Summer Assignment 2 - Set on 24th July 2025, Video Solutions on 6th August 2025

Introduction

This assignment is split into three sections:

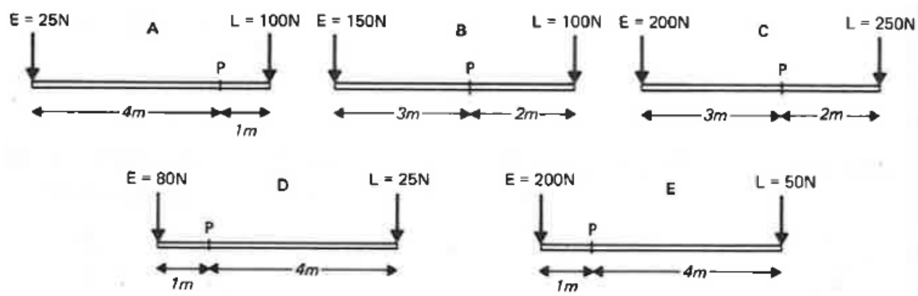
- Section A: 20 marks of multiple choice questions, split into 3 parts:
  - Q1-6 = fairly easy
  - Q7-11 = BPhO Senior Challenge level
  - Q14-20 = questions taken from past PAT papers

  Even though they are multiple choice, don't forget to show your working!
- Section B: Four questions worth 20 marks.
- Section C: One long question worth 20 marks, taken from a past PAT paper. (Please note, though, 20-mark questions are no longer used in the PAT. Instead there are shorter, 10-mark questions. But this one is still good practice!)

Section A

Part 1

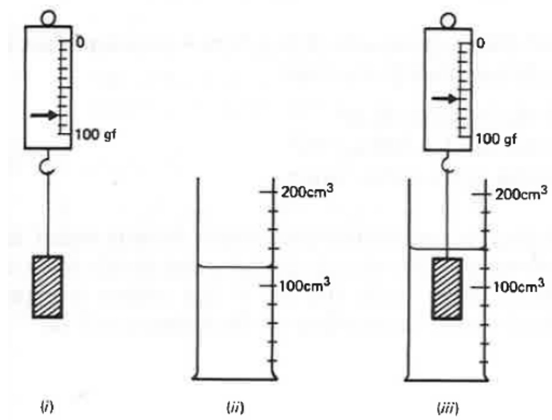
The diagrams show five levers. P marks the pivot, E the effort and L the load. Assume all are initially at rest.



1. Which lever will rotate clockwise?

2. Which lever will start to rotate most rapidly anti-clockwise?

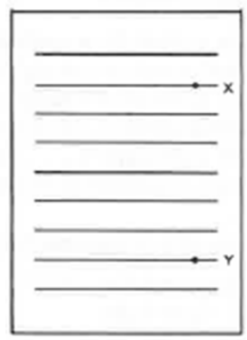
The diagrams show (i) a spring balance calibrated from $0-100\,\text{gf}$ in steps of $10\,\text{gf}$, weighing an object in air (ii) a measuring cylinder measuring $0-200\,\text{cm}^3$ in steps of $20\,\text{cm}^3$ and containing some water (iii) the object lowered into the water.



3. Which of these statements is/are correct?
   (a) The weight of the object is $80\,\text{gf}$
   (b) The volume of the water is $120\,\text{cm}^3$
   (c) The upthrust on the object when it is in the water is $20\,\text{gf}$

4. Which of these statements is/are correct?
   (a) The volume of the object is $20\,\text{cm}^3$
   (b) The mass of the object is $80\,\text{g}$
   (c) The density of the object is $0.25\,\text{g}\,\text{cm}^{-3}$

A straight wooden bar oscillates up and down in a ripple tank at 2.0 Hz and produces plane waves as shown in the diagram. Points X and Y are 60 cm apart.



5. The wavelength is
   (a) 10 cm
   (b) 30 cm
   (c) 35 cm
   (d) 60 cm
   (e) 70 cm

6. The velocity of the wave is
   (a) $5\,\mathrm{cm\,s^{-1}}$
   (b) $10\,\mathrm{cm\,s^{-1}}$
   (c) $20\,\mathrm{cm\,s^{-1}}$
   (d) $30\,\mathrm{cm\,s^{-1}}$
   (e) $120\,\mathrm{cm\,s^{-1}}$

Part 2

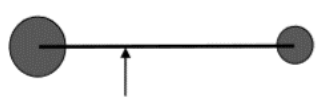
7. An estimate of the energy stored in a 1.5 V torch battery is

   (a) 10^4 J
   (b) 3×10^5 J
   (c) 10^7 J
   (d) 3×10^8 J

   Hint: consider how long you might expect such a battery to power something.

