ICSE CLASS 10 · PHYSICS

Chapter 3 : MACHINES

STEP-BY-STEP SOLUTIONS & MARKING SCHEME (40 MARKS)

Maximum Marks: 40 · Section A (20) compulsory · Section B: any two of three questions (2 × 10 = 20) · g = 10 m s⁻²

Marks for each step are shown in square brackets on the right.

SECTION A (20 Marks)

Question 1 — Multiple choice [8 marks, 1 mark each]

No.	Answer	Reason
(i)	**(b)** effort arm ÷ load arm	Law of levers: M.A. = L ÷ E = effort arm ÷ load arm.
(ii)	**(c)** the forearm lifting a load on the palm	Class III levers always have M.A. = V.R. less than 1 (the effort lies between fulcrum and load). The forearm is a class III lever; the others have V.R. ≥ 1.
(iii)	**(a)** 2	For a single movable pulley the effort moves 2d while the load moves d, so V.R. = 2.
(iv)	**(d)** less than 1	Because of friction and the weight of moving parts, work output < work input, so η < 1 (less than 100%).
(v)	**(c)** Both (A) and (R) are true, and (R) is the correct explanation for (A).	Both are true: the fixed pulley has M.A. = 1 but allows the effort to be applied downwards, a more convenient direction; (R) explains (A).
(vi)	**(b)** 6	Ideal M.A. of a block and tackle = number of pulleys = 6 (ideal M.A. = V.R. = n).
(vii)	**(a)** 4	M.A. = V.R. × η → V.R. = 3 ÷ 0.75 = 4.
(viii)	**(b)** class II lever	Raising the body on the toes: fulcrum at the toes, load (body weight) in the middle, effort by muscles at the other end → class II.

Question 2 [6 marks]

(a) **Efficiency** is the ratio of the work output to the work input: η = (W_{output} ÷ W_{input}) × 100%. [1] **[2]**

Relation: **M.A. = V.R. × η** (η as a fraction), i.e. η = M.A. ÷ V.R. [1]

(b) (i) The fulcrum F lies between the load (at A) and the effort (at B): **class I lever**. [1] **[3]**

(ii) Load arm FA = 0.3 m; effort arm FB = 1.5 − 0.3 = 1.2 m. M.A. = effort arm ÷ load arm = 1.2 ÷ 0.3 = **4**. [1]

(iii) M.A. = L ÷ E → E = L ÷ M.A. = 24 ÷ 4 = **6 kgf**. (Check: 24 × 0.3 = 6 × 1.2.) [1]

(c) **Velocity ratio** (it depends only on the design, i.e. d_E ÷ d_L); friction lowers M.A. and η. [1] **[1]**

Question 3 [6 marks]

(a) (i) Load arm = 20 cm. Effort arm = 120 − 20 = **100 cm**. [1] **[3]**

(ii) M.A. = effort arm ÷ load arm = 100 ÷ 20 = **5**. [1]

(iii) E = L ÷ M.A. = 150 ÷ 5 = **30 kgf**. [1]

(b) (i) The effort lies between the fulcrum and the load: **class III lever**. [1] **[3]**

(ii) M.A. = effort arm ÷ load arm = 12 ÷ 36 = **1/3 (≈ 0.33)**. [1]

(iii) Moments about F: E × 12 = 1.2 × 36 → E = 43.2 ÷ 12 = **3.6 kgf**. [1]

SECTION B (20 Marks) — any two questions

Question 4 [10 marks]

(a) (i) The rivet (fulcrum) is between the effort and the load: **class I**. M.A. = effort arm ÷ load arm = 6 ÷ 12 = **0.5**. [1] **[3]**

(ii) Load = M.A. × E = 0.5 × 10 = **5 kgf**. [1]

(iii) M.A. < 1 and V.R. < 1, so it is a **speed multiplier** (the blades move farther than the handles). [1]

(b) Let the effort E move through d_E and the load L through d_L. Work input = E × d_E; work output = L × d_L. [1] **[3]**

η = output ÷ input = (L × d_L) ÷ (E × d_E) = (L ÷ E) × (d_L ÷ d_E). [1]

But L ÷ E = M.A. and d_E ÷ d_L = V.R., so η = M.A. ÷ V.R. → **M.A. = V.R. × η**. [1]

