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ANSWER BOOK

Work, energy and power

Further Mechanics 1 · Year FM

7 questions · 30 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Work = Fd cos θ, where θ is the angle between the force and the displacement. [2]
The normal reaction acts at right angles to the surface and so at right angles to the motion along it, making cos θ = 0 and the work done zero. B1 for the formula, B1 for the normal reaction doing no work.

A2 Work = 40 × 12 × cos25° = 480 × 0.9063 = **435** J to three significant figures. M1 for 40 × 12 × cos25°, A1 for 435 J. Ignoring the angle would give 480 J, an overestimate of about 10%. [2]

SECTION B · Standard

B1 Work by gravity = 60(9.8)(10)sin20° = **2011** J. Normal reaction = 60(9.8)cos20° = 553 N, so friction is 166 N and the work against it is **1658** J. By the work-energy principle the kinetic energy gained is 2011 - 1658 = **353.5** J, so ½(60)v² = 353.5, v² = 11.78 and v = **3.43** m/s. M1 for the work done by gravity, A1 for 2011 J, M1 for the normal reaction and friction, A1 for 1658 J, M1 for the work-energy principle, A1 for 3.43 m/s. Resolve perpendicular to the slope for the normal reaction before touching the friction, since R = mg cos20° rather than mg. [6]

B2 Driving force = 12000/20 = **600** N. Resultant = 600 - 400 = 200 N, so a = 200/900 = **0.222** m/s². At maximum speed the acceleration is zero, so 12000/v = 400 and v = **30** m/s. M1 for P = Fv, A1 for 600 N, M1 for the resultant, A1 for the acceleration, B1 for 30 m/s. [5]

B3 With P fixed, the driving force P/v falls as v rises. The resistance meanwhile grows, so the resultant force shrinks from both ends and the acceleration falls with it. At the speed where the driving force has dropped to equal the resistance, the acceleration reaches zero and the car can go no faster. B1 for the driving force falling, B1 for the resistance rising, B1 for the resultant shrinking to zero. [3]

B4 A slope of 1 in 20 means the component of weight along the slope is 80(9.8)/20 = **39.2** N. At steady speed the driving force balances that plus the resistance: 39.2 + 25 = 64.2 N. Power = Fv = 64.2 × 6 = **385** W to three significant figures. M1 for the component of weight, A1 for 39.2 N, M1 for P = Fv, A1 for 385 W. [4]

SECTION C · Stretch

C1 On the level the greatest speed comes when the driving force has fallen to the resistance, so $20000/v = 500$ and $v =$ **40** m/s. [8]
A hill of 1 in 14 has $\sin\theta = 1/14$, so the component of weight down the slope is $1000(9.8)/14 =$ **700** N. Climbing at a steady speed needs a driving force of $500 + 700 = 1200$ N, so $20000/v = 1200$ and $v =$ **16.7** m/s.
At 10 m/s the driving force is $20000/10 = 2000$ N. Newton's second law along the slope gives $2000 - 500 - 700 = 1000a$, so $a =$ **0.8** m/s^2.
M1 for $20000/v = 500$, A1 for 40 m/s, M1 for the component of weight, A1 for 700 N, M1 for the driving force needed, A1 for 16.7 m/s, M1 for Newton's second law, A1 for the acceleration.
Power is fixed, not force, so the driving force must be recomputed at every speed. Include the component of weight on the hill and omit it on the level, and never carry the maximum-speed driving force into an acceleration calculation.