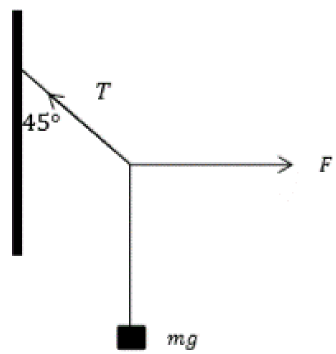
8. Two spheres of the same density but different masses are supported with their centres at the ends of a uniform bar of length $L = 10$ units. The larger sphere has three times the mass of the smaller sphere, and the bar itself has a mass equal to the mass of the smaller sphere.

   How many units from the left hand end should the pivot be placed to balance the bar?



   (a) 1 unit
   (b) 2 units
   (c) 3 units
   (d) 4 units

An object of mass m is suspended from a light string attached to a wall, as shown in the diagram. The force F is horizontal.



. **A weight hanging from a string attached to a wall.**

9. If the mass is doubled so that mg is replaced by $2mg$, how do forces F and T change?

   (a) F and T remain the same

   (b) T halves

   (c) F and T double

   (d) F halves

10. Which of these is a correct relationship?

    (a) $T \tan 45° = F$

    (b) $F \sin 45° = T$

    (c) $T \sin 45° = F$

    (d) $mg \sin 45° = T$

11. How are the magnitudes of F, T and mg related?

    (a) $F = mg$

    (b) $F < mg$

    (c) $F > mg$

    (d) $F + mg = T$

Part 3

12. A car of mass 1500 kg is towing a trailer of mass 1000 kg at a steady speed. The driver decides to overtake another car and accelerates at $4\,\mathrm{m\,s^{-2}}$. If the frictional force on the trailer is 2500 N, what is the force on the towbar during the manoeuvre?

    (a) 6500 N
    (b) 8500 N
    (c) 10 000 N
    (d) 12 500 N

13. A physics lecture theatre is situated 3 m east and 4 m above reception. Calculate the minimum energy that a 60 kg receptionist would have to expend to reach the lecture theatre.

    (a) 1800 J
    (b) 2400 J
    (c) 3000 J
    (d) 4200 J

14. Two resistors R_1 and R_2 are in parallel with a potential difference V across them. The total power dissipated in the circuit is

    (a)
    $$V^2 \times \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

    (b)
    $$\frac{V^2}{R_1 + R_2}$$

    (c)
    $$\frac{V^2}{(1/R_1) + (1/R_2)}$$

    (d)
    $$V^2(R_1 + R_2)$$

15. A drop slide in a fairground has a very steep initial slope which gradually curves into a gentler slope. If a child drops down the slide, what happens to her speed v and the magnitude of her acceleration a?

    (a) v and a both increase
    (b) v increases and a stays the same
    (c) v increases and a decreases
    (d) v decreases and a increases

16. A light-dependent resistor is connected across an ideal 12 V source and placed in the open in the middle of a desert. When is the power dissipated in the resistor highest?

    (a) dawn
    (b) mid-morning
    (c) noon
    (d) midnight

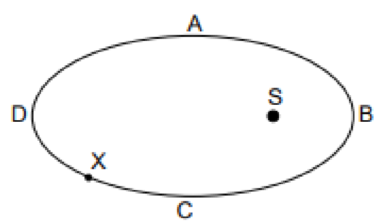
17. The visible universe contains about 400 billion galaxies (where 1 billion equals 10^9). Our galaxy contains about 250 billion stars. The mass of our sun is about 2×10^{30} kg. NASA estimates that dark matter out-masses stars by about 20:1. Use this data to estimate the total mass of the visible universe.

    (a) 4.2×10^{36} kg
    (b) 9.5×10^{51} kg
    (c) 2.0×10^{53} kg
    (d) 4.2×10^{54} kg

18. A block of Niobium, a metal with density $8570\,\mathrm{kg\,m^{-3}}$, has sides of length 3 cm, 4 cm and 5 cm. What is the maximum pressure that can be exerted by the block when it is stood upright on one of its faces?

(a) $4.3\,\mathrm{kPa}$
(b) $430\,\mathrm{kPa}$
(c) $2.6\,\mathrm{kPa}$
(d) $510\,\mathrm{kPa}$

19. The diagram shows the approximate orbit of the dwarf planet Eris (X) around the sun (S).



Which of the following statements is false?

(a) Eris moves fastest at point D.
(b) Eris moves at the same speed at points A and C.
(c) Eris moves in an ellipse with the sun at one focus.
(d) The potential energy of Eris changes during the orbit.

20. In quantum mechanics, the de Broglie wavelength of an object depends on its momentum according to $\lambda = h/p$ where h is Planck's constant.

Protons of charge e and mass m are accelerated from rest through a potential V. What is their de Broglie wavelength?

