^6 \text{ J/kg}$
Latent Heat of Fusion	$L_f$	$= 80 \text{ kcal/kg} = 3.3 \times 10^5 \text{ J/kg}$
Density	$\rho_w$	$= 1.0 \times 10^3 \text{ kg/m}^3$
Specific heat	$c_w$	$= 1.0 \text{ kcal/kg} \cdot \text{K} = 4.2 \times 10^3 \text{ J/kg} \cdot \text{K}$
Specific heat (ice)	$c_i$	$= 0.50 \text{ kcal/kg} \cdot \text{K} = 2.1 \times 10^3 \text{ J/kg} \cdot \text{K}$
Specific heat (vapor)	$c_v$	$= 0.48 \text{ kcal/kg} \cdot \text{K} = 2.0 \times 10^3 \text{ J/kg} \cdot \text{K}$