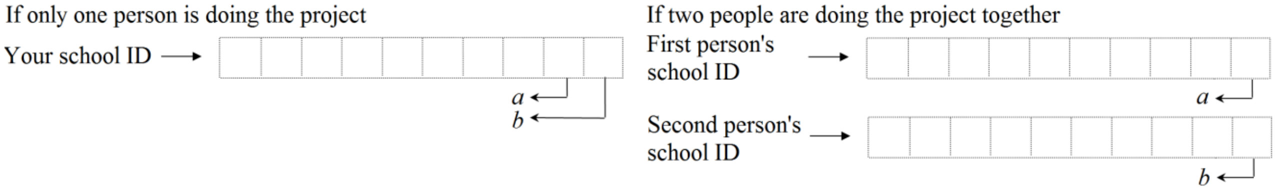
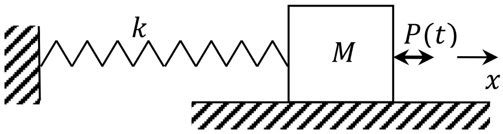
DESIGN PROJECT # 3

Due to Monday, January 24, 2022

Use the following numbers in your calculations



Consider the spring-mass system shown. A dynamic load, $P(t)$, is applied with a frequency of (200 + 3*b*) rpm. When installed, the spring force is to vary between (100 + 12*a*) and (800 + 12*a*) N while the spring length varies over a range of (20 + 0.5*b*) mm. The object attached to its end has a mass of (0.3+0.05*a*) kg.



(*a*) Derive an expression for natural frequency. (*b*) Develop a computer program to design a spring such that its cost is **minimum**. Costs of springs made of different materials are given in the table. Assume that the processing cost of squaring operation is more or less the same for different values of d and D and for different materials. Standard wire diameters and the range of available diameters for different materials are given in the formula sheet. *C* must be between 4 and 12. The spring is shot-peened (Figure 12.15 applies). Spring ends are squared, but not ground. Presetting operation will ***not*** be done. Even if the spring closes solid, the shear stress must not exceed shear yield strength. Safety factor against spring surge must be at least 5. Infinite fatigue life is desired. Safety factor against fatigue failure should be at least 1.2. Springs should also be safe against buckling failure. The computer program should read the inputs from an input file or within the program and find the design values without user intervention through iterations. Print out your program and output file. The output file must include the following **in the given order**: Minimum force (F_{min}), maximum force (F_{max}), wire diameter (d), spring index (C), coil diameter (D), clash allowance (δ_{cl}), spring rate (k), number of active coils (N_a), total number of coils (N_t), solid length (L_s), free length (L_f), the force that closes the spring (F_s), K_s, K_w, slenderness ratio (L_f/D), deflection ratio, safety factor against buckling (infinite if no $\delta_{allowable}$ can be found from the graph or the analytical formula does not give a result due to negative value of square root), mass of the active coils, natural frequency (Hz), safety factor against spring surge, ultimate tensile strength (S_{ut}), ultimate shear strength (S_{us}), yield strength (S_y), shear yield strength (S_{ys}), stress in solid state (τ_s), safety factor against yielding, alternating and mean stresses (τ_a and τ_m), torsional stress (S_s) (in Fig. 12.15), safety factor against fatigue failure. (Note: use SI unit system). In addition, return a softcopy of the code. Note: Two people may form a project group and work on the project together. However, project groups may not get any help from each other. Do not show your code to another group. Any similarity in the algorithm and computer code will be presumed as cheating.

Hint: The governing equation: $\dfrac{\partial^2 u(x,t)}{\partial x^2} = \dfrac{1}{\beta^2}\dfrac{\partial^2 u(x,t)}{\partial t^2}$. Axial force in the spring: $F(x,t) = Lk\dfrac{\partial u(x,t)}{\partial x}$

where *u* is the displacement in the *x* direction, *L* is the length of the spring, *k* is the spring rate, *m* is the total mass of the spring, $\beta^2 = L^2 k/m$. You may use separation of variables assuming $u(x,t) = X(x)T(t)$.

Cost of springs

Material	Cost (d and D are in cm)
A227	$100d^2N_t\mathrm{D}$
A228	$200d^2N_t\mathrm{D}$
A229	$130d^2N_t\mathrm{D}$
A232	$250d^2N_t\mathrm{D}$
A401	$400d^2N_t\mathrm{D}$