(a)
$$\frac{2h}{\sqrt{meV}}$$

(b)
$$\frac{h}{\sqrt{2meV}}$$

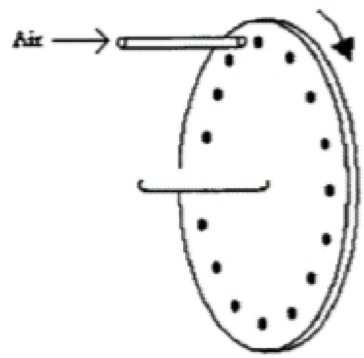
(c)
$$\frac{h}{\sqrt{meV}}$$

(d)
$$\frac{h}{eV}$$

Section B

21. A truck (with a faulty handbrake) starts from rest and rolls down a slope of constant gradient. After the truck has rolled 50 m along the slope, the speedometer reads $36\,\mathrm{km\,h^{-1}}$. Calculate the gradient of the slope. (You may neglect friction and other losses.) [4]

22. The diagram shows the basic idea behind a disk siren. It consists of a disk in which there are 16 equally spaced holes, all at the same distance from its axle. When a jet of air is directed at the holes and the disk is rotated at a particular constant rate, the frequency of the sound produced is 320 Hz.



(a) Calculate the frequency of the note produced when a disk containing 24 holes is rotated at 4/3 times the rate. [1]

(b) Explain how a sound is produced by the siren. [2]

23. A fibre optic cable is used to transmit signals. When a short pulse of light passes along a fibre, it spreads out. This limits the rate of transmission of the signals down the fibre.

(a) Suggest two reasons why the pulse of light might spread out. [2]

A fibre of length 10.0 km is illuminated with red light from an LED which is turned on and off repeatedly for equal amounts of time. The speed of the pulse of light ranges from $1.95 \times 10^8\ \mathrm{m\,s^{-1}}$ to $2.05 \times 10^8\ \mathrm{m\,s^{-1}}$.

(b) Calculate the range of times taken for the pulse to travel down the optical fibre. [1]

(c) What is the maximum frequency of the LED such that the pulses arrive without overlapping? [3]

(d) The wavelength which the LED emits is 1310 nm in air. Calculate the frequency of the light used. [1]

24. While exploring Mars an astronaut finds a cave containing a liquid pool and some coloured cubes. Lacking any measuring instruments, she uses her gloved hand as a measure and determines that:

- A red cube and a green cube together are as long as her hand.
- Two green cubes and a blue cube together are twice as long as her hand.
- A red cube and a blue cube together are as long as two green cubes.
- Two red cubes, two green cubes and two blue cubes weigh the same as the astronaut in her space suit.

She puts all of the cubes in the pool and observes that all of the cubes float with half of their volume submerged. On returning to base she finds that her gloved hand is 22 cm long and she has a mass of 120 kg in her spacesuit.

Find the density of the liquid in the pool. [6]

Section C

25. In this question you will use a simple model to estimate how the energy used by a car depends on its design and how it is driven. Begin by neglecting air and ground resistance and assume that the car travels at a constant velocity between regular equally spaced stops.

    (a) A stationary car of mass m is rapidly accelerated to a velocity v, driven for a distance s, and is then rapidly brought to a halt by its brakes. Calculate the energy dispersed by the brakes. [1]

    (b) Assuming the car restarts immediately, calculate the time between subsequent stops and hence the average power dissipated. [2]

    (c) Hence, or otherwise, calculate the energy used in travelling a total distance d. [2]

(d) Taking $m = 1000\,\mathrm{kg}$, $v = 10\,\mathrm{m\,s^{-1}}$ and $s = 100\,\mathrm{m}$, calculate the energy used in travelling 1 km. What would be the effect of doubling the speed to $20\,\mathrm{m\,s^{-1}}$? [3]

Now consider the effect of air resistance. This can be estimated by assuming that the car has to accelerate all the air it travels through to the same average velocity as itself. (You may ignore the rapid random motion of individual air molecules in this calculation.)

(e) Treating the car as a disc with cross sectional area A travelling at a velocity v, calculate the volume of air swept out in a time t. If the air has density D, calculate the kinetic energy transferred to the air in this time, and hence the power needed to overcome the air resistance. [5]

(f) Taking $A = 1\,\mathrm{m}^2$, $v = 10\,\mathrm{m\,s^{-1}}$ and $D = 1\,\mathrm{kg\,m^{-3}}$, calculate the energy used in travelling 1 km. [2]

(g) Using the data above, calculate the distance between stops at which the energy dissipated in the brakes is the same as that lost to air resistance. [2]

(h) Comment on the significance of these calculations for the design of cars optimised for driving in cities and cars optimised for driving on highways. [3]