# The Geometry of Power – Advanced Simple Machines (Advanced)

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

## Section A — Choose the correct answer 8 × 1 = 8 marks

1. A steering wheel of radius 16 cm turns an axle of radius 2 cm. The mechanical advantage is:
   **(a)** 0.13 **(b)** 14 **(c)** 18 **(d)** 8

2. A wheel and axle has a wheel 19 times the radius of its axle. The effort needed on the wheel to overcome a load of 2,000 N is (ideal machine): (Give the answer to 2 decimal places where needed.)
   **(a)** 38,000 N **(b)** 111.11 N **(c)** 105.26 N **(d)** 5.54 N

3. A machine lifts an 80 N load through 4 m while an effort of 100 N moves through 4 m. Its efficiency is:
   **(a)** 95% **(b)** 81% **(c)** 125% **(d)** 80%

4. In a gear train, a driving gear turns at 960 turns per minute. The gear it drives turns once for every 10 turns of the driver. How fast does the driven gear turn?
   **(a)** 9.6 turns per minute **(b)** 9,600 turns per minute
   **(c)** 96 turns per minute **(d)** 960 turns per minute

5. The mechanical advantage of a wheel and axle is:
   **(a)** radius of the wheel ÷ radius of the axle **(b)** radius of the wheel + radius of the axle
   **(c)** radius of the axle ÷ radius of the wheel **(d)** radius of the wheel × radius of the axle

6. A 27 kg mass hangs at rest from a rope. The tension in the rope is: Take g = 9.8 $m/s^2$.
   **(a)** 27 N **(b)** 264.6 N **(c)** 132.3 N **(d)** 529.2 N

7. A 12 kg mass on a rope is lowered with an acceleration of 1 $m/s^2$. The tension in the rope is: Take g = 9.8 $m/s^2$.
   **(a)** 105.6 N **(b)** 12 N **(c)** 129.6 N **(d)** 117.6 N

8. Masses of 9 kg and 3 kg hang on either side of a light, frictionless pulley. The acceleration of the system is: Take g = 9.8 $m/s^2$. (Give the answer to 2 decimal places where needed.)
   **(a)** 9.8 $m/s^2$ **(b)** 6.53 $m/s^2$ **(c)** 4.9 $m/s^2$ **(d)** 19.6 $m/s^2$

## Section B — Short answer 8 × 2 = 16 marks

9. A wheel of radius 21 cm is fixed to an axle of radius 19 mm. What effort on the wheel lifts a 1,500 N load hanging from the axle (ideal machine)? (Give the answer to 2 decimal places where needed.)

10. A wheel and axle must have a mechanical advantage of 6. If the axle's radius is 3 cm, what must the wheel's radius be?

**11.** A wheel of radius 72 cm and an axle of radius 6 cm lift a 300 N load with an effort of 31.25 N. Find the efficiency of the machine.

**12.** An object of mass 30 kg hangs at rest from a single fixed pulley. Find the tension in the rope. Take g = 9.8 m/s$^2$.

**13.** A bucket of mass 18 kg is pulled up a well with an acceleration of 5 m/s$^2$. Find the tension in the rope. Take g = 9.8 m/s$^2$.

**14.** Masses of 12 kg and 8 kg are connected over a frictionless pulley. Find the acceleration of the masses. Take g = 9.8 m/s$^2$. (Give the answer to 2 decimal places where needed.)

**15.** A 12 kg mass and a 9 kg mass hang on either side of a frictionless pulley. Find the tension in the string. Take g = 9.8 m/s$^2$. (Give the answer to 2 decimal places where needed.)

**16.** In a pulley experiment, masses of 2 kg and 1.5 kg hang on either side. Find the net force that makes the system move. Take g = 9.8 m/s$^2$. (Give the answer to 2 decimal places where needed.)

## Section C — Word problems — 4 × 4 = 16 marks

**17.** A truck's steering needs a turning force of 2,100 N at the axle. The steering wheel has a radius of 16 cm and the axle 2 cm. (a) Find the mechanical advantage. (b) What effort is needed on the rim of an ideal steering wheel? (c) What effort is needed if the steering is only 60% efficient? (Give the answer to 2 decimal places where needed.)

**18.** Masses of 7 kg and 1 kg hang over a frictionless pulley and are released from rest. Take g = 9.8 m/s$^2$. Find (a) the acceleration, (b) the tension in the string, (c) the distance each mass moves in 1 s and (d) the speed after 1 s. (Give the answer to 2 decimal places where needed.)

**19.** A gear train has three gears in a row. Each gear turns once for every 60 turns of the gear before it, and its radius is 60 times as large. The first gear has a radius of 12 mm. Find (a) the radius of the second gear in mm, (b) the radius of the third gear in metres and (c) how many turns the first gear makes for one turn of the third gear.

**20.** A lift with its passengers has a mass of 1,250 kg. Take g = 9.8 m/s$^2$. Find the tension in its cable when it (a) moves up at a steady speed, (b) accelerates upward at 3.5 m/s$^2$ and (c) accelerates downward at 3.5 m/s$^2$.

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# Answer key

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| Q | Answer | Working |
|---|---|---|
| 1 | **(d) 8** | MA = radius of wheel ÷ radius of axle = 16 ÷ 2 |
| 2 | **(c) 105.26 N** | effort = load ÷ MA = 2,000 ÷ 19 |
| 3 | **(d) 80%** | η = output work ÷ input work × 100 = 320 J ÷ 400 J × 100 |
| 4 | **(c) 96 turns per minute** | 960 ÷ 10 |
| 5 | **(a) radius of the wheel ÷ radius of the axle** | a bigger wheel multiplies the force more |
| 6 | **(b) 264.6 N** | at rest, T = mg = 27 × 9.8 |
| 7 | **(a) 105.6 N** | mg − T = ma, so T = m(g − a) = 12 × 8.8 |
| 8 | **(c) 4.9 m/s$^2$** | a = $(m_1 - m_2)g \div (m_1 + m_2)$ = 6 × 9.8 ÷ 12 |
| 9 | **135.71 N** | MA = 210 mm ÷ 19 mm; effort = 1,500 ÷ MA |
| 10 | **18 cm** | R = MA × r = 6 × 3 |
| 11 | **80%** | per turn: output 300 × 2π × 6, input 31.25 × 2π × 72; η = (300 × 6) ÷ (31.25 × 72) × 100 |
| 12 | **294 N** | T = mg = 30 × 9.8 |
| 13 | **266.4 N** | T = m(g + a) = 18 × (9.8 + 5) |
| 14 | **1.96 m/s$^2$** | 12g − T = 12a and T − 8g = 8a; adding: a = 4 × 9.8 ÷ 20 |
| 15 | **100.8 N** | T = $2m_1m_2g \div (m_1 + m_2)$ = 2 × 12 × 9 × 9.8 ÷ 21 |
| 16 | **4.9 N** | (2 − 1.5) × 9.8 |
| 17 | **(a) 8; (b) 262.5 N; (c) 437.5 N** | (a) 16 ÷ 2; (b) 2,100 ÷ 8; (c) 262.5 × 100 ÷ 60 |
| 18 | **(a) 7.35 m/s$^2$; (b) 17.15 N; (c) 3.68 m; (d) 7.35 m/s** | (a) $(m_1 - m_2)g \div (m_1 + m_2)$; (b) T = $m_2(g + a)$; (c) s = ½at$^2$; (d) v = at |
| 19 | **(a) 720 mm; (b) 43.2 m; (c) 3,600** | (a) 12 × 60; (b) 12 × 60 × 60 = 43,200 mm = 43.2 m; (c) 60 × 60 = 3,600 |
| 20 | **(a) 12,250 N; (b) 16,625 N; (c) 7,875 N** | (a) steady: T = mg; (b) T = m(g + a); (c) T = m(g − a) |



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