1. The condition for static equilibrium is:

(a) \( \sum \vec{F} = 0 \)  \hspace{1cm} (b) \( \sum \vec{\tau} = 0 \)  \hspace{1cm} (c) \( \sum \vec{F} = 0 \) or \( \sum \vec{\tau} = 0 \)  \hspace{1cm} (d) \( \sum \vec{F} = 0 \) and \( \sum \vec{\tau} = 0 \)

**Questions 2-4.** Consider a tower crane shown in the picture below. The mass of the counterweight is \( m_1=2000 \) kg, and the mass of the load is \( m_2= 500 \) kg. Ignore the mass of the beam and take \( g \approx 10 \) m/s\(^2\).

![Diagram of a tower crane with masses and forces](image)

2. How far from the vertical beam must the counterweight \( m_1 \) be located?

   (a) 1 m  \hspace{1cm} (b) 2 m  \hspace{1cm} (c) 5 m  \hspace{1cm} (d) 10 m

3. What is the normal force \( F_N \) on the horizontal beam exerted by the vertical beam?

   (a) 5000 N  \hspace{1cm} (b) 15000 N  \hspace{1cm} (c) 20000 N  \hspace{1cm} (d) 25000 N

4. What is the maximum weight that can be lifted with this crane?

   (a) 500 kg  \hspace{1cm} (b) 1000 kg  \hspace{1cm} (c) 2000 kg  \hspace{1cm} (d) 5000 kg

5. Resonance occurs when the frequency of the external (driving) force is equal or close to the natural frequency of the oscillator.

   (a) True  \hspace{1cm} (b) False  \hspace{1cm} (c) cannot be answered
Questions 6-7. A uniform steel beam has a mass $M$ and length $L$. On it is resting half of an identical beam, as shown below.

6. The magnitude of the vertical support force on the left side $F_1$ is:

(a) $\frac{3}{2}Mg$  (b) $\frac{3}{4}Mg$  (c) $\frac{7}{8}Mg$  (d) $\frac{5}{8}Mg$

7. The magnitude of the vertical support force on the right side $F_2$ is:

(a) $\frac{3}{2}Mg$  (b) $\frac{3}{4}Mg$  (c) $\frac{7}{8}Mg$  (d) $\frac{5}{8}Mg$

Questions 8-9. An object with mass $M=0.5$ kg is supported with two cables, as in the picture below. Take $g\approx10$ m/s$^2$.

8. The magnitude of tension force $F_1$ is:

(a) $\frac{5\sqrt{3}}{2}$ N  (b) $\frac{2\sqrt{5}}{3}$ N  (c) $\frac{2\sqrt{3}}{5}$ N  (d) $\frac{3\sqrt{2}}{5}$ N

9. The magnitude of tension force $F_2$ is:

(a) 2.0 N  (b) 2.5 N  (c) 3.5 N  (d) 4.0 N
Questions 10-12. A uniform beam 1 m long and with mass m= 10 kg is mounted on a wall by a pin. The beam is held in a horizontal position by a cable that makes an angle $\theta=30^\circ$, as shown in the picture below. Take $g\approx10$ m/s$^2$.

10. The magnitude of the tension force $F_T$ is:

(a) 50 N  
(b) 87 N  
(c) 100 N  
(d) 141 N

11. The magnitude of the $x$ component of the force that the pin exerts on the beam $F_{Px}$ is:

(a) 50 N  
(b) 87 N  
(c) 100 N  
(d) 141 N

12. The magnitude of the $y$ component of the force that the pin exerts on the beam $F_{Py}$ is:

(a) 50 N  
(b) 87 N  
(c) 100 N  
(d) 141 N

13. Stress is defined as:

(a) $\frac{\Delta L}{L}$  
(b) $\frac{E}{L}$  
(c) $\frac{F}{A}$  
(d) $\frac{F}{\Delta L_0}$

14. In the proportional region the relation between the elongation and applied force is:

(a) $\Delta L = E \frac{F}{A} L_0$  
(b) $\Delta L = \frac{1}{E} \frac{L_0}{A} F$  
(c) $\Delta E = \frac{1}{L_0} \frac{F}{A} \Delta L$  
(d) $\Delta L = \frac{1}{E} \frac{L_0}{A} F$

15. The force of spring, as given by Hooke’s law is:

(a) $F = -kx^2$  
(b) $F = -\frac{1}{2}kx$  
(c) $F = -\frac{1}{2}kx^2$  
(d) $F = -kx$
Questions 16-17. Consider a graph of displacement versus time for a simple harmonic oscillator shown below.

![Graph of displacement versus time for a simple harmonic oscillator](image)

16. The amplitude of oscillations is:
   (a) 0.2 m   (b) 0.4 m   (c) 0.8 m   (d) $2\pi$ m

17. The frequency of oscillations is:
   (a) 0.5 Hz   (b) 1 Hz   (c) 1.5 Hz   (d) 2 Hz

Questions 18-20. Consider a simple harmonic oscillator with the mass $m = 1$ kg. The displacement as a function of time is given by:

$$x(t) = (5.0m)\cos\left(\frac{2\pi}{5}t + \frac{\pi}{4}\right)$$

where $x$ is in meters and $t$ is in seconds.

18. The frequency of oscillations is:
   (a) 0.2 Hz   (b) 0.5 Hz   (c) 1 Hz   (d) 1.25 Hz

19. How far from the origin is the oscillator at $t = \frac{5}{24}$ s?
   (a) 1.5 m   (b) 2.5 m   (c) 3.5 m   (d) 4.5 m

20. The total mechanical energy of the oscillator is:
   (a) $\pi$ J   (b) $\pi^2$ J   (c) $2\pi^2$ J   (d) $4\pi^2$ J