(c) (i) B is a fixed pulley: it only **changes the direction of the effort** (the effort is applied downwards). [1] **[4]**

(ii) The effort moves twice as far as the load, so V.R. = 2. M.A. = L ÷ E = 90 ÷ 50 = **1.8**. [1]

(iii) η = M.A. ÷ V.R. = 1.8 ÷ 2 = 0.9 = **90%**. [1]

(iv) Two strands support A and the load: 2E = L + w → 2 × 50 = 90 + w → **w = 10 N**. [1]

Question 5 [10 marks]

(a) Load L = mg = 12 × 10 = 120 N; effort E = 150 N. **[3]**

(i) M.A. = L ÷ E = 120 ÷ 150 = **0.8**. [1]

(ii) For a single fixed pulley $d_E = d_L$, so V.R. = **1**; η = M.A. ÷ V.R. = 0.8 = **80%**. [1]

(iii) Power = (E × d_E) ÷ t = (150 × 6) ÷ 8 = **112.5 W**. [1]

(b) (i) Four strands support the load, so V.R. = n = **4**. M.A. = L ÷ E = 400 ÷ 125 = **3.2**. [1] **[3]**

(ii) η = M.A. ÷ V.R. = 3.2 ÷ 4 = 0.8 = **80%**. [1]

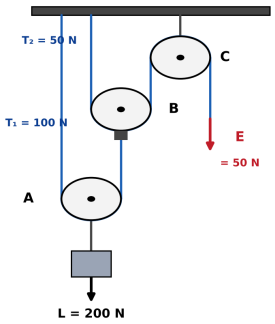
(iii) d_E = V.R. × d_L = 4 × 2 = **8 m**; work done by the effort = 125 × 8 = **1000 J** (work on the load = 400 × 2 = 800 J, and 800 ÷ 1000 = 80%). [1]

(c) (i) A: two strands support the load, so $2T_1 = 200$ → **T_1 = 100 N**. [1] **[4]**

B: two strands support B, which carries T_1, so $2T_2 = T_1$ → **T_2 = 50 N**. [1]

(ii) The fixed pulley C only changes direction, so **E = T_2 = 50 N**. M.A. = 200 ÷ 50 = **4**; V.R. = 2^2 = **4** (two movable pulleys). [1]

(iii) M.A. = V.R. × η = 4 × 0.8 = 3.2, so E = L ÷ M.A. = 200 ÷ 3.2 = **62.5 N**. [1]



Solution to Q5(c)

Question 6 [10 marks]

(a) (i) Nodding of the head: **class I** lever (the spine is the fulcrum, load at the front, effort at the rear). [1] **[3]**

(ii) Raising the body on the toes: **class II** lever (fulcrum at the toes, load in the middle). [1]

(iii) Raising a load on the palm: **class III** lever; the fulcrum is the **elbow joint** (the biceps pull between elbow and palm). [1]

(b) Any three (1 mark each): **[3]**

• Fixed pulley: axle fixed to a rigid support. Movable pulley: axle is free to move with the load.

• Ideal M.A. of a fixed pulley = 1; of a movable pulley = 2.

• V.R. of a fixed pulley = 1; of a movable pulley = 2.

• A fixed pulley only changes the direction of the effort; a movable pulley acts as a force multiplier.

• In a fixed pulley the load and effort move in opposite directions; in a movable pulley (effort upwards) they move in the same direction.

• The weight of a fixed pulley does not affect its M.A.; the weight of a movable pulley reduces its M.A.

(c) (i) The load lies between the fulcrum (wheel centre B) and the effort: **class II lever**. [1] **[4]**

(ii) Load arm BA = **30 cm**; effort arm BC = **90 cm**. [1]

(iii) M.A. = effort arm ÷ load arm = 90 ÷ 30 = **3**. [1]

(iv) E = L ÷ M.A. = 45 ÷ 3 = **15 kgf**. (Check: 45 × 30 = 15 × 90.) [1]

Marks summary	
Section A: Q1 (8) + Q2 (2 + 3 + 1 = 6) + Q3 (3 + 3 = 6)	**20**
Section B: any two of Q4 – Q6 (10 marks each)	**20**
Total	